TOCHNOG PROFESSIONAL User's manual

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Contents

1 Basic information

1.1 How to perform a calculation and how to get started

Create an input file, e.g. **problem.dat**. The default input file is **tochnog.dat**, which will be used if no other input file is specified. Thus the command **tochnog tochnog.dat** yields output on the screen while **tochnog tochnog.dat** > **tochnog.out** redirects the output to a file.

So to get started do, for example, the following:

- **cd test/other**
- **tochnog condif1.dat**

Use the **condif1.dat** test to get started.

- Copy **condif1.dat** to **tochnog.dat**.
- Use your favorite editor to open the file **tochnog.dat** and study it.
- Change **echo** to **-yes**.
- Remove the parentheses (...) surrounding the **control_print** statement and save the file.
- Run by typing **tochnog** or **tochnog tochnog** or **tochnog tochnog.dat**.
- Study the output on the screen.
- Study the **tochnog.log** file.
- Study the **tochnog.dbs** file. It contains the database after the calculation, and is an input file itself!

Read at least once the start of the data part introduction section.

1.2 Pre- and postprocessing

You can use **GID** both for preprocessing (mesh generation) and post processing (plotting). **GID** is commercially available at the **www.gidhome.com** Internet page. A free demo version of is available for download.

Alternatively to **GID** you can use **Mecway** for preprocessing **input_abaqus** and post processing **control_print_gmsh**. **Mecway** is commercially available at the **mecway.com**

Internet page. It is very affordable, and also has build in FE calculations (mostly for mechanical engineering). A free demo version of Mecway is available for download.

You can also use **GMSH** both for preprocessing and post processing. **GMSH** is freely available at **www.geuz.org/gmsh**.

Postprocessing files are written for the visualization program **PARAVIEW**. The **PARAVIEW** program is freely available at **www.paraview.org**.

Furthermore. postprocessing files are written for the visualization program **TECPLOT**. These **TECPLOT** are less well maintained then the files for other postprocessing programs.

With **GNUPLOT** you can plot files resulting from **control_print_history** and **control_print_data_versus_data**. Also any other x-y plotting program can be used for such files.

1.3 Space discretization, time discretization

The computational domain is divided into finite elements. The elements connect at nodes. Either one-dimensional (1D), two-dimensional (2D), three-dimensional (3D) or axi-symmetrical (2D) domains can be used.

Only first order in time equations are solved. Time derivatives are approximated with Euler backward time discretization.

1.4 Program capabilities

- Input

  Format free input. Words and no 'magic numbers' in rigidly defined columns are used.

  Boundary conditions can be imposed onto at geometrical entities, as well as onto elements and nodes.

- Output/plotting

  Output can be printed over user-specified geometrical objects (points, lines, quadrilaterals,...) as well as at nodes.

  The history of each variable, and for functions of variables, can be printed over user-specified geometrical objects as well as at nodes.

  Interface files for the GID pre- and post processor.

- Finite elements

  1D, 2D and 3D. Tochnog mostly uses isoparametric elements. There are also springs, trusses, beams and contact-springs however.

  Linear and quadratic simplex elements (triangles, tetrahedrons). Linear and quadratic prism elements. A full family of first to fourth order bar, quadrilateral and brick elements.

- Mesh generation/refining/etc.

  Macro regions are automatically divided into finite elements.

  Local h-refinement

  Global h-refinement (more elements).

  Global p-refinement (polynomial refinement).

- Differential equations (materials)

  Convection-diffusion equation:

  - Temperature calculations.

  Fluids:

  - Stokes and Navier-Stokes.

  Solids:

  - Elasticity (isotropy and transverse isotropy).

  - Elasto-Plasticity (Von-Mises, Mohr-Coulomb, Gurson, etc.; plasticity surfaces can be arbitrarily combined).

  - Hypo-Plasticity (Von-Wolffersdorff, Masin, cohesion, intergranular strains, pressure dependent initial void ratio).

  - Damage.

  - Thermal stresses.

  - Hypoelasticity.

  - Viscoelasticity.

  - Viscoplasticity.

  - Viscosity.

  Ground water flow equation:

  - Storage equation. - saturated and non-saturated - multiple phreatic levels - piping and lifting safety - fully coupled consolidation analysis

  Wave equation.

- Interaction analysis

  Automatic fluid-solid interaction.

  Temperature effects on fluids, solids.

- Contact analysis

  Contact with and without friction.

  Frictional heat generation.

- Frames of description

  Lagrangian and Eulerian

- Types of analysis

  Static, quasi-static and dynamic analysis.

- Parallelization

  Full shared memory parallelization node and element loops

- Special features

  Automatic time-stepping (large steps for good iteration behavior, small steps for bad iteration behavior).

  Automatic distribution of tendon trusses over finite elements (automatic embedment).

  Restart possibility.

  Convection wiggle stabilization (both for low and high order elements).

1.5 Files used by Tochnog

- Input file. For example **condif1.dat**. The input file consists of an initialization part (which dof's should be solved, etc.) and a data part (elements, nodes, etc.).
- Runtime input file. For example **condif1.run**. Use it to give Tochnog data records on the fly (while it is running).
- Plot files. For example **condif1_flavia.msh** and **condif1_flavia.res**.
- Database file. For example, after the calculation with input file **condif1.dat** the database file **condif1.dbs** will be written. It contains everything (nodes, elements, solutions fields, etc.). On error exit for example **condif1_error.dbs** will be generated.
- Scratch file **tochnog_tmp.txt**. Don't use this name yourself.
- Log file **tochnog.log**. Contains log messages of calculations.

2 Equations

2.1 Convection and diffusion of heat

2.1.1 Convection-diffusion equation

$$\rho C(\dot{T} + \beta_i \frac{\partial T}{\partial x_i}) = k_i \frac{\partial^2 T}{\partial {x_i}^2} - aT + f$$

The primary dof is the **condif_temperature** T. Further notation: ρ **group_condif_density**; C **group_condif_capacity**; x space coordinate; β_i **group_condif_flow** in i-direction; k_i **group_condif_conductivity** in i-direction; a **group_condif_absorption**; f **condif_heat_volume**. Typical applications are heat conduction and heat conduction in a flow.

2.1.2 Convection to environment

$$q_c = \alpha_c(T - T_c)$$

Here q_c is the **condif_convection_edge_normal** heat flux, α_c is the convection coefficient and T_c is the environmental temperature for convection.

2.1.3 Radiation to environment

$$q_r = \alpha_r(T^4 - {T_r}^4)$$

Here q_r is the **condif_radiation_edge_normal** heat flux, α_r is the radiation coefficient and T_r is the environmental temperature for radiation.

2.2 Material deformation and flow

$$\rho \dot{v_i} = \frac{\partial \sigma_{ij}}{\partial x_j} + (1 - \beta T)\rho g_i - d v_i + f_i$$

Notations: ρ **group_materi_density**; v_i **materi_velocity** in i-direction; σ_{ij} **materi_stress** matrix; x space coordinate; β **group_materi_expansion_volume**; T (optional) **condif_temperature**; g_i **force_gravity**; d is the **group_materi_damping** coefficient (see also the dynamics section near the end of this manual); f_i **force_volume**. The equation is given for space coordinates following the material velocities v_i.

TOCHNOG allows you to build your favorite material, by adding separate contributions to the stresses σ_{ij}. In this way you can build solids or fluids or things in between. The separate contributions will be listed below. First two typical examples are given.

Nearly incompressible Navier Stokes:

```
...
materi_velocity
materi_stress
end_initia
...
mesh -fixed_in_space -fixed_in_space
timestep_predict_velocity 0 -yes
...
group_type 0 -materi
group_materi_elasti_compressibility 0 1.0
group_materi_viscosity 0 1.2
...
```

Linear solid:

```
...
materi_velocity
materi_velocity_integrated
materi_stress
end_initia
...
group_type 0 -materi
group_materi_elasti_young 0 1.e10
group_materi_elasti_poisson 0 0.2
group_materi_memory 0 -updated_linear
```

2.2.1 Memory

The **-updated** Lagrange formulation

Deformations (i.e. the incremental deformation matrix F) refers to the previous time point. TOCHNOG decomposes the incremental deformation tensor with a polar decomposition into $F = RU$ with F the incremental deformation matrix, R the incremental rotation matrix and U the incremental stretch matrix. The incremental stretch matrix U is used to determine the incremental strain matrix $0.5(U + U^T) - I$ with I the identity tensor. The stresses at a new timepoint are calculated as:

- calculate extra stresses due to incremental strain matrix
- add these extra stresses to the stresses of the previous time point
- rotate these new stresses by the matrix R

The **-updated_jaumann** Lagrange formulation

Deformations (i.e. the incremental deformation matrix F) refers to the previous time point. The incremental stretch matrix U is used to determine the incremental strain matrix $0.5(F + F^T) - I$ with I the identity tensor. The incremental rotation matrix R is $0.5(F - F^T) + I$. The stresses at a new timepoint are calculated as:

- calculate extra stresses due to incremental strain matrix
- add these extra stresses to the stresses of the previous time point
- rotate these new stresses by the matrix R

The **-updated_linear** Lagrange formulation

Deformations (i.e. the incremental deformation matrix F) refers to the previous time point. Any rigid body rotation between the two time points are neglected, so TOCHNOG decomposes the incremental deformation tensor with a polar decomposition into $F = U$ with F the incremental deformation matrix, and U the incremental stretch matrix. The linear engineering strains in the deformed configuration are used as incremental strain matrix $0.5(F + F^T) - I$. The stresses at a new timepoint are calculated as:

- calculate extra stresses due to incremental strain matrix
- add these extra stresses to the stresses of the previous time point

The **-total** Lagrange formulation

Deformations (i.e. the total deformation matrix F) refers to the time 0. TOCHNOG decomposes the total deformation tensor with a polar decomposition into $F = RU$ with F

the total deformation matrix, R the total rotation matrix and U the total stretch matrix. The total stretch matrix U is used to determine the total strain matrix $0.5(U + U^T) - I$ with I the identity tensor. The stresses at a new timepoint are calculated as:

- back-rotate the old stresses at the previous time point to time 0 with the old rotation matrix
- calculate extra stresses due to incremental strain matrix
- add these extra stresses to the back-rotated old stresses of the previous time point
- rotate the added stresses with the new rotation matrix R to the new configuration

The **-total_linear** Lagrange formulation

Deformations (i.e. the total deformation matrix F) refers to the time 0. TOCHNOG neglects any rigid body rotations and uses linear engineering strains $0.5(F + F^T) - I$. The difference in these linear engineering strains between two time points are the incremental strains.

The stresses at a new timepoint are calculated as:

- calculate extra stresses due to incremental strain matrix
- add these extra stresses to the stresses of the previous time point

See also **group_materi_memory**.

2.2.2 Elasticity

The elastic stress rate is

$$C_{ijkl}\dot{\epsilon_{kl}}^{\text{elas}}$$

where C_{ijkl} is the elastic modulus tensor (which is a doubly symmetric tensor: $C_{ijkl} = C_{jikl}$, $C_{ijkl} = C_{ijlk}$ and $C_{ijkl} = C_{jilk}$), and $\dot{\epsilon_{kl}}^{\text{elas}}$ is the elastic strain rate. See the plasticity section for a definition of the elastic strain rate.

For an isotropic material

$$C_{0000} = C_{1111} = C_{2222} = \frac{E(1-\nu)}{(1+\nu)(1-2\nu)}$$
$$C_{0011} = C_{0022} = C_{1122} = \frac{E\nu}{(1+\nu)(1-2\nu}$$
$$C_{0101} = C_{0202} = C_{1212} = \frac{E}{1+\nu}$$

with E **group_materi_elasti_young** modulus and ν **group_materi_elasti_poisson** ratio (the remaining non-zero moduli follow from the double symmetry conditions).

For a transverse isotropic material the material has one unique direction (think of an material with fibers in one direction). Here we take '2' as the unique direction; '1' and '3' are the transverse directions. The material is fully defined by E_1, E_2, ν_1, ν_2, and G_2. This set of parameters leads directly to a set of elasticity coefficients C_{ijkl}. The parameters can be given in **group_materi_elasti_transverse_isotropy**,

The nonlinear elasticity polynomials is a strain dependent model. In this model, the 'young's stiffness' modulus is made dependent of the size of the strains via a series of polynomials

$$E = E_0 + E_1\epsilon^1 + E_2\epsilon^2 + \ldots \tag{1}$$

where

$$\epsilon = \sqrt{(\epsilon_{ij}\epsilon_{ij})} \tag{2}$$

with ϵ_{ij} the components of the strain matrix. The parameters E_0 etc. need to be specified in the **group_materi_elasti_young_polynomial** record.

If the pressure state in a point is positive, we apply $E = E_0$.

The power law nonlinear elasticity is a stress dependent model which typically is used to model the elastic behavior of granular materials. It can be combined with plastic models, for example with the di Prisco plasticity model for soils, and with a poisson ratio.

In this model, the 'young's stiffness' modulus is made a function of the average stress state:

$$E = E_0 + E_1(p/p_1)^\alpha \tag{3}$$

with conditions however:

$$E >= E_2 \tag{4}$$

$$E <= E_3 \tag{5}$$

where p is the pressure. The parameters E_0, E_1, E_2, E_3, p_1, and α need to be specified in the **group_materi_elasti_young_power** record.

In the**group_materi_elasti_poisson_power** model, the poisson ratio is made a function of the average stress state:

$$\nu = \nu_0 + \nu_1(p/p_1)^\alpha \tag{6}$$

with condition however:

$$\nu <= \nu_2 \tag{7}$$

where p is the pressure. The parameters ν_0, ν_1, ν_2, p_1, and α need to be specified in the **group_materi_elasti_poisson_power** record.

The stiffness matrix C_{ijkl} for the Borja Tamagnini nonlinear elasticity model is specified in

The model contains G_0, α, $\hat{k}$ and p_r as user specified constants which need to be specified in the **group_materi_elasti_borja_tamagnini** record.

The Lade nonlinear elasticity is a stress dependent model which typically is used to model the elastic behavior of granular materials. It can be combined with plastic models, for example with the di Prisco plasticity model for soils.

The stress rates are linked to the strain rates by the equation:

$$\dot{\epsilon_{ij}} = \frac{\partial W^2}{\partial \sigma_{ij} \partial \sigma_{hk}} \dot{\sigma_{hk}} \tag{8}$$

where the function W is

$$W = \frac{X^{1-\lambda}}{2B(1-\lambda)}$$

where

$$X = p^2 + R^* \text{abs}(s_{ij} s_{ij})$$

with pressure $p = (\sigma_{11} + \sigma_{22} + \sigma_{33})/3$ and deviatoric stresses $s_{ij} = \sigma_{ij} - p\delta_{ij}$.

The model contains three user specified constants B, R, λ which need to be specified in the **group_materi_elasti_lade** record. B and λ are defined by means of an isotropic unloading test, and R by means of an unloading-standard-triaxial-compression test. For example for a loose sand $B = 1028$, $R = 0.25$, $\lambda = 0.28$. See [10] for the details.

The model cannot be used in combination with a poisson ratio.

2.2.3 Elasto-Plasticity

Plastic strain

In plastic analysis, the **materi_strain_elasti** rate follows by subtracting from the **materi_strain_total** rate the **materi_strain_plasti** rate

$$\dot{\epsilon_{ij}}^{\text{elas}} = \dot{\epsilon_{ij}} - \dot{\epsilon_{ij}}^{\text{plas}}$$

where the **materi_strain_total** rate is

$$\dot{\epsilon_{ij}} = 0.5(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i})$$

The **materi_strain_plasti** rate follows from the condition that the stress cannot exceed the yield surface. This condition is specified by a yield function $f^{\text{yield}}(\sigma_{ij}) = 0$. The direction of the plastic strain rate is specified by the stress gradient of a flow function $\frac{\partial f^{\text{flow}}}{\partial \sigma_{ij}}$. If the yield function and flow function are chosen to be the same, the plasticity is called associative, otherwise it is non-associative.

Von-Mises is typically used for metal plasticity. Mohr-Coulomb and Drucker-Prager are typically used for soils and other frictional materials. *The plasticity models can freely be combined; the combination of the plasticity surfaces defines the total plasticity surface.*

Typically, if you use Mohr-Coulomb or Drucker-Prager to model shear failure for soils, you should use the tension limiting model to limit tension stresses, preferably **group_materi_plasti_tension_direc**

First some stress quantities which are used in most of the plasticity models are listed.

Equivalent Von-Mises stress:

$$\bar{\sigma} = \sqrt{\frac{s_{ij}s_{ij}}{2}}$$

Mean stress:

$$\sigma_m = \frac{\sigma_{11} + \sigma_{22} + \sigma_{33}}{3}$$

Deviatoric stress:

$$s_{ij} = \sigma_{ij} - \sigma_m \delta_{ij}$$

CamClay plasticity model

Here we provide the equations of the Cam Clay model (Roscoe and Burland, 1968, summarized e.g. by Wood, 1990, see [20]). All stresses are effective (geotechnical) stresses, i.e.compression is positive! Definitions of variables:

$$p = (\sigma_1 + \sigma_2 + \sigma_3)/3$$

$$q = \{\frac{1}{2}[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]\}^{1/2}$$

in the principal stress axes. The CamClay yield rule, which is also the flow rule, reads:

$$f = g = q^2 - M^2[p(p_0 - p)] = 0$$

M is a soil constant and p_0 is a history (hidden) variable which corresponds to the preconsolidation mean pressure. The hardening function, evolution, of p_0 reads:

$$dp_0 = \frac{p_0(1+e)d\varepsilon_v^p}{\lambda - \kappa}$$

in which

$$d\varepsilon_v^p = d\varepsilon_{11}^p + d\varepsilon_{22}^p + d\varepsilon_{33}^p$$

and λ and κ are user specified soil constants. Further e is the void ratio with the evolution equation:

$$de = -d\varepsilon_v(1+e)$$

in which

$$d\varepsilon_v = d\varepsilon_{11} + d\varepsilon_{22} + d\varepsilon_{33}$$

Notice that this is a geometrical linear approximation for void ratio changes. The poisson ratio ν reads:

$$\nu = \frac{3K - 2G}{2G + 6K}$$

in which the elastic bulk modulus K is given by:

$$K = (1+e)p/\kappa$$

and the Young's modulus E:

$$E = 2. * G * (1+\nu)$$

in which G is a user specified soil constant, By using this ν and E the classical isotropic stress-strain law is used to calculate the stresses.

The soil constants M, κ, λ need to be specified in **group_materi_plasti_camclay**. The soil constant G, need to be specified in **group_materi_elasti_camclay_g**. For an alternative see **group_materi_elasti_camclay_poisson**. The history variables e, p_0 need to be initialized by **materi_plasti_camclay_history** record (and given initial values in **node_dof** records).

Remark 1: An additional parameter N can be often found in textbooks on the Cam Clay model. We don't include it since it is linked to other model parameters via:

$$1 + e = N - \lambda \ln p_0 + \kappa \ln(p_0/p)$$

Remark 2: If you apply a geometrical linear analysis, see section 8.4, then also the calculation of de void ratio development is linearized, and so will contain some error as compared to the exact void ratio change. Hence for very large deformations, say above 10 percent or so, don't use such geometrical linear analysis.

Remark 3: This camclay law is very sensitive for near-zero stresses. It is best to only use it in combination with application of initial gravity stresses by means of **control_reset_dof**.

Cap1 plasticity model

This **group_materi_plasti_cap1** model is the first cap model that accounts for permanent plastic deformations under high pressures for granular materials. It is intended to be used in combination with shear plasticity models like Drucker-Prager, Mohr-Coulomb, etc.

First the average stress p and the equivalent shear stress q are introduced:

$$p = -(\sigma_{11} + \sigma_{22} + \sigma_{33})/3$$

$$q = \{\frac{1}{2}[(\sigma_{11} - \sigma_{22})^2 + (\sigma_{22} - \sigma_{33})^2 + (\sigma_{33} - \sigma_{11})^2] + 3(\sigma_{12}^2 + \sigma_{23}^2 + \sigma_{31}^2)\}^{1/2}$$

These are used to define the cap plastic yield function:

$$f = \frac{q^2}{M^2} + p^*(p^* - p_c^*)$$

where

$$p^* = p + c\cot\phi \qquad p_c^* = p_c + c\cot\phi$$

The parameter p_c is a history variable of this model. The parameter ϕ is the coulomb friction angle in radians, and c is the cohesion. The parameter M denotes the tangent of the Critical State Line in the model, Typically you can use:

$$M = \frac{6\sin\phi}{3 - \sin\phi}$$

The history parameter p_c is assumed to harden with the cap plastic volume strain rate according to the rate form:

$$\dot{\epsilon}^p_{cv} = \frac{\lambda^*/\kappa^* - 1}{K^{ref}} \left(\frac{p^{ref}}{p^*_c} \right)^m \dot{p}_c$$

Here κ^* is the swelling index (e.g. 0.03), λ^* is the compression index (e.g. 0.15), K^{ref} is the bulk modulus at stress p^{ref} (typically $100kPa$), which typically can be taken as: $K^{ref} = \frac{E^{ref}}{3(1-2\nu)}$, and finally m is an exponent (e.g. 0.6).

Initialize **materi_plasti_cap1_history** in the initialization part. The state variable p_c for this hardening soil model enters the **node_dof** records. You need to give an initial value for it in the **node_dof** records. See also [2].

Cap2 plasticity model

This is the second cap model that accounts for permanent plastic deformations under high pressures for granular materials. It is intended to be used in combination with shear plasticity models like Drucker-Prager, Mohr-Coulomb, etc.

First a deviatoric stress measure t and hydrostatic stress measure p are defined

$$t = \sqrt{3}\bar{\sigma}$$

$$p = -\sigma_m$$

See above for $\bar{\sigma}$ and σ_m. The yield rule for the **group_materi_plasti_cap2** model reads:

$$f = \sqrt{(p - p_a)^2 + \left[\frac{Rt}{(1 + \alpha - \frac{\alpha}{cos\phi}} \right]^2} - R(c + p_a tan\phi)$$

Here c is the cohesion and ϕ is the friction angle which should be taken equal to the values in the shear flow rule which you use. The parameter p_a follows from

$$p_a = \frac{p_b - Rc}{1 + R\ tan\phi}$$

where the hydrostatic compression yield stress p_b is to be defined with an table of volumetric plastic strains ϵ^p_v versus p_b with $\epsilon^p_v = \epsilon^p_{11} + \epsilon^p_{22} + \epsilon^p_{33}$. As always, positive strain denote extension whereas negative strains denote compression.

Associative flow is used, so the flow rule is taken equal to the yield rule.

Summarizing the **group_materi_plasti_cap2** model needs as input the cohesion c, the friction angle ϕ, the parameter α (typically $1.\ 10^{-2}$ up to $5.\ 10^{-2}$), and a table ϵ^p_v versus p_b.

Compression limiting plasticity model

This **group_materi_plasti_compression** model uses a special definition for the equivalent stress

$$\bar{\sigma} = \sqrt{{\sigma_{min}}^2}$$

where σ_{min} is the largest compressive principal stress. The model now reads

$$\bar{\sigma} - \sigma_y = 0$$

This plasticity surface limits the allowed compressive stresses.

di Prisco plasticity model

The di Prisco model is an non-associative plastic model for soils, which can be typically combined with the 'Lade elastic model'. This di Prisco model is a rather advanced soil model, which is explained in more detail in [3] and [9]. The yield rule reads:

$$f = 3\beta_f(\gamma - 3)\ln\left(\frac{r}{r_c}\right) - \gamma J_{3\eta^*} + \frac{9}{4}(\gamma - 1)J_{2\eta^*}$$

and the flow rule yields:

$$g = 9(\gamma - 3)\ln\left(\frac{r}{r_g}\right) - \gamma J_{3\eta^*} + \frac{9}{4}(\gamma - 1)J_{2\eta^*}$$

This is an anisotropic model in which the first and second invariant of the stress rate η^* are defined relative to the rotation axes χ.

$$r = \sigma_{ij}\chi_{ij}$$
$$J_{3\eta^*} = \eta^*_{ij}\eta^*_{jk}\eta^*_{ki}$$
$$J_{2\eta^*} = \eta^*_{ij}\eta^*_{ij}$$
$$\eta^*_{hk} = \sqrt{3}\frac{s^*_{hk}}{r}$$

where s^* follows from

$$s^*_{hk} = \sigma^*_{hk} - r\chi_{hk}$$

Further $r_g = 1$.

The history variables are χ_{ij} (rotation axes, 9 values), β (yield surface form factor), and r_c (preconsolidation mean pressure). The evolution laws for these history variables can be found in the papers listed above. The history variables χ_{ij} (9 values), β, r_c need to be initialized by the **group_plasti_diprisco_history 11** record (and should be given initial values in **node_dof** records). In a normally consolidated sand with isotropic initial conditions $\chi_{ij} = \frac{\delta_{ij}}{\sqrt{3}}$, $\beta = 0.0001$ and r_c equals $\sqrt{3}$ times the means pressure.

The total model, yield rule and flow rule and evolution laws for history variables, contains a set of soil specific constants. In **group_materi_plasti_diprisco** you need to specify these constants. These constants are explained in more detail in the papers mentioned above, but here we give a short explanation. The constants $\hat{\theta}_c$, $\hat{\theta}_e$, ξ_c and ξ_e are linked to the dilatancy and the stress state during failure (standard triaxial compression and extension test in drained conditions). The constants γ, c_p, β_f and β_f^0 are defined by means of the experimental curves (q-ϵ_{axial}, ϵ_{vol}-ϵ_{axial}) obtained by performing a standard compression test in drained conditions. Moreover, β_f, β_f^0 and t_p can also be determined by means of the effective-stress path obtained by performing a standard triaxial compression test in undrained conditions.

Finally b_p can determined from an isotropic compression test. For a loose sand $\hat{\theta}_c = 0.253$, $\hat{\theta}_e = 0.0398$, $\xi_c = -0.2585$, $\xi_e = -0.0394$, $\gamma = 3.7$, $c_p = 18.$, $\beta_f = 0.5$, $\beta_f^0 = 1.1$, $t_p = 10.$, and $b_p = 0.0049$.

di Prisco plasticity model with varying density

This essentially is the same as the normal di Prisco model, but instead of one set of parameters you need to specify two sets of parameters, one of loose soil and one for dense soil. The actual applied parameters will then be interpolated from the loose parameters and dense parameters depending on the actual density of the soil. The parameters need to be specified in **group_materi_plasti_diprisco_density**.

The history variables are those of **group_materi_plasti_diprisco** and finally extra the relative density (for example 20 or 40). So there are 12 history variables in total.

Drucker-Prager plasticity model

The **group_materi_plasti_druck_prag** model reads

$$3\alpha\sigma_m + \bar{\sigma} - K = 0$$
$$\alpha = \frac{2\sin(\phi)}{\sqrt{3}(3 - \sin(\phi))}$$
$$K = \frac{6c\cos(\phi)}{\sqrt{3}(3 - \sin(\phi))}$$

Here c is the cohesion, which needs to be specified both for the yield function and the flow rule; by choosing different values non-associative plasticity is obtained.

You should also include tension cut-off, preferably with **group_materi_plasti_tension_direct**.

Generalised Non Associate CamClay for Bonded Soils plasticity model

It is a modification of the 'Milan' model of Prof. Roberto Nova.

Gurson plasticity model

The **group_materi_plasti_gurson** model reads

$$\frac{3\bar{\sigma}^2}{\sigma_y^2} + 2q_1 f^* \cosh(q_2 \frac{3\sigma_m}{2\sigma_y}) - (1 + (q_3 f^*)^2) = 0$$

Here f^* is the volume fraction of voids. The rate equation

$$\dot{f^*} = (1 - f^*) f^* \epsilon_{kk}^{\text{plas}}$$

defines the evolution of f^* if the start value for f^* is specified. Furthermore, q_1, q_2 and q_3 are model parameters.

Hardening-Soil model

In this section, the principal stresses are ordered such that

$$\sigma_3 > \sigma_2 > \sigma_1$$

so that σ_1 is the largest compressive stress. Likewise for the principal plastic strains:

$$\epsilon_3^p > \epsilon_2^p > \epsilon_1^p$$

First the elasticity parameters are defined. The elasticity parameters for the first loading are:

$$\text{Young}'\text{s modulus} = E_{50} = E_{50}^{ref} \left(\frac{\sigma_3 + c \ \cot\phi}{\sigma_{50}^{ref} + c \ \cot\phi} \right)^m \quad \text{and Poisson}'\text{s ratio} = \nu_{50}$$

The elasticity parameters for the elastic unloading and reloading are:

$$\text{Young}'\text{s modulus} = E_{ur} = E_{ur}^{ref} \left(\frac{\sigma_3 + c \ \cot\phi}{\sigma_{ur}^{ref} + c \ \cot\phi} \right)^m \quad \text{and Poisson}'\text{s ratio} \ = \ \nu_{ur}$$

The yield function reads:

$$f = \frac{1}{E_{50}} \frac{q}{1 - q/q_a} - \frac{2q}{E_{ur}} - \gamma^p$$

where q is the equivalent shear stress and γ^p is the equivalent plastic shear strain.

The equivalent asymptotic shear stress reads

$$q_a = \frac{q_f}{R_f}$$

in which q_f is the shear failure stress, and R_f is the failure ratio.

Specify all elasticity parameters in **group_materi_elasti_hardsoil**. Typically you have:

- E_{50}^{ref} from experiment at stress σ_{50}^{ref}
- ν_{ur} from experiment or the typical undrained value 0.495 or the typical drained value 0.3
- m from experiment or the typical value 0.5
- E_{ur}^{ref} from experiment at stress σ_{ur}^{ref}, or the typical value $3E_{50}^{ref}$
- ν_{ur} from experiment or the typical undrained value 0.495 or the typical drained value 0.2

Specify all plasticity parameters in **group_materi_plasti_hardsoil**.

- ϕ from experiment (maximum friction angle)
- c from experiment (cohesion)
- ψ from experiment (maximum dilatancy angle)
- R_f from experiment or the typical value 0.9 (failure ratio)

Initialize **materi_strain_plasti_hardsoil** in the initialization part. This causes that the **node_dof** records will be filled with the shear plastic strains. Also initialize **materi_plasti_hardsoil_history**.

You can add an initial contribution to the γ^p by setting **control_materi_plasti_hardsoil_gammap_initial** to **-yes**. This tells tochnog to create an extra contribution to γ^p exactly such that the yield function is zero-valued. This is convenient to start the calculation with hardsoil with deviatoric stresses which would have been outside the yield surface without this extra contribution. The extra addition to γ^p is saved in the record **element_intpnt_materi_plasti_hardsoil_gammap_in** for each integration point of elements. The creation of this extra initial contribution is done in the first timestep of the timesteps of the corresponding **control_timestep** record with the same index.

See also [18] for some details. Especially notice that the model is more suited for monotonic loading than for load cycling (since it violates thermodynamics and tends to generate energy).

Mohr-Coulomb plasticity model

The **group_materi_plasti_mohr_coul** model reads

$$0.5(\sigma_1 - \sigma_3) + 0.5(\sigma_1 + \sigma_3)\sin(\phi) - c\ \cos(\phi) = 0$$

Here c is the cohesion, σ_1 is the largest principal stress and σ_3 is the smallest principal stress. The angle ϕ needs to be specified for both the yield condition and the flow rule; by choosing different values, non-associative plasticity is obtained.

As an alternative consider using **group_materi_plasti_mohr_coul_direct**, which is more stable and fast.

You should also include tension cut-off, preferably with **group_materi_plasti_tension_direct**.

Mohr-Coulomb hardening-softening plasticity model

The **group_materi_plasti_mohr_coul_hardening_softening** model is the same as the standard Mohr-Coulomb model. Now, however, the parameters c and ϕ (both for the yield rule and for the flow rule) are softened on the effective plastic strain κ^{shear}.

For example, for the cohesion a linear variation is taken between the initial value c_0 at $\kappa^{shear} = 0$, up to c_1 at a specified critical value of κ^{shear}, and constant c_1 for larger values of κ^{shear}. The same is done for ϕ for the yield rule and for the flow rule.

You should also include tension cut-off, preferably with **group_materi_plasti_tension_direct**.

Tension limiting plasticity model

This **group_materi_plasti_tension** model uses a special definition for the equivalent stress

$$\bar{\sigma} = \sqrt{{\sigma_{max}}^2}$$

where σ_{max} is the largest principal tension stress.

$$\bar{\sigma} - \sigma_y = 0$$

This plasticity surface limits the allowable tension stresses.

A simple model for concrete can be obtained as follows. Use **group_materi_plasti_tension** to limit the tension strength *ft*. Use **group_materi_plasti_vonmises** to limit the compressive strength *fc*. The tension strength could be softened to zero over an effective plastic strain κ of, say, 1 percent. The compressive strength could be softened to zero over an effective plastic strain κ of, say, 10 percent.

Von-Mises plasticity model

The **group_materi_plasti_vonmises** model reads

$$\sqrt{3}\ \bar{\sigma} - \sigma_y = 0$$

where without hardening the yield value is fixed $\sigma_y = \sigma_{y0}$.

If however the **group_materi_plasti_vonmises_nadai** hardening law for Von-Mises plasticity is specified then

$$\sigma_y = \sigma_{y0} + C(\kappa\_0 + \kappa)^n$$

where C, κ_0 and n are parameters for the hardening law, and κ is the isotropic hardening parameter (see later). The parameter σ_{y0} is specified by **group_materi_plasti_vonmises**.

Isotropic Hardening and softening

The size of the total plastic strains rate is measured by the **materi_plasti_kappa** parameter

$$\dot{\kappa} = \sqrt{0.5 \dot{\epsilon}_{ij}^{\text{plas}} \dot{\epsilon}_{ij}^{\text{plas}}}$$

The size of the shear plastic strains rate is measured by the **materi_plasti_kappa_shear** parameter

$$\dot{\kappa}^{shear} = \sqrt{0.5 \dot{\epsilon}_{ij}^{\text{shear,plas}} \dot{\epsilon}_{ij}^{\text{shear,plas}}}$$

where the plastic shear strains are defined by

$$\dot{\epsilon}_{ij}^{\text{shear,plas}} = \dot{\epsilon}_{ij}^{\text{plas}} - \delta_{ij}(\dot{\epsilon}_{11}^{\text{plas}} + \dot{\epsilon}_{22}^{\text{plas}} + \dot{\epsilon}_{33}^{\text{plas}})/3$$

These parameters κ and κ^{shear} can be used for isotropic hardening. Use the **dependency_diagram** for this.

Kinematic Hardening

The **materi_plasti_rho** matrix ρ_{ij}, governs the kinematic hardening in the plasticity models. It is used in the yield rule and flow rule to get a new origin by using the argument $\sigma_{ij} - \rho_{ij}$:

$$f^{\text{yield}} = f^{\text{yield}}(\sigma_{ij} - \rho_{ij})$$
$$f^{\text{flow}} = f^{\text{flow}}(\sigma_{ij} - \rho_{ij})$$

where the rate of the matrix ρ_{ij} is taken to be

$$\dot{\rho_{ij}} = a \ \dot{\epsilon_{ij}}^{\text{plas}}$$

where a is a user specified factor (see **group_materi_plasti_kinematic_hardening**).

Plastic heat generation

The plastic energy loss can be partially turned into heat rate per unit volume q:

$$q = \eta \, \sigma_{ij} \, \dot{\epsilon_{ij}}^{\text{plas}}$$

where η is a user specified parameter (between 0 and 1) specifying which part of the plastic energy loss is turned into heat (see **group_materi_plasti_heat_generation**).

2.2.4 Hypo-Plasticity

In hypoplasticity a direct relation is used between strain rates and effective stress rates. Rigid body rotations (objectivity) are treated elsewhere (see the section on memory). The effective stress tensor σ_{ij} follows from the total stress tensor σ_{ij} minus any pore pressures (see groundflow). The Masin law is tuned to clays. The Wolffersdorff law is tuned to sands but can also be used for clays. The Niemunis visco law describes time dependent soil behaviour. If you need a cyclic law, you should use the Wolffersdorff law with intergranular strains and especially specify the correct theta. For many cycles the isa-intergranular strain formulation can be used.

Masin law

The law proposed by MASIN [11] and [12] is used. This law is formulated in kPa; you need to make the remainder of the input file consistent with that.

The constitutive equation in rate form reads:

$$\mathring{\mathbf{T}} = \boldsymbol{\mathcal{L}} : \mathbf{D} + f_d \mathbf{N} \|\mathbf{D}\| \tag{9}$$

where $\mathbf{D}$ is the Euler's stretching tensor, $\mathbf{T}$ is the Cauchy stress tensor and

$$\boldsymbol{\mathcal{L}} = 3 f_s \left(c_1 \boldsymbol{\mathcal{I}} + c_2 a^2 \hat{\mathbf{T}} \otimes \hat{\mathbf{T}} \right) \qquad \mathbf{N} = \boldsymbol{\mathcal{L}} : \left(-Y \frac{\mathbf{m}}{\|\mathbf{m}\|} \right) \qquad \hat{\mathbf{T}} = \frac{\mathbf{T}}{\operatorname{tr} \mathbf{T}} \tag{10}$$

$\mathbf{1}$ is the second–order identity tensor and $\boldsymbol{\mathcal{I}}$ is the fourth–order identity tensor, with components:

$$(\mathcal{I})_{ijkl} = \frac{1}{2} \left(1_{ik} 1_{jl} + 1_{il} 1_{jk} \right) \tag{11}$$

The functions $f_s(\mathrm{tr}\,\mathbf{T})$ (*barotropy* factor) and $f_d(\mathrm{tr}\,\mathbf{T}, e)$ (*pyknotropy* factor) are given by:

$$f_s = -S_i \frac{\mathrm{tr}\mathbf{T}}{\lambda^*}\left(3 + a^2 - 2^\alpha a\sqrt{3}\right)^{-1} f_d \qquad = \left[-\frac{2\mathrm{tr}\mathbf{T}}{3sp_r}\exp\left(\frac{\ln(1+e) - N}{\lambda^*}\right)\right]^\alpha \tag{12}$$

where p_r is the reference stress for the parameter N, typically taken as 1 kPa, and the factor S_i is a function of sensitivity s:

$$S_i = \frac{s - k(s - s_f)}{s} \tag{13}$$

The scalar function Y and the second–order tensor $\mathbf{m}$ are given, respectively, by:

$$Y = \left(\frac{\sqrt{3}a}{3 + a^2} - 1\right)\frac{(I_1 I_2 + 9I_3)\left(1 - \sin^2\varphi_c\right)}{8I_3 \sin^2\varphi_c} + \frac{\sqrt{3}a}{3 + a^2} \tag{14}$$

in which:

$$I_1 = \mathrm{tr}\mathbf{T} \qquad I_2 = \frac{1}{2}\left[\mathbf{T} : \mathbf{T} - (I_1)^2\right] \qquad I_3 = \det\mathbf{T}$$

and

$$\mathbf{m} = -\frac{a}{F}\left[\hat{\mathbf{T}} + \hat{\mathbf{T}}^* - \frac{\hat{\mathbf{T}}}{3}\left(\frac{6\ \hat{\mathbf{T}} : \hat{\mathbf{T}} - 1}{(F/a)^2 + \hat{\mathbf{T}} : \hat{\mathbf{T}}}\right)\right] \tag{15}$$

in which:

$$\hat{\mathbf{T}}^* = \hat{\mathbf{T}} - \frac{\mathbf{1}}{3} \qquad F = \sqrt{\frac{1}{8}\tan^2\psi + \frac{2 - \tan^2\psi}{2 + \sqrt{2}\tan\psi\cos 3\theta}} - \frac{1}{2\sqrt{2}}\tan\psi \tag{16}$$

$$\tan\psi = \sqrt{3}\|\hat{\mathbf{T}}^*\| \qquad \cos 3\theta = -\sqrt{6}\frac{\mathrm{tr}\left(\hat{\mathbf{T}}^* \cdot \hat{\mathbf{T}}^* \cdot \hat{\mathbf{T}}^*\right)}{\left(\hat{\mathbf{T}}^* : \hat{\mathbf{T}}^*\right)^{3/2}} \tag{17}$$

Finally, the scalars a, α, c_1 and c_2 are given as functions of the material parameters φ_c, λ^*, κ^* and r by the following relations:

$$a = \frac{\sqrt{3}\left(3 - \sin\varphi_c\right)}{2\sqrt{2}\sin\varphi_c} \qquad \alpha = \frac{1}{\ln 2}\ln\left[\frac{\lambda^* - \kappa^* S_i}{\lambda^* + \kappa^* S_i}\left(\frac{3 + a^2}{a\sqrt{3}}\right)\right] \tag{18}$$

$$c_1 = \frac{2\left(3 + a^2 - 2^\alpha a\sqrt{3}\right)}{9rS_i} \qquad c_2 = 1 + (1 - c_1)\frac{3}{a^2} \tag{19}$$

Evolution of the state variables e (void ratio) and s (sensitivity) is governed by

$$\dot{e} = (1 + e)\,\mathrm{tr}\,\mathbf{D} \tag{20}$$

$$\dot{s} = -\frac{k}{\lambda^*}(s - s_f)\sqrt{(\dot{\epsilon}_v)^2 + \frac{A}{1 - A}(\dot{\epsilon}_s)^2} \tag{21}$$

where $\dot{\epsilon}_v = \mathrm{tr}\,\mathbf{D}$ and $\dot{\epsilon}_s = \sqrt{2/3}\|\mathrm{dev}\ \mathbf{D}\|$.

The basic hypoplastic model requires five constitutive parameters, namely φ_c, λ^*, κ^*, N and r, state is characterised by the Cauchy stress $\mathbf{T}$ and void ratio e.

	φ_c	λ^*	κ^*	N	r	k	A	s_f
London clay	22.6°	0.11	0.016	1.375	0.4	-	-	-
Pisa clay	21.9°	0.14	0.0075	1.56	0.3	0.4	0.1	1

Table 1: *Typical parameters of the hypoplastic model for clays.*

An extended model allows us to take into account the effects of meta-stable structure of natural clays. This extension requires three additional parameters (k, A, s_f), and one additional state variable s. A basic model without the structure effects is recovered if $s = s_f = 1$ and $A \neq 1$. The s should be always greater or equal to 1.

The basic law parameters should be specified in **group_materi_plasti_hypo_masin**. The extended parameters for the structure should be specified in **group_materi_plasti_hypo_masin_structu** The hypoplastic history variables, e for this basic model, and e and s for the extended model, should be initialised with **materi_plasti_hypo_history**. As an alternative to specify the e you can specify the OCR at the start of the calculation in **group_materi_plasti_hypo_masin_ocr** (which is used to determine the initial e via $e = exp(N - \lambda^* \, ln(|OCR|) - \lambda^* \, ln(|p/p_r|)) - 1.$).

Masin clay law

This law is an improved version of the Masin law of the previous section. This law is formulated in kPa, so you should use that as units in your input file.

Anisotropy of sedimentary clays is such a significant feature of their mechanical behaviour that it cannot be ignored in finite element calculations. The hypoplastic model for clays with explicit formulation of the asymptotic state boundary surface is combined with an anisotropic form of the stiffness tensor. The resulting model predicts correctly the very small strain stiffness anisotropy. Anisotropy influences the undrained stress path, and this model is able to model such influence. For theoretical backgroup see [13] and [14].

User input can be defined with the following records: **control_materi_plasti_hypo_masin_clay_ocr_appl**

group_materi_plasti_hypo_cohesion,
group_materi_plasti_hypo_masin_clay,
group_materi_plasti_hypo_masin_clay_advanced_parameters,
group_materi_plasti_hypo_masin_clay_advanced_direction,
group_materi_plasti_hypo_masin_clay_ocr,
group_materi_plasti_hypo_masin_clay_structure,
group_materi_plasti_hypo_strain_intergranular_masin_clay.

A biaxial input file showing all available options is given here below:

```
echo -no
number_of_space_dimensions 2
materi_velocity
materi_displacement
materi_strain_intergranular
```

```
materi_strain_total
materi_plasti_hypo_history
materi_stress
end_initia

node 1  0.00 0.00
node 2  1.00 0.00
node 3  0.00 1.00
node 4  1.00 1.00

element 1 -quad4 1 2 3 4

start_define
  left_edge geometry_line 0
end_define
left_edge  0.00 0.00 0.00 1.00 1.e-5
start_define
  lower_edge geometry_line 1
end_define
lower_edge 0.00 0.00 1.00 0.00 1.e-5
start_define
  upper_edge geometry_line 2
end_define
upper_edge 0.00 1.00 1.00 1.00 1.e-5
start_define
  right_edge geometry_line 3
end_define
right_edge 1.00 0.00 1.00 1.00 1.e-5

start_define
  sig0 -50.
end_define

force_edge_normal_geometry   0  -geometry_line 3
force_edge_normal            0  sig0

bounda_dof     0  -left_edge -velx
bounda_dof     1  -lower_edge -vely
bounda_dof     2  -upper_edge -vely
bounda_time    2  -1.

group_type 0  -materi
group_materi_plasti_hypo_masin_clay_ocr 0  1.2
group_materi_plasti_hypo_cohesion 0  0.
group_materi_plasti_hypo_masin_clay 0
                        25 (phic in degrees)
                        0.1 (lambda_star)
                        0.01 (kappa_star)
```

```
                        1 (N)
                        0.2 (nu_pp)

(
group_materi_plasti_hypo_masin_clay_structure 0
                        0.4 (k)
                        0.1 (A)
                        1.5 (s_f)
group_materi_plasti_hypo_strain_intergranular_masin_clay 0
                        5.e-5 (R)
                        270. (A_g)
                        1.0 (n_g)
                        0.5 (m_rat)
                        0.08 (beta_r)
                        7.0 (chi)
                        7.0 (theta)
group_materi_plasti_hypo_masin_clay_visco 0
                        1.e-6 (D_r)
                        0.1 (I_v)
group_materi_plasti_hypo_masin_clay_ocr 0
                        1.5 (ocr)
group_materi_plasti_hypo_masin_clay_advanced_double 0
                        1.0 (alpha_g)
                        equation 40  (alpha_f)
                        0.3 (a_y)
                        2.0 (o_c)
)

post_point 1 0.5 0.5

control_reset_dof             10  -hyhis0
control_reset_value_constant  10  0.6
control_reset_dof             20  -sigxx -sigzz
control_reset_value_constant  20  sig0
control_reset_dof             30  -sigyy
control_reset_value_constant  30  sig0
control_reset_dof             40  -hyhis4 (structure)
control_reset_value_constant  40   2
control_reset_dof             50  -epixx
control_reset_value_constant  50  -0.00001
control_reset_dof             60  -epiyy
control_reset_value_constant  60  -0.00001
control_reset_dof             70  -epizz
control_reset_value_constant  70  -0.00001

control_print_history         80  -post_point_dof 1 -sigyy

control_timestep              90  1.e-4 0.1
```

```
control_materi_plasti_hypo_masin_clay_ocr_apply 90  -no
control_print                  90  -time_current -post_node_rhside_ratio -post_point_dof
control_print_history          90  -post_point_dof 1 -sigyy
end_data
```

A final notice: this law only functions well if the OCR does not become below 1. If Tochnog detects a void ratio violating this condition, it will automatically change the void ratio in such a way that the OCR becomes 1, and the calculation can continue.

Wolffersdorff law

The law proposed by WOLFFERSDORFF [19] is used.

$$\dot{\sigma}_{ij} = L_{ijkl}\dot{\epsilon}_{ij} + f_d N_{ij}\sqrt{\dot{\epsilon}_{kl}\dot{\epsilon}_{kl}} = L_{ijkl}(d_{kl} - f_d Y m_{kl}||d||)$$

Here the part with L_{ijkl} gives a linear relation between strain rates and stress rates and the part with N_{ij} gives a nonlinear relation. The constitutive tensors L_{ijkl} and $f_d N_{ij}$ are functions of the effective stress tensor σ_{ij} and void ratio e. In the above d denotes the strain rate tensor ϵ, Y denotes the degree of nonlinearity $Y = ||L^{-1} : N||$ and the flowrule m is defined by $m = -(L^{-1} : N)^{\rightarrow}$ where a $\rightarrow$ denotes euclidian normalisation.

$$L_{ijkl} = f_b f_e \frac{1}{\hat{\sigma}_{mn}\hat{\sigma}_{mn}} \hat{L_{ijkl}}$$

$$N_{ij} = f_b f_e \frac{F\,a}{\hat{\sigma}_{kl}\hat{\sigma}_{kl}} \left(\hat{\sigma}_{ij} + \hat{\sigma}^*_{ij}\right)$$

$$\text{and} \quad \hat{\sigma}_{ij} = \sigma_{ij}/(\sigma_{mn}\delta_{mn}) \quad , \quad \hat{\sigma}^*_{ij} = \hat{\sigma}_{ij} - \tfrac{1}{3}\,\delta_{ij} \quad , \quad I_{ijkl} = \delta_{ik}\delta_{jl} \ ,$$

$$a = \frac{\sqrt{3}(3 - \sin\varphi_c)}{2\sqrt{2}\sin\varphi_c}$$

$$F = \sqrt{\frac{1}{8}\tan^2\psi + \frac{2 - \tan^2\psi}{2 + \sqrt{2}\tan\psi\cos 3\theta}} - \frac{1}{2\sqrt{2}}\tan\psi \ ,$$

$$\tan\psi = \sqrt{3}\sqrt{\hat{\sigma}^*_{ij}\hat{\sigma}^*_{ij}} \quad , \quad \cos 3\theta = -\sqrt{6}\,\frac{\hat{\sigma}^*_{ij}\hat{\sigma}^*_{jk}\hat{\sigma}^*_{ki}}{[\hat{\sigma}^*_{mn}\hat{\sigma}^*_{mn}]^{3/2}} \quad .$$

For the $\hat{L_{ijkl}}$ above we have:

$$\hat{L}_{ijkl} = \left(F^2\, I_{ijkl} + a^2\,\hat{\sigma}_{ij}\hat{\sigma}_{kl}\right)$$

For $\hat{\sigma}^*_{ij} = 0$ is $F = 1$.

The scalar factors f_b, f_e and f_d take into account the influence of mean pressure and density:

$$f_b = \frac{h_s}{n}\left(\frac{e_{i0}}{e_{c0}}\right)^{\beta}\frac{1+e_i}{e_i}\left(-\frac{\sigma_{ij}\delta_{ij}}{h_s}\right)^{1-n}\left[3+a^2-a\sqrt{3}\left(\frac{e_{i0}-e_{d0}}{e_{c0}-e_{d0}}\right)^{\alpha}\right]^{-1} \quad ,$$

$$f_d = \left(\frac{e-e_d}{e_c-e_d}\right)^{\alpha} \quad .$$

and $f_e = \left(\frac{e_c}{e}\right)^{\beta}$.

Three characteristic void ratios – e_i (during isotropic compression at the minimum density), e_c (critical void ratio) and e_d (maximum density) – decrease with mean stress:

$$\frac{e_i}{e_{i0}} = \frac{e_c}{e_{c0}} = \frac{e_d}{e_{d0}} = \exp\left[-\left(-\frac{\sigma_{ij}\delta_{ij}}{h_s}\right)^{n}\right]$$

The range of admissible void ratios is limited by e_i and e_d. The model parameters can be found in Tab. 2. They correspond to Hochstetten sand from the vicinity of Karlsruhe, Germany [19].

φ [°]	h_s [MPa]	n	e_{c0}	e_{d0}	e_{i0}	α	β
33	1000	0.25	0.95	0.55	1.05	0.25	1.0

Table 2: *Basic hypoplastic parameters of Hochstetten sand.*

The basic law parameters should be specified in **group_materi_plasti_hypo_wolffersdorff**. The hypoplastic history variables should be initialised with **materi_plasti_hypo_history**.

Wolffersdorff law - extended Niemunis version

An extended version of this hypoplastic law is given in [16]. An extra term is added to $\hat{L}_{ijkl}$, in index notation:

$$b^2(\delta_{ik}\delta_{jl} - \frac{1}{3}\delta_{ij}\delta_{kl})$$

Here b^2 is given in [16], depending on the input parameter ν, which can be seen as the classical Poisson ratio, typically 0.2 or 0.3. The first part of f_d is determined:

$$\text{if } e >= e_d \text{ then } f_d = \left(\frac{e-e_d}{e_c-e_d}\right)^{\alpha}$$

$$\text{if } e < e_d \text{ then } f_d = -\left(\frac{e_d-e}{e_c-e_d}\right)^{\alpha}$$

Then $\overline{f}_d$ is determined:

$$\overline{f}_d \quad \text{equation 4.221 in [16]}$$

where

$$M_e^{(d)} \text{ and } M_T^{(d)} \quad \text{equation 4.211 in [16]}$$

Finally f_d is checked

$$\text{if } (f_d < 1) \text{ then } f_d := f_d + (1 - f_d)^z \ \overline{f}_d$$

where z is an input parameter specified, typically 5.

You need to specify the parameters ν and z in **group_materi_plasti_hypo_wolffersdorff_niemunis**.

Wolffersdorff pressure dependent initial void ratio extension

You can correct the initial void ratio e_0, as specified in the initial value for the history variable in the **node_dof** records, for the initial pressure to obtain a corrected initial void ratio e.

$$\frac{e}{e_0} = \exp\left[-\left(-\frac{\sigma_{ij}\delta_{ij}}{h_s}\right)^n\right]$$

See the basic law description for the parameters h_s and n. The σ_{ij} denotes the effective stress tensor (total stresses minus any groundflow pressure). This pressure dependent initial void ratio correction can be activated by **control_materi_plasti_hypo_pressure_dependent_void_ratio**. After the initial void ratio has been established, the development of the void ratio is governed by volumetric compression or extension of the granular skeleton.

Niemunis visco law

For visco hypoplasticity with intergranular strains the stress rate reads:

$$\dot{\sigma}_{ij} = M_{ijkl}\dot{\epsilon}_{kl} - L_{ijkl}\dot{\epsilon}^{vis}_{kl}$$

For visco hypoplasticity the L_{ijkl} reads:

$$L_{ijkl} = f_b \hat{L}_{ijkl}$$

where

$$f_b = \frac{-\sigma_{kk}}{(1 + a^2/3)\kappa}$$

where κ is a user specified material constant κ (= Butterfield's swelling index upon isotropic unloading), and a relates to the user specified residual (=critical) friction angle φ_c as:

$$a = \frac{\sqrt{3}(3 - \sin\varphi_c)}{2\sqrt{2}\sin\varphi_c}$$

The pressure normalised stiffness is:

$$\hat{L}_{ijkl} = F^2\, I_{ijkl} + a^2\, \hat{\sigma}_{ij}\hat{\sigma}_{kl} + b^2(I_{ijkl} - \frac{1}{3}I_{ikjl})$$

where

$$b^2 = \frac{(1 + \frac{1}{3}a^2)(1 - 2\nu)}{1 + \nu} - 1$$

Notice that the equation for b only holds true for non-negative right-hand-side, so that puts limits on the allowed values for φ_c and ν.

For visco hypoplasticity the M_{ijkl} reads:

$$\begin{aligned} M_{ijkl} &= [\rho^{\chi} m_T + (1-\rho^{\chi}) m_R] L_{ijkl} + \\ &+ \begin{cases} \rho^{\chi}(1-m_T) L_{ijmn} \hat{S}_{mn} \hat{S}_{kl} & \text{for} \quad \hat{S}_{ij}\dot{\epsilon}_{ij} > 0 \\ \rho^{\chi}(m_R - m_T) L_{ijmn} \hat{S}_{mn} \hat{S}_{kl} & \text{for} \quad \hat{S}_{ij}\dot{\epsilon}_{ij} \leq 0 \end{cases} \end{aligned}$$

where $\hat{S}$ intergranular strains are the same as in the formulation without viscosity.

The viscosity strain rate is assumed to be:

$$\dot{\epsilon}_{ij}^{vis} = D_r \hat{m}_{ij} (\frac{1}{OCR})^{\frac{1}{I_v}}$$

where the normalised flow rule $\hat{m}_{ij}$ is

$$\hat{m}_{ij} = \frac{m_{ij}}{\sqrt{m_{ij} m_{ij}}}$$

with

$$m_{ij} = -\left[\frac{F^2}{a^2} (\hat{\sigma}_{ij} + \hat{\sigma}_{ij}^*) + \hat{\sigma}_{kl} \hat{\sigma}_{kl} \hat{\sigma}_{ij}^* - \hat{\sigma}_{ij} \hat{\sigma}_{kl} \hat{\sigma}_{kl}^* \right]$$

The over-consolidation ratio OCR appearing in the expression for the viscous creep rate is a function of the effective stress σ_{ij} and of the void ratio e

$$\text{OCR} = \frac{p_e}{{p_e}^+}$$

wherein the void ratio is hidden in the equivalent pressure p_e and ${p_e}^+$ is a special stress invariant.

The equivalent pressure p_e is calculated from

$$\ln\left(\frac{1+e_{e0}}{1+e}\right) = \lambda \ln\left(\frac{p_e}{p_{e0}}\right)$$

with a user specified material constant λ (= Butterfield's first compression index) and also user-specified reference parameters e_{e0}, p_{e0} which describe any pair of the void ratio and the effective pressure registered upon an isotropic D_r-isotach, i.e. during an isotropic first (= virgin) compression test with a constant volumetric rate of deformation equal to $-\sqrt{3} D_r \frac{\lambda}{\lambda - \kappa}$.

The stress invariant ${p_e}^+$ is calculated using

$${p_e}^+ = \begin{cases} \frac{p}{\beta_R - 1} \left[\beta_R \sqrt{1 + \eta^2 ({\beta_R}^2 - 1)} - 1 \right] & \text{if } \eta < 1 \\ p(1+\eta^2)^{\frac{1+\beta_R}{2}} & \text{otherwise} \end{cases}$$

wherein

$$\eta = q/(Mp) \quad \text{and} \quad M = \frac{6F \sin\varphi_c}{3 - \sin\varphi_c}$$

where $p = -\sigma_{kk}/3$ and $q = \sqrt{\frac{3}{2}\sigma^*_{kl}\sigma^*_{kl}}$ are the popular Roscoe's stress invariants. and β_R (= flattening factor for the Rendulic's cap) are the user supplied material constants.

You can specify an initial value of the void ration e_0 in **-hyhis0** with **control_reset_dof**. Then the OCR can be calculated with the above equations. As an alternative you can specify the OCR at the start of the calculation in **group_materi_plasti_hypo_niemunis_visco_ocr**; then the initial void ratio will be calculated as follows: p_e^+ will be determined from the equation above, then p_e is determined from $p_e = \mathrm{OCR} p_e^+$ and then the initial void ratio e_0 is determined from $e_0 = (1+e_e0) * (p_e/p_{e0})^{-\lambda} - 1$. (reference: Niemunis communications). Application of the specified OCR is triggered by **control_materi_plasti_hypo_niemunis_visco_ocr_apply**.

User parameters should be specified in **group_materi_plasti_hypo_niemunis_visco**.

Cohesion extension

A simplistic approach to include cohesion is used here. Instead of feeding the real effective stress state σ_{ij} into the hypoplastic law, an alternative effective stress state σ^c_{ij} is used. Cohesion is modeled by subtracting in each of the normal stress components a value c representing cohesion: $\sigma^c_{11} = \sigma_{11} - c$, $\sigma^c_{22} = \sigma_{22} - c$ and $\sigma^c_{33} = \sigma_{33} - c$. The shear stresses are not altered: $\sigma^c_{12} = \sigma_{12}$, etc.

The cohesion value should be specified in **group_materi_plasti_hypo_cohesion**.

Intergranular strains extension

In order to take into account the recent deformation history, an additional tensorial state variable S_{ij}[1] is introduced.

Denoting the normalized magnitude of S_{ij}

$$\rho = \frac{\sqrt{S_{ij}S_{ij}}}{R}$$

(R is a material parameter) and the direction of S_{ij}

$$\hat{S}_{ij} = \frac{S_{ij}}{\sqrt{S_{kl}S_{kl}}}$$

($\hat{S}_{ij} = 0$ for $S_{ij} = 0$), the evolution equation for the intergranular strain tensor reads:

$$\dot{S}_{ij} = \begin{cases} (I_{ijkl} - \rho^{\beta_r}\hat{S}_{ij}\hat{S}_{kl})\dot{\epsilon}_{kl} & \text{for} \quad \hat{S}_{ij}\dot{\epsilon}_{ij} > 0 \\ \dot{\epsilon}_{ij} & \text{for} \quad \hat{S}_{ij}\dot{\epsilon}_{ij} \leq 0 \end{cases} ,$$

where $\dot{S}_{ij}$ is the objective rate of intergranular strain. Rigid body rotations are treated elsewhere (see the section on memory). From the evolution equation (2.2.4) it follows that ρ must remain between 0 and 1.

[1] S_{ij} is denoted δ_{ij} in the paper [15]. However, in order to avoid confusion with Kronecker delta, another symbol is used here.

The general stress-strain relation is now written as

$$\dot{\sigma}_{ij} = M_{ijkl}\dot{\epsilon}_{kl} \quad .$$

The fourth order tensor M_{ijkl} represents the incremental stiffness and is calculated from the hypoplastic tensors L_{ijkl} and N_{ij} which may be modified by scalar multipliers m_T and m_R, depending on ρ and on the product $\hat{S}_{ij}\dot{\epsilon}_{ij}$:

$$\begin{aligned} M_{ijkl} &= [\rho^{\chi} m_T + (1-\rho^{\chi}) m_R] L_{ijkl} + \\ &+ \begin{cases} \rho^{\chi}(1-m_T) L_{ijmn}\hat{S}_{mn}\hat{S}_{kl} + \rho^{\theta} f_d N_{ij}\hat{S}_{kl} & \text{for} \quad \hat{S}_{ij}\dot{\epsilon}_{ij} > 0 \\ \rho^{\chi}(m_R - m_T) L_{ijmn}\hat{S}_{mn}\hat{S}_{kl} & \text{for} \quad \hat{S}_{ij}\dot{\epsilon}_{ij} \leq 0 \end{cases} \end{aligned}$$

χ and θ are additional material parameters.

An example intergranular parameters can be found in Tab. 3.

R	m_R	m_T	β_r	χ	θ
$1 \cdot 10^{-4}$	5.0	2.0	0.50	6.0	6.0

Table 3: *Example of Intergranular hypoplastic parameters.*

The intergranular parameters should be specified in **group_materi_plasti_hypo_strain_intergranular**. Additionally you need to include **materi_strain_intergranular** in the initialisation part.

The additional parameter theta is very important only for the accumulation of permanent displacements or pore pressures in cyclic or dynamic analysis with small strains. For monotonic loading or higher strains theta is not very important. And thus for such monotonic loading or higher strains you should take $\theta = \chi$.

ISA-Intergranular strains extension

Author: William Fuentes

The ISA plasticity [6] stands from Intergranular Strain Anisotropy and refers to a mathematical platform which allows to formulate new constitutive models or to extend existing hypoplastic models for soils. This family of models enables the simulation of small strain effects, such as the increase of stiffness and the reduction of the plastic accumulation under repetitive loops. Similar to the original intergranular strain concept by Niemunis and Herle (1996), it allows to couple existing hypoplastic relations to extend their capabilities for cyclic loading. However, the ISA plasticity contrasts with the previous formulation with the incorporation of an elastic locus related to a specific strain amplitude. This new feature makes its formulation elastoplastic, but the yield surface is now defined within the intergranular strain space.

The general stress-strain relation is now written according to:

$$\overset{\circ}{\sigma_{ij}} = M_{ijkl}\dot{\epsilon}_{kl}$$

whereby M_{ijkl} is the stiffness tensor. The yield surface F of the model is defined within the space of the intergranular strain S_{ij} and distinguishes elastic conditions $F < 0$ from plastic conditions $F = 0$. The formulation of M_{ijkl} reads:

$$M_{ijkl} = \begin{cases} m(L_{ijkl} + \rho^x f_d N_{ij}\hat{n}_{kl}) & \text{for } F \geq 0 \\ m_R L_{ijkl} & \text{for } F = 0 \end{cases}$$

whereby m, ρ^x, f_d and m_R are scalar factors, N_{ij} is the non-linear stiffness tensor, L_{ijkl} is the linear stiffness tensor and $\hat{n}_{kl}$ is the intergranular strain model flow rule. The ISA model proposes an evolution equation for the intergranular strain S_{ij} with an elastoplastic formulation:

$$\dot{S}_{ij} = \dot{\varepsilon}_{ij} - \dot{\lambda}_H \hat{n}_{ij}$$

whereby $\dot{\lambda}_H$ is a plastic multiplier ($\dot{\lambda}_H = 0$ for $F < 0$). The model may be enhanced to capture the plastic accumulation for larger number of cycles with an additional state variable ε_{acc}. This variable is able to distinguish between consecutive cycles or non-consecutive cycles [7]:

$$\varepsilon_{\text{acc}} = \varepsilon_{\text{acc}} + \frac{C_a}{R}(1 - y_h - \varepsilon_{\text{acc}})\sqrt{\Delta\varepsilon_{ij}\Delta\varepsilon_{ij}}$$

The parameter C_a controls the rate at which the plastic accumulation reduces upon consecutive cycles. The exponent χ is increased to $\chi_{\max}$ to produce this effect on the constitutive equation.

Typical parameters are $\chi_{\max} = 20$ and $C_a = 0.017$. See also **group_materi_plasti_hypo_strain_isa**.

2.2.5 Damage

In the presence of **materi_damage** d, the **materi_stress** follows:

$$\sigma_{ij}^{\text{damaged}} = (1 - d)\sigma_{ij}^{\text{undamaged}}$$

For the damage, the **group_materi_damage_mazars** model is available:

$$d = d_t\ \alpha^{\beta}\ +\ d_c\ (1 - \alpha)^{\beta}$$

where

$$d_t = 1. - (1 - a_t)\ \frac{\epsilon^0}{\epsilon^{\text{eq}}} - a_t\ e^{-b_t(\epsilon^{\text{eq}} - \epsilon^0)}$$

and

$$d_c = 1. - (1 - a_c)\ \frac{\epsilon^0}{\epsilon^{\mathrm{eq}}} - a_c\ e^{-b_t(\epsilon^{\mathrm{eq}} - \epsilon^0)}$$

Here ϵ^{eq} contains the positive principal strains. The parameter α is given by the ratio $\frac{\epsilon^{\mathrm{eq}}}{\epsilon}$, where ϵ contains the total strains (both negative and positive). The parameter ϵ^0 is the strain threshold for damage; other material parameters are β , a_t , b_t , a_c , b_c. Typically for concrete:

$1.e{-}4 < \epsilon^0 < 3.e{-}4$; $\beta = 1.$; $1 < a_t < 1.5$; $500 < b_c < 2000$; $0.7 < a_c < 1.2$; $e^4 < b_t < 5e^4$

You can combine damage freely with plasticity models or other material behavior.

2.2.6 Average stress (hydrostatic compressibility)

An extra average stress contribution on each of σ_{11}, σ_{22} and σ_{33} is

$$\frac{1}{co}\frac{\partial v_i}{\partial x_i}$$

where co is the **group_materi_elasti_compressibility**, which should not be 0. This pressure term can e.g. be used to model nearly incompressible fluids. The compressibility contribution should be combined with a contribution for the deviatoric stresses (e.g. **group_materi_viscosity**).

2.2.7 Undrained groundflow analysis

In case you want to perform an undrained groundflow analysis, but do not want to have both the material velocity and groundflow equations at the same time in system matrix, you can use **group_materi_undrained_capacity**. Then the following equation will be used to determine the total groundwater pressure changes in an element:

$$C\ \dot{p}_{total} = \frac{\partial v_i}{\partial x_i}$$

which actually is the groundflow storage equation without permeability. The above equation can be solved on an element-by-element level, so that the groundflow hydraulic pressure head and the storage equation do not need to be added to the complete system matrix. The capacity C should be specified in **group_materi_undrained_capacity**. Results for the pressure in a element will be written to **element_intpnt_materi_undrained_pressure**. Application of this undrained analysis can be switched off and on with **control_materi_undrained_apply**.

This option is convenient to prevent the need for large, and ill-conditioned, system matrices in coupled soil - groundwater analysis. Typically the computational strategy may be like this:

...
(include capacity for undrained analysis in relevant groups)
group_materi_undrained_capacity ...
...
(set the hydraulic pressure heads, and fix them for the remainder of the calculation)
control_reset_dof ...-pres
bounda_dof ...-tpres
...
(solve material displacements in the remainder of the calculation)
control_timesteps ...
control_materi_undrained_apply ... -yes
...

The advantage of the above computational strategy is that never a system matrix with both material velocities and groundflow pressures needs to be solved. When solving the remainder of the calculation Tochnog uses the fixed total pressure from the hydraulic pressure heads plus the excessive undrained pressure of the remainder of the calculation as the full total pressure (when determining total stresses from effective stresses plus full total pressure). Alternatively to setting the hydraulic pressure head at the start with the **control_reset_dof**, you can also solve the gravity state for hydraulic pressure heads and material displacements (at the expense of a system matrix with both material velocities and groundflow hydraulic pressures in this gravity calculation; but in the gravity calculation only and the remainder of the calculation).

2.2.8 Thermal stresses

Temperature rates cause fictitious thermal strain rates

$$-\alpha\dot{T}\delta_{ij} \quad \text{where} \quad \delta_{ij} = 1 \quad \text{if} \quad i = j \quad \text{else} \quad \delta_{ij} = 0$$

where α is the **group_materi_expansion_linear** coefficient and $\dot{T}$ is the **condif_temperature**. These fictitious thermal strain rates in turn lead to stress rates.

2.2.9 Hyper elasticity

Hyper elasticity is used to model rubbers. It should be combined with a total Lagrange formulation for the memory of the material (so use **-total** for **group_materi_memory**).

The stresses follow from a strain energy function (with C_{ij} components of the matrix C, and where F is the deformation tensor and U is the stretch tensor following from the polar decomposition of the deformation tensor)

$$2\frac{\partial W}{\partial C_{ij}}$$

$$C = F^T F = U^T U$$

Deviatoric contributions

To obtain a purely deviatoric function, the following strain measures are used (with I_1, I_2 and I_3 the first, second and third invariant of the elastic strain matrix C respectively)

$$J_1 = I_1 I_3^{\frac{-1}{3}} \quad J_2 = I_2 I_3^{\frac{-2}{3}}$$

The **group_materi_hyper_besseling** function reads (with K_1, K_2 and α user defined constants)

$$W = K_1(J_1 - 3)^\alpha + K_2(J_2 - 3)$$

The **group_materi_hyper_mooney_blatz_ko** function reads (with G and β user defined constants)

$$W = G * 0.5 * (I_1 - 3.0 + (2.0/\beta)(J^{-\beta} - 1.));$$

This Blatz-Ko hyperelastic material hardens in compression, and softens slightly in tension; it models a foamlike rubber.

The **group_materi_hyper_mooney_rivlin** function reads (with K_1 and K_2 user defined constants)

$$W = K_1(J_1 - 3) + K_2(J_2 - 3)$$

The **group_materi_hyper_neohookean** function reads (with K_1 a user defined constant)

$$W = K_1(J_1 - 3)$$

The **group_materi_hyper_reduced_polynomial** function reads (with K_i user defined constants)

$$W = K_i(J_1 - 3)^i$$

where a summation over $i = 1, 2, \ldots$ is applied.

Volumetric contributions

First we define $J = \sqrt{I_3}$. Then a volumetric part can be added to the strain energy.

The **group_materi_hyper_volumetric_linear** contribution reads:

$$W = \frac{K}{2}(J-1)^2$$

The **group_materi_hyper_volumetric_murnaghan** contribution reads:

$$W = \frac{K}{\beta}(\frac{1}{\beta - 1}J^{-\beta} + 1)J$$

The **group_materi_hyper_volumetric_polynomial** contribution reads:

$$W = \frac{K_i}{2}(J-1)^{2i}$$

for $i = 0, 1, \ldots$.

The **group_materi_hyper_volumetric_simo_taylor** contribution reads:

$$W = \frac{K}{2}((J-1)^2 + (lnJ)^2)$$

The **group_materi_hyper_volumetric_ogden** contribution reads:

$$W = \frac{K}{\beta}(\frac{1}{\beta}(J^{-\beta} - 1) + lnJ)$$

As an example, you can combine the **group_materi_hyper_mooney_rivlin** energy function with the **group_materi_hyper_volumetric_linear** so that the total strain energy function becomes:

$$W = K_1(J_1 - 3) + K_2(J_2 - 3) + \frac{K}{2}(J-1)^2$$

Here the initial shear modulus and bulk modulus are included as:

$$\text{initial shear modulus} = 2(K_1 + K_2)$$

and

$$\text{initial bulk modulus} = K$$

respectively.

2.2.10 Viscoelasticity

Viscoelasticity is modeled with n parallel **group_materi_maxwell_chain**. Each of the chains contains a spring with stiffness E^m in line with a dash pot with relaxation time t^m (m indicates the m-th maxwell chain). The viscoelastic stress rate is given by (with C^m_{ijkl} is the elastic tensor modulus of the m-th maxwell chain (depending on E^m and the poisson ratio))

$$\sum_{m=0}^{m=n-1} ({C_{ijkl}}^m \dot{\epsilon_{kl}}^{\text{elas}} - \frac{{\sigma_{ij}}^m}{t^m})$$

2.2.11 Viscoplasticity

Viscoplasticity is a model for rate-dependent plasticity. Rate dependent plasticity is important for (high-speed) transient plasticity calculations. It should be used in combination with a plasticity law. Viscoplasticity influences the stresses via the plastic strains.

The **group_materi_plasti_visco_exponential** model reads

$$\dot{\epsilon_{kl}}^{\text{plas}} = \gamma \; p \; e^{\alpha f} \; \frac{\partial f^{\text{flow}}}{\partial \sigma_{kl}}$$

where γ and α are material fluidity constants and p is the pressure. In case the αf becomes larger than a limit, it is substituted by the limit to prevent the exponent from becoming excessive large. You can set the limit with the **group_materi_plasti_visco_exponential_limit** record. This model was first developed for visco-plastic soil behavior.

The **group_materi_plasti_visco_power** model reads

$$\dot{\epsilon_{kl}}^{\text{plas}} = \eta (f)^p \; \frac{\partial f^{\text{flow}}}{\partial \sigma_{kl}}$$

where η (fluidity constant), and p (power) are user specified parameters.

2.2.12 Viscosity

The viscous contribution to the total stress is

$$2\nu D_{ij}$$

where

$$D_{ij} = 0.5(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i})$$

and divergence is neglected since we only model slightly compressible flows.

Viscous heat generation

The viscous energy loss is turned into heat rate per unit volume q:

$$q = 2\nu D_{ij} D_{ij}$$

See **group_materi_viscosity_heatgeneration**.

2.3 Contact analysis

2.3.1 Penalty formulation

Attention: the contact algorithm is experimental and needs more testing.

In contact analysis, normal forces F_n follow from the condition that bodies cannot penetrate each other. Since we use a penalty formulation, the normal force is given by

$$F_n = \lambda u_n$$

where u is the penetration and λ is called the **contact_penalty_velocity** because its generates forces on the velocity dof's. You can also impose **groundflow_pressure** and **condif_temperature** contact conditions by specifying the penalty factors **contact_penalty_pressure** and **contact_penalty_temperature**.

The contact algorithm is presently under development, and not guruanteed to work for all calculations. You must check your results.

2.3.2 Friction and frictional heat generation

This normal force leads to a friction force F_f which equals

$$F_f = \nu \, F_n$$

where ν is the *friction* coefficient (see **contact_plasti_friction**. The friction force causes heat generation rate Q:

$$Q = \eta \, F_f \, v_f$$

where v_f is the slip velocity, and the factor η is a user specified factor which determines which part of the frictional energy loss is transformed into heat (η is between 0 and 1; see **contact_heat_generation**).

2.4 Ground water flow

2.4.1 Storage equation for fully saturated analysis

The equations in this section come from [22]. The hydraulic pressure head h follows from the storage equation (with infinite stiffness solid particles):

$$c\,\dot{h} = (k_1^p \frac{\partial^2 h}{\partial {x_1}^2} + k_2^p \frac{\partial^2 h}{\partial {x_2}^2} + k_3^p \frac{\partial^2 h}{\partial {x_3}^2}) + \frac{\partial v_i}{\partial x_i} - \alpha \dot{T} + f$$

Primary dof is the hydraulic pressure head h, which is initialised with **groundflow_pressure** in the initialisation part, and which gets a label **-pres** in the **node_dof** records. Further notation: c **group_groundflow_capacity** (storativity); k_i^p **group_groundflow_permeability** in i-direction (permeability); x_i space coordinate; v_i material velocity (if present); α **group_groundflow_expansi** is the expansion coefficient of the groundwater for temperature changes. The equation is given for space coordinates following material velocities v_i (if present). The water mass acceleration (water newton inertia) is neglected in the above equation. See the naming conventions later how to determine the permeability from experimental data.

Groundflow velocities

The groundflow velocities, after initializing **groundflow_velocity**, follow from:

$${v_i}^{\mathrm{g}} = k_i^p \frac{\partial h}{\partial x_i}$$

Total groundwater pressure

The total groundwater pressure, or pore-pressure, is for example needed to calculate the total stresses in soils. The total groundwater pressure follows from:

$$p_{\mathrm{total}} = h - \rho g z$$

where g is the gravitational acceleration, and ρ is the **groundflow_density** (Please notice that g and z typically are negative numbers).

Tochnog considers pressure a pore pressure of $p = 0$, or positive, as indication that there is in fact no water pressure, so the porous soil skeleton is filled with air. In this case. the total soil stress is only composed by the effective stress of the soil skeleton.

The total stress in saturated soils follows from: total soil stress = effective soil stress + total groundwater pressure (pore pressure). This will only be done for isoparametric finite elements which have groundflow data specified.

For non-saturated soild you optionally can specify **groundflow_pressure_factor** such that the total groundwater pressure will be added only with this specified factor.

Static groundwater pressure

The static pressure due to gravity is:

$$p_{\text{static}} = \rho g \Delta z$$

where the Δz is the distance to the groundwater level, the phreatic level. The phreatic level needs to be specified with the **groundflow_phreatic_level** record. Alternatively you can specify **post_calcul_static_pressure_height** or **post_calcul_static_pressure**. If all of these are not specified, the static pressure cannot be determined, so it remains zero.

Dynamic groundwater pressure

The dynamic groundwater pressure follows from

$$p_{\text{dynamic}} = p_{\text{total}} - p_{\text{static}}$$

Boundary conditions

If the groundwater velocity is 0 normal to an edge (say at the interface with a rock layer it is zero), then you should prescribe nothing on that edge (Tochnog will then take care of that boundary conditions for you).

At the phreatic level where the groundflow meets free air the hydraulic pressure head should become $\rho g z$. You can either set this yourself by using **bounda_dof** combined with **bounda_time** or else demand that Tochnog automatically does it for you by activating the option **groundflow_phreatic_bounda**.

At edges where you have some other hydraulic pressure head you need to specify that head yourself with **bounda_dof** and **bounda_time** records. If you want to set directly the hydraulic head you need to use **-pres** in **bounda_dof**, however if you want to set the total pressure (pore pressure) you need to use **-topres** in **bounda_dof**.

If gravity is not of importance, e.g. in biomechanics where the storage equation is used to model fluid transport in soft tissues, the hydraulic pressure head h is equal to the total pressure, and thus is zero at edges where the water meets the free air. In this case, set h to zero by using **bounda_dof** combined with **bounda_time**.

Postprocessing

For all printing, plotting etc. you normally get the hydraulic pressure head h since it is the primary dof solved in the storage equation. The total pressure, static pressure and dynamic pressure are obtained using the **post_calcul** option.

Capacity and permeability explanation

Following conventional naming, we remind the user that the capacity depends on the porosity n and water compressibility β:

$$c = n\ \beta$$

and the permeability k^p used in the storage equation above you can determine from an experiment with

$$k^p = \frac{k_{experiment}}{\rho\ |g|}$$

where $k_{experiment}$ is the experimental value in units $\frac{length}{time}$ (by example $\frac{m}{s}$ in SI units).

2.4.2 Non-saturated analysis

with diagrams

You can perform a non-saturated analysis by making the permeability dependent on the groundwater total pressure (= pore pressure) by a dependency diagram. The diagram accounts for high permeability at saturation and low permeability at non-saturation. For example, do something like:

```
...
dependency_item 10 -group_groundflow_permeability 0 -to_pres 4
dependency_diagram 10 -100. 0.0 0.05 100.
1.e-2 1.e-2 1.e-8 1.e-8
1.e-2 1.e-2 1.e-8 1.e-8
...
...
```

The atmospheric air pressure is 0, so that is where the permeability starts changing it's value in the table. You can also specify a table for **group_groundflow_capacity** to model non-saturated capacity.

van Genuchten

As an alternative to specifying diagrams you can use the specific van-Genuchten model for non-saturated ground water flow. The pore-pressure head is defined by

$$\phi_p = -\frac{p}{\rho g}$$

with p the pore pressure (= total pressure), ρ the ground water density and g is the absolute value of the gravity acceleration (typically 9.81). De degree of saturation is a function of the pore-pressure head

$$S = S(\phi_p)$$

The total capacity is the sum of the saturated capacity and a non-saturated part:

$$c = c_{\text{sat}} + n\frac{dS(\phi_p)}{d\phi_p}$$

where where c_{sat} is the saturated groundflow capacity as specified by **group_groundflow_capacity** and n is the porosity specified by **group_porosity**. The total permeabilities k_i are written as a relative factor of the saturated permeabilities

$$k_i = k_{\text{rel}}(S)k_{sat,i}$$

where k_i is the total permeability in direction i, $k_{\text{rel}}(S)$ is a factor dependent on the saturation S and $k_{sat,i}$ is the saturated permeability specified by **group_groundflow_permeability**.

Now for the van-Genuchten model we have

$$S(\phi_p) = S_{\text{residu}} + (S_{\text{sat}} - S_{\text{residu}})\left(1 + (g_a|\phi_p|)^{g_n}\right)^{(1-g_n)/g_n}$$

which has the following model parameters: S_{residu} is the residual saturation, S_{sat} normally is 1.0 but may be less than 1.0 if in case of trapped air, and g_a and g_n are constants to be determined experimentally. The derivative of this law defines the additional non-saturated capacity as defined above. After definition of the effective saturation S_e

$$S_e = \frac{S - S_{\text{residu}}}{S_{\text{sat}} - S_{\text{residu}}}$$

the relative permeability factor is defined as

$$k_{\text{rel}}(S) = (S_e)^{g_l}\left(1 - (1 - S_e^{g_n/(g_n-1)})^{(g_n-1)/g_n}\right)^2$$

To use the model you need to specify the saturated parameters **group_groundflow_capacity** and **group_groundflow_permeability** as usual, specify the porosity in **group_porosity**, specify specific van-Genuchten parameters in **group_groundflow_nonsaturated_vangenuchten** and initialise **groundflow_saturation** in the initialisation part.

2.4.3 Consolidation analysis

Look in the 'Consolidation' section of the 'Interaction analyzes and advanced analyzes' chapter in the end of this manual on how to perform consolidation analyzes (combined groundwater flow with soil stress analyzes).

In case you have **groundflow_total_pressure_limit** set to 0 and the total pressure is 0, then Tochnog assumes that there is no water so the consolidation part in the equations will also be skipped. In case you have **groundflow_total_pressure_limit** set to a high positive value this will not be done, so the consolidation part will also be used in case the total pressure is 0 (or positive).

2.5 Wave equation

$$\frac{\partial \dot{s}}{\partial t} = c^2 \left(\frac{\partial^2 s}{\partial {x_1}^2} + \frac{\partial^2 s}{\partial {x_2}^2} + \frac{\partial^2 s}{\partial {x_3}^2} \right)$$

$$\frac{\partial s}{\partial t} = \dot{s}$$

The primary dof's are the **wave_scalar** s and its first time derivative **wave_fscalar** $\dot{s}$ (as TOCHNOG only solves first order in time equations, the first time derivative of s also becomes primary dof in order to turn this second order in time equation into a set of first order in time equations). Further notation: x space coordinate, t time and c speed of sound.

2.6 Probabilistic distributions

The section summarises mathematical formulation of the so-called random finite element method, as described, e.g. in [8].

Distribution of a random variable (e.g., C) is controlled by these basic parameters: parameters of the statistical distribution (typically mean value μ_C and standard deviation σ_C) and so-called correlation length θ_C that controls spatial variability of variable C.

Two probabilistic distributions are available in Tochnog: normal distribution and log-normal distribution. Probability function $P(C)$ of normal distribution is defined as:

$$P(C) = \frac{1}{\sigma_C \sqrt{2\pi}} \exp\left[-\frac{(C-\mu_C)^2}{2\sigma_C^2}\right] \tag{22}$$

where μ_C is a mean value and σ_C is standard deviation. Probability function $P(C)$ of log-normal distribution is defined as:

$$P(C) = \frac{1}{C\sigma_{\ln C}\sqrt{2\pi}} \exp\left[-\frac{(\ln C - \mu_{\ln C})^2}{2\sigma_{\ln C}^2}\right] \tag{23}$$

Quantities $\mu_{\ln C}$ and $\sigma_{\ln C}$ may be calculated from μ_C and σ_C using

$$\sigma_{\ln C} = \sqrt{\ln\left[1 + \left(\frac{\sigma_C}{\mu_C}\right)^2\right]} \qquad \mu_{\ln C} = \ln \mu_C - \frac{1}{2}\sigma_{\ln C}^2 \tag{24}$$

2.6.1 Generation of random field

A number of different techniques to generate random fields is available (see, e.g., [5]). In this following, the most simple method based on Cholesky decomposition of the correlation matrix.

First, vector $\mathbf{X}$ of statistically independent random numbers $x_1, x_2, \ldots, x_n$ (where n is number of elements in the FE mesh) with a standard normal distribution (i.e., with probability function of Eq. (22) with $\mu_C = 0$ and $\sigma_C = 1$) is generated.

A correlation matrix $\mathbf{K}$, which represents the correlation coefficient between each of the element used in the finite element analysis, is assembled. The correlation matrix $\mathbf{K}$ has the following form:

$$\mathbf{K} = \begin{bmatrix} 1 & \rho_{12} & \ldots & \rho_{1n} \\ \rho_{21} & 1 & \ldots & \rho_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{n1} & \rho_{n2} & \ldots & 1 \end{bmatrix} \tag{25}$$

where ρ_{ij} is the correlation coefficient between elements i and j, calculated using Markov function:

$$\rho_{ij} = \exp\left[-\frac{2x_{ij}}{\theta_C}\right] \tag{26}$$

where x_{ij} is absolute distance between elements i and j (distance between centers of gravity of elements i and j). For anisotropic case Eq. (26) reads

$$\rho_{ij} = \exp\left[-2\sqrt{\left(\frac{\tau_{xij}}{\theta_{Cx}}\right)^2 + \left(\frac{\tau_{yij}}{\theta_{Cy}}\right)^2 + \left(\frac{\tau_{zij}}{\theta_{Cz}}\right)^2}\right] \tag{27}$$

where θ_{Cx} is a correlation coefficient in direction of x-axis and τ_{xij} is a distance between two elements i and j in x direction. The same notation applies for y and z directions.

The matrix $\mathbf{K}$ is positive definite and hence, the standard Cholesky decomposition algorithm can be used to factor the matrix into upper and lower triangular forms, $\mathbf{S}$ and $\mathbf{S}^T$, respectively:

$$\mathbf{S}^T\mathbf{S} = \mathbf{K} \tag{28}$$

The vector of correlated random variables $\mathbf{G}$ (i.e., $G_1, G_2, \ldots, G_n$, where G_i specifies the random component of variable C in element i) is calculated by

$$\mathbf{G} = \mathbf{S}^T\mathbf{X} \tag{29}$$

Vector $\mathbf{X}$ is generated as described above.

Finally, value of the variable C is assigned to each element (C_i) by the following transformation:

- for normally distributed variable C:

$$C_i = \mu_C + \sigma_{CA} G_i \tag{30}$$

  where σ_{CA} is calculated from σ_C as described in the following section.

- for log-normally distributed variable C:

$$C_i = \exp\left(\mu_{\ln C} + \sigma_{\ln CA} G_i\right) \tag{31}$$

  where $\mu_{\ln C}$ is calculated by Eq. (24)b using $\sigma_{\ln CA}$ instead of $\sigma_{\ln C}$; $\sigma_{\ln CA}$ is calculated from $\sigma_{\ln C}$ as described in the following section.

2.6.2 Local averaging

The input parameters of C that relate to the mean, standard deviation and spatial correlation length are assumed to be defined at the point level. Due to the finite size of each finite element, point statistical distribution must be averaged over the element. This results in reduced $\sigma_{\ln C}$ in the case of log-normal distribution and reduced σ_C in the case of normal distribution. $\mu_{\ln C}$ in the first case and μ_C in the second case remain unaffected.

The locally-averaged standard deviations ($\sigma_{\ln CA}$, σ_{CA}), which are used in Eqns. (30, 31), are calculated from their point values using

$$\sigma^2_{\ln CA} = \gamma\ \sigma^2_{\ln C} \qquad\qquad \sigma^2_{CA} = \gamma\ \sigma^2_C \tag{32}$$

where γ is the variance reduction factor calculated by integration of the Markov function (26). In 1D for a finite element of side length $\alpha\theta_C$

$$\gamma = \frac{2}{(\alpha\theta_C)^2} \int_0^{\alpha\theta_C} \exp\left(-\frac{2}{\theta_C}\sqrt{x^2}\right)(\alpha\theta_C - x)dx \tag{33}$$

In 2D for square finite element of side length $\alpha\theta_C$

$$\gamma = \frac{4}{(\alpha\theta_C)^4} \int_0^{\alpha\theta_C}\int_0^{\alpha\theta_C} \exp\left(-\frac{2}{\theta_C}\sqrt{x^2+y^2}\right)(\alpha\theta_C - x)(\alpha\theta_C - y)dxdy \tag{34}$$

In 3D for hexahedral finite element of side length $\alpha\theta_C$

$$\gamma = \frac{8}{(\alpha\theta_C)^6} \int_0^{\alpha\theta_C}\int_0^{\alpha\theta_C}\int_0^{\alpha\theta_C} \exp\left(-\frac{2}{\theta_C}\sqrt{x^2+y^2+z^2}\right)(\alpha\theta_C - x)(\alpha\theta_C - y)(\alpha\theta_C - z)dxdydz \tag{35}$$

For the anisotropic case in 2D:

$$\gamma = \frac{4}{l^4} \int_0^{l}\int_0^{l} \exp\left[-2\sqrt{\left(\frac{x}{\theta_{Cx}}\right)^2 + \left(\frac{y}{\theta_{Cy}}\right)^2}\right](l - x)(l - y)dxdy \tag{36}$$

and for the anisotropic case in 3D:

$$\gamma = \frac{8}{l^6} \int_0^{l}\int_0^{l}\int_0^{l} \exp\left[-2\sqrt{\left(\frac{x}{\theta_{Cx}}\right)^2 + \left(\frac{y}{\theta_{Cy}}\right)^2 + \left(\frac{z}{\theta_{Cz}}\right)^2}\right](l - x)(l - y)(l - z)dxdydz \tag{37}$$

In order to calculate the variance reduction due to local averaging correctly, all elements in the mesh should be of the same size and all elements should be regular squares. If irregular elements are used, exact value of γ is in Tochnog approximated by calculation of γ for an equivalent square element using Eq. (35) with area equal to an average area of all elements in the mesh.

The approximate value of γ requires that you use as much as possible elements of the same size and shape in the complete calculation domain.

2.6.3 Monte Carlo simulations

The most simple but very powerful technique to solve the probabilistic problem is a Monte Carlo technique. The same problem is solved many times, each time with different fields of random variables generated according to prescribed parameters.

The whole problem is solved in the following steps:

1. Generate random fields according to Sec. 2.6.1 using **control_distribute** command as many times as many variables are treated as random. In principle, any variable can be related as random. For example material parameters, dof's (e.g., history variables), etc.

2. Solve the problem using finite element method. Collect required results of each Monte Carlo realisation into an output file. The user can prescribe any result to be collected into an output file using **control_repeat_save** command (e.g., **time_current**, final displacement of a selected point, etc.).

3. Repeat items 1. and 2. m-times, where m is a prescribed number of Monte Carlo realisations. m value is specified in Tochnog input file using **control_repeat** command.

4. Evaluate results statistically. More complex statistical evaluation is done by the user, calculation of mean value and standard deviation can be done in Tochnog using **control_repeat_save_calculate** command.

2.6.4 Input data records

A typical piece of input file could be like this:

print_group_data ... (print in the gid files distributed group data so that you get a plot of it)
...
control_distribute 10 ... (distribute something with correlation in space)
control_distribute_parameters 10 ...
control_distribute_correlation_length 10 ...
control_distribute 20 ... (distribute something else without correlation in space)
control_distribute_parameters 20 ...
...
control_timestep 30 ... (do timesteps)
control_timestep_iterations_automatic 30 ... (with automatic timestepping)
control_timestep_iterations_automatic_stop 30 -continue (don't abort the calculation if the minimum step size is reached, e.g. in a stability calculation)
...
control_print_data_versus_data 40 ... (save data for repeats in a dvd file)
...
control_repeat 50 100 10 (jump 100 times back to control index 10)
control_repeat_save 50 ... (select results to be saved for each repeat)
control_repeat_save_calculate 50 -yes (perform statistical analysis on saved results)
...
control_print_gid 100 -yes
control_print 100 -repeat_save_result -repeat_save_calculate_result
...

3 Input file, general remarks

The input is free format. Comments are enclosed between ( ), e.g. (this is comment only); a comma , is not allowed inside comments. The input should consist of an initialization part and a data part, separated by **end_initia** and ended by **end_data**

initialization
...
initialization
end_initia
data_item index data_values
...
data_item index data_values
end_data

Bold printed data in this manual can be used literally. *Italic* printed data is only symbolic (it represents a number or a word).

4 Input file, initialization part

The initialization part contains initialization records and an **end_initia** record

initialization
...
initialization
end_initia

The example below initializes a solid material

echo -yes
number_of_space_dimensions 2
materi_velocity
materi_strain_total
materi_stress
end_initia

The **echo** (always the first record), **number_of_space_dimensions** (always the second record), and **end_initia** record should be supplied always. Use **echo -yes** to echo the input and **echo -no** to not echo the input. Use **number_of_space_dimensions 1** for 1D problems, etc.. The records **materi_velocity**, **materi_strain_total** and **materi_stress** create a velocity, strain and stress field in the entire domain. In the following sections, all possible *initialization* records are discussed. Most of these records create an doffield, a physical field like a temperature field or a strain field, over the computational domain.

4.1 echo *switch* (first record of initialization part)

If *switch* is **-yes** the input will be echoed. If *switch* is **-no** the input will not be echoed. This needs to be the first record.

4.2 number_of_space_dimensions *number_of_space_dimensions* (second record of initialization part)

Set *number_of_space_dimensions* to 1 in 1D, etc.. This needs to be the second record.

4.3 derivatives (third record of initialization part, if specified)

If this record is included, the time derivative and the space derivatives will be stored in the **node_dof** records. This is only required for a limited number of models. The model description will specify if this **derivatives** initialization is needed.

4.4 beam_rotation

The beam rotations ϕ_x, ϕ_y and ϕ_z are added to the **node_dof** records.

Please notice that always all three rotations are included. Typically for a 2D calculation you may want to fix the ϕ_x and ϕ_y to 0, by using a **bounda_dof** record.

4.5 condif_temperature

The temperature T is added to the **node_dof** records.

4.6 groundflow_pressure

The pressure p is added to the **node_dof** records.

4.7 groundflow_pressure_gradient

The gradient of the hydraulic pressure $\frac{dh}{dx}\frac{dh}{dy}\frac{dh}{dz}$ is added to the **node_dof** records.

4.8 groundflow_saturation

The groundflow saturation S is added to the **node_dof** records.

4.9 groundflow_velocity

The ground water flow velocity ${v_i}^{\mathrm{g}}$ is added to the **node_dof** records.

4.10 materi_damage

The damage d is added to the **node_dof** records. Also **materi_velocity** and **materi_strain_total** should be initialized.

4.11 materi_acceleration

The accelerations a_i are added to the **node_dof** records.

4.12 materi_displacement

The displacements u, v, w are added to the **node_dof** records. If **materi_displacement** is initialized, then equations like the convection and diffusion of heat equation or the ground water flow equation are evaluated over the deformed volume, which is the sum of the nodal coordinates plus its displacements. Also if **materi_displacement** is initialized, the total Lagrange model will be used in stress analysis.

Condition: also **materi_velocity** should be initialized because the displacement follows from integration of the velocity.

4.13 materi_displacement_relative

Displacement relative to a previous point in the calculation. These are the current displacements minus the displacements before these were changed with timesteps in **control_timestep** or a displacement reset in **control_reset_dof**.

For example, this option comes handy when you want to understand the extra displacements caused by the last timesteps.

4.14 materi_history_variable *number_of_variables*

Generic history variables which can e.g. be used in some user supplied routines or otherwise.

4.15 materi_maxwell_stress *number_of_chains*

Maxwell stress ${\sigma_{11}}^m$ ${\sigma_{12}}^m$ ${\sigma_{13}}^m$ ${\sigma_{22}}^m$ ${\sigma_{23}}^m$ ${\sigma_{33}}^m$ is added to the **node_dof** records. The parameter *number_of_chains* should match data item **group_materi_maxwell_chain**. The number of maxwell stresses is 6 * *number_of_chains*.

4.16 materi_plasti_camclay_history

The history variables e_0 and p_0 for the camclay plasticity models are added to the **node_dof** records.

4.17 materi_plasti_cap1_history

The history variable p_c for the cap1 plasticity models is added to the **node_dof** records.

4.18 materi_plasti_diprisco_history *number_of_history_variables*

The history variable di Prisco plasticity models are added to the **node_dof** records. For the **group_materi_plasti_diprisco** model you need to set *number_of_history_variables* to 11. For the **group_materi_plasti_diprisco_density** model you need to set *number_of_history_variables* to 12.

4.19 materi_plasti_f

The plastic yield rule f is added to the **node_dof** records. This should only be used for elasto-plastic calculations, and not for visco-plastic calculations.

4.20 materi_plasti_f_nonlocal

The nonlocal plastic yield rule fn is added to the **node_dof** records. See also: **nonlocal**.

4.21 materi_plasti_generalised_non_associate_cam_clay_for_bonded_soils_his

The history variables for the Generalised Non Associate Cam Clay for Bonded Soils plasticity model are added to the **node_dof** records.

4.22 materi_plasti_hardsoil_history

The history variable $abs(p)$ for the hardsoil plasticity model is added to the **node_dof** records. It contains the maximum pressure history.

4.23 materi_plasti_hypo_history

Eight history variables for the hypo-plasticity models are added to the **node_dof** records.

The first history variable **-hyhis0** contains the void ratio, and should be initialized by initially specifying **node_dof** records, or optionally specifying an OCR value with a **group_materi_plasti_hypo..** record.

The second history variable **-hyhis1** will be filled with the time step size of the hypoplastic substepping scheme; this is meant for postprocessing only.

The third history variable **-hyhis2** will be filled with the mobilized friction angle in degrees; this is meant for postprocessing only.

The fourth history variable **-hyhis3** will be filled with the a measure of the effective stiffness following from the hypoplasticity law ($\sqrt{M_{ijkl}M_{ijkl}}$); this is meant for postprocessing only.

The fifth history variable **-hyhis4** for all laws with the structure option, will be filled with the structure variable s and should be initialized by initially specifying **node_dof** records.

The sixth history variable **-hyhis5**, will be filled with the OCR value; this is meant for postprocessing only. This is only available for the **group_materi_plasti_hypo_masin_clay** and **group_materi_plasti_hypo_niemunis_visco** laws.

The seventh history variable **-hyhis6** for the **group_materi_plasti_hypo_wolffersdorff**, will be filled with the density index $I_d = \frac{ec-e}{ec-ed}$; this is meant for postprocessing only.

The eight history variable **-hyhis7** for hypoplasticity laws with intergranular strains, will be filled with the intergranular strain variable ρ; this is meant for postprocessing only.

4.24 materi_plasti_kappa

The size of the plastic strain κ is added to the **node_dof** records. See the theory section.

4.25 materi_plasti_kappa_shear

The size of the shear part of the plastic strain κ^{shear} is added to the **node_dof** records. See the theory section.

4.26 materi_plasti_phimob

The mobilized friction angle ϕ_{mob} is added to the **node_dof** records. It is defined as the angle, in radians, for which the yield function

$$f = 0.5(\sigma_2 - \sigma_0) + 0.5(\sigma_2 + \sigma_0) * sin(\phi_{mob}) - ccos(\phi_{mob})$$

becomes zero. This is available for mohr-coulomb plasticity only. Please realise that in regions with substantial cohesion the mobilized friction angle ϕ_{mob} can exceed the friction angle ϕ from the plasticity law. In case of zero cohesion, or cohesion small relative to the stresses, yield is reached if the ϕ_{mob} reaches the friction angle ϕ. The definition above can give either negative or positive values for ϕ_{mob}; negative values simply indicate that the stress state is far away from yielding. The phimob is calculated in degrees.

4.27 materi_plasti_rho

The plastic kinematic hardening vector ρ_{11} ρ_{12} ρ_{13} ρ_{22} ρ_{23} ρ_{33} is added to the **node_dof** records. See also **group_materi_plasti_kinematic_hardening**.

4.28 materi_strain_energy

The material strain energy $0.5\sigma_{ij}\epsilon_{ij}{}^{\text{elas}}$ is added to the **node_dof** records. You can print or plot it to see where energy is stored after loading. Also **materi_stress** and **materi_strain_elasti** should be initialised.

4.29 materi_strain_elasti

The elastic strain $\epsilon_{kl}{}^{\text{elas}}$ is added to the **node_dof** records. See also: **materi_strain_total**.

4.30 materi_strain_intergranular

The intergranular strain S_{ij} is added to the **node_dof** records. This can be used by hypoplasticity laws, see the theory section.

4.31 materi_strain_isa_c

The ISA intergranular back-strain C_{ij} is added to the **node_dof** records. This can be used by hypoplasticity laws with ISA-intergranular strains, see the theory section.

4.32 materi_strain_isa_eacc

The ISA intergranular accumulated-strain ϵ_{acc} is added to the **node_dof** records. This can be used by hypoplasticity laws with ISA-intergranular strains, see the theory section.

4.33 materi_strain_plasti

The plastic strain $\epsilon_{kl}{}^{\text{plas}}$ is added to the **node_dof** records. See also: **materi_strain_total**.

4.34 materi_strain_plasti_camclay

The plastic strain $\epsilon_{kl}{}^{\text{plas}}$ specifically for the camclay model is added to the **node_dof** records. See also: **materi_strain_plasti**.

4.35 materi_strain_plasti_cap

The plastic strain $\epsilon_{kl}{}^{\text{plas}}$ specifically for cap models is added to the **node_dof** records. See also: **materi_strain_plasti**.

4.36 materi_strain_plasti_compression

The plastic strain $\epsilon_{kl}{}^{\text{plas}}$ specifically for the compression model is added to the **node_dof** records. See also: **materi_strain_plasti**.

4.37 materi_strain_plasti_diprisco

The plastic strain $\epsilon_{kl}{}^{\text{plas}}$ specifically for the diprisco model is added to the **node_dof** records. See also: **materi_strain_plasti**.

4.38 materi_strain_plasti_generalised_non_associate_cam_clay_for_bonded_s

The plastic strain $\epsilon_{kl}{}^{\text{plas}}$ specifically for the generalised non associate cam clay for bonded soils model is added to the **node_dof** records. See also: **materi_strain_plasti**.

4.39 materi_strain_plasti_druckprag

The plastic strain $\epsilon_{kl}{}^{\text{plas}}$ specifically for the drucker-prager model is added to the **node_dof** records. See also: **materi_strain_plasti**.

4.40 materi_strain_plasti_hardsoil

The plastic strain $\epsilon_{kl}{}^{\text{plas}}$ specifically for the hardsoil model is added to the **node_dof** records. See also: **materi_strain_plasti**.

4.41 materi_strain_plasti_mohr_coul

The plastic strain $\epsilon_{kl}{}^{\text{plas}}$ specifically for the mohr_coulomb models is added to the **node_dof** records. See also: **materi_strain_plasti**.

4.42 materi_strain_plasti_tension

The plastic strain $\epsilon_{kl}{}^{\text{plas}}$ specifically for the tension model is added to the **node_dof** records. See also: **materi_strain_plasti**.

4.43 materi_strain_plasti_vonmises

The plastic strain $\epsilon_{kl}{}^{\text{plas}}$ specifically for the von-mises model is added to the **node_dof** records. See also: **materi_strain_plasti**.

4.44 materi_strain_total

The total strain ϵ_{kl} is added to the **node_dof** records. All strains are time integrals of the strain rates for a specific material particle which happens to be present in the node.

4.45 materi_strain_total_kappa

The maximum strain size is added to the **node_dof** records.

4.46 materi_strain_total_compression_kappa

The maximum principal compression total strain as occurred in history is added to the **node_dof** records.

4.47 materi_strain_total_shear_kappa

The maximum size of the deviatoric part of the total strain as occurred in history is added to the **node_dof** records.

4.48 materi_strain_total_tension_kappa

The maximum principal tensional total strain as occurred in history is added to the **node_dof** records.

4.49 materi_stress

The stresses σ_{11} σ_{12} σ_{13} σ_{22} σ_{23} σ_{33} are added to the **node_dof** records.

4.50 materi_stress_pressure_history

The maximum of the absolute value of the pressure which occurs over time is added to the **node_dof** records. See also **group_materi_elasti_stress_pressure_history_factor** in the data part.

4.51 materi_velocity

The velocities v_i are added to the **node_dof** records.

4.52 materi_velocity_integrated

The integrated velocities vi_i are added to the **node_dof** records. The integration of nodal velocities in fact results in displacements. But asking for these integrated velocities doesn't activate automatically that the calculation is done over the total deformed volume (as is the case when you initialize **materi_displacement**), and not automatically a total Lagrange model is used in stress analysis.

4.53 materi_void_fraction

The material void fraction f^* is added to the **node_dof** records. This is required for the **group_materi_plasti_gurson** model.

4.54 materi_work

The material second order work $\dot{\sigma}_{ij}\dot{\epsilon}_{ij}$ is added to the **node_dof** records. You can print or plot it to see where material instabilities are present.

4.55 **mrange** *maximum_range_length*

Sets the maximum length of ranges **-ra** ...**-ra**.

4.56 **mstring** *maximum_number_of_strings*

Sets the maximum number of strings in a define block.

4.57 **wave_scalar**

Scalar in wave equation is **node_dof** records. Condition: also **wave_fscalar** should be initialized.

4.58 **wave_fscalar**

The first time derivative in the wave equation is added to the **node_dof** records. Condition: also **wave_scalar** should be initialized.

4.59 **end_initia (last record of initialization part)**

5 Input file, data part, introduction

Data items in the data part are used to control the calculation, select required output, give dof's initial values, etc.. Note that an **end_data** record is needed.

data_item index data_values
...
data_item index data_values
end_data

Consider the following example

element 0 -tria3 0 1 2
element 1 -tria3 1 2 3
node 0 0. 0.
node 1 1. 0.
node 2 0. 1.
node 3 1. 1.
...
end_data

Note that the data items **element** and **node** are indexed. In fact most data items need to be indexed. Indexing starts at 0 (all numbering in TOCHNOG starts at 0). Indices need not strictly be sequential (e.g. only the indices 1,2 and 5 of a data item may be specified).

The following sections first treat some extras that can be used in the data part. After that, all possible data items are specified.

Arithmetic blocks

You also can use the arithmetic expressions **plus**, **minus**, **multiply** and **divide**. We show some examples:

(make **A** equal to 4.1)
start_arithmetic
A 1.1 plus 3
end_arithmetic
...
(make **B** equal to 3.2)
start_arithmetic
B 3.2

end_arithmetic
...
(make **C** equal to 7.3)
start_arithmetic
C A plus B
end_arithmetic
...
(make **D** equal to 14.6)
start_arithmetic
D A plus B multiply 2.
end_arithmetic

Expressions will be evaluated from left to right. Words from define blocks will *not* be recognized in arithmetic blocks.

Automatic counting: the counters

The words **counter_a**, **counter_b**, **counter_c** and **counter_d** are reserved words in the data part. If they are found, they will be substituted by their integer value. After its value is substituted, the counter will be incremented by 1. Initially the value for counters is 0. The example below shows a typical application.

start_define
left_edge geometry_line counter_a
end_define
start_define
right_edge geometry_line counter_a
end_define
...
left_edge 0. 0. 0. 10. 1.e-4
right_edge 2. 0. 2. 10. 1.e-4
...
bounda_dof 1 -left_edge -velx
bounda_time 1 0.
bounda_dof 2 -right_edge -velx
bounda_time 2 1.3
...

Notice that we automatically give the geometry lines a unique number in this way; the unique number is not really of interest in the remainder of the input file, so the application of a counter is convenient.

Finally, also the words **counter_a_apply**, **counter_b_apply**, **counter_c_apply** and

counter_d_apply are available. They will be substituted by the current value of the counters, without that the counters are incremented.

Conditional blocks

Parts of the input file can be processed conditionally within **start_if** ... **end_if** blocks. This is illustrated below with an example:

Example:

```
start_define
do_complete_calculation true
end_define
...
start_if do_complete_calculation
...
end_if
...
```

The part in the **start_if** ... **end_if** block is only done if **do_complete_calculation** is set to **true**, like in the example. If **do_complete_calculation** is set to **false** that part will be skipped. You also can use **start_if_not** ... **end_if_not** blocks, so that actions are NOT taken if the defined variable is set to true.

Control indices

All possible data items are defined in the following sections. It only makes sense to specify some of the data items before the calculation; the other data items are only meant to be printed after the calculation. The example below specifies a 1D temperature calculation.

```
echo -no
number_of_space_dimensions 1
condif_temperature
end_initia

node 1 0
node 2 1
node 3 2

element 1 -bar2 1 2
element 2 -bar2 2 3
```

bounda_dof 0 1 -temp
bounda_time 0 0.0 0. 1. 1. 100. 1.
bounda_dof 1 3 -temp
bounda_time 1 0.0 0.0 100.0 0.

group_type 0 -condif
group_condif_density 0 1.0
group_condif_capacity 0 0.1
group_condif_conductivity 0 0.1
group_condif_flow 0 0.

control_timestep 0 0.1 10.0
control_print 0 -time_current -node_dof
control_print_database 1 -separate_index
control_timestep 2 0.2 10.0
control_print 2 -time_current -node_dof

end_data

Note how the indices of control items like **control_timestep** and **control_print** are used to control the sequence of events. First, (*index=0*) time steps of size 0.1 are taken and for each time step results are printed. Then (*index=1*) the database is printed which can serve as a point of restart. Finally (*index=2*) time steps of size 0.2 are taken and for each time step results are printed.

Define blocks

You can define a word to represent a set of strings. For each word defined, you need to specify a **start_define** ... **end_define** block. Within the block, you first specify the word, and then you specify the set of strings. Later in the data part, you can use the defined words as the replacement of the set of strings.

Example:

start_define
velocity 1.34
end_define
start_define
left_edge geometry_line 1
end_define
...
left_edge 0. 0. 0. 10. 1.e-4
...
bounda_dof 1 -left_edge -velx
bounda_time 1 0. 0. 100. velocity

...

The words **plus**, **minus**, **multiply** and **divide** as used in arithmetic blocks are prohibited in define blocks.

Include files

You can use **include** *filename* in the data part, to request that the file with name *filename* is included. This is handy to include often used data parts, or include a mesh generated by a pre-processor, etc.

The included file itself is not allowed to have an **include** in the data part.

The included file should not contain comments (...). The included file needs to be ended with an **end_data**. On some MS windows computers two **end_data** records are needed, so try that in case of trouble. On MS windows 32 bit computers include is not available.

Numbering of values in records

The numbering of values in records in illustrated by **node_dof** records. Look at the following piece of input file

```
...
number_of_space_dimensions 2
materi_velocity
materi_stress
end_initia
...
node_dof 1 0.0 0.0 -1.0 0.0 0.0 -1.0 0.0 -1.0
node_dof 2 0.0 0.0 -1.0 0.0 0.0 -1.0 0.0 -1.0
...
end_data
```

Here **node_dof** records 1 and 2 are initialized. The initial velocities are 0, and for the initial stresses we use $\sigma\_xx = -1$, $\sigma\_yy = -1$ and $\sigma\_zz = -1$. The total list of dof's in the **node_dof** record is **-velx**, **-vely**, **-sigxx**, **-sigxy**, **-sigxz**, **-sigyy**, **-sigyz** and **-sigzz**.

We refer to **-velx** as the 0'th value in the **node_dof** record, **-vely** as the 1'th value, etc. So printing the history of the **-sigxx** stress of **node_dof** record 1 is obtained by this:

...

control_timestep 10 ...
control_print_history 10 -node_dof 1 2
...
end_data

where the number 2 refers to the **-sigxx** stress. See also the definition of the **control_print_history** record for this. As an alternative, sometimes you can use names instead of numbers, for example here:

...
control_timestep 10 ...
control_print_history 10 -node_dof 1 -sigxx
...
end_data

Ranges

Ranges are general input formats used for indices and data values. Possible ranges are illustrated by the following examples

-all
-ra 12 32 44 -ra
-ra -from 5 -to 16 -ra
-ra -from 5 -to 25 -step 2 -ra

The **-all** range is not available for indices.

The data values for a data item can be specified as a range if this is allowed for in the description of the data item. All words in the data part (or part of an index) need to be preceeded with a 'tic' (-). In the example the **node_dof** records 1 to 100 are initialized

node_dof -ra -from 1 -to 100 -ra 1. 0. 0.

Types of dof's

Some of the dof's are principal dof's: these are **materi_velocity**, **condif_temperature**, **groundflow_pressure**, **wave_fscalar**. These are the dof's which are solved by the equilibrium equations (conservation laws).

The other dof's, like **materi_stress** and so, follow from these principal dof's (strains follow from displacement derivatives, stresses follow from strains by material laws, etc.).

Furthermore, for all the dof's we have primary values, which are the dof's themselves, and derived dof's, which are the space and time derivatives of the primary dof's.

6 Input file, data part, data records

6.1 area_element_group *index geometry_ entity_ item geometry_ entity_ index element_ group*

This record is used to generate **element_group** records. Each element, all of whose nodes are part of the *geometry_ item*, will get an **element_group** record with value *element_ group*. Please realise that the geometry entity can be a two-dimensional area, a volume, etc.

This option comes handy whenever a part of the domain gets some specific element data. For example, this would be the case if different areas in the structure have different material properties like stiffness, etc.

Beware: any directly specified **element_group** records will be overwritten. Attention: default this **area_element_group** will only evaluated at the very start of the calculation. By setting *switch* in **area_element_group_time** to **-yes** however you can require that this record is evaluated at all times.

We show here two ways to get different element data in different regions: Both ways give elements with young 1.2 from x=0 to x=1, and elements with young 3.3 from x=1 to x=2.

First way:

```
..
node 1 0.
node 2 1.
node 3 2.
element 1 -bar2 1 2
element 2 -bar2 2 3
element_group 1 0
element_group 2 1
..
group_type 0 -materi
group_materi_elasti_young 0 1.2
group_type 1 -materi
group_materi_elasti_young 1 3.3
..
control_mesh_refine_globally 10 -h_refinement
..
```

Second way:

```
..
node 1 0.
node 2 1.
node 3 2.
element 1 -bar2 1 2
element 2 -bar2 2 3
..
group_type 0 -materi
group_materi_elasti_young 0 1.2
group_type 1 -materi
group_materi_elasti_young 1 3.3
..
geometry_line 1 0. 1. 1.e-4
geometry_line 2 1. 2. 1.e-4
area_element_group 1 -geometry_line 1 0
area_element_group 2 -geometry_line 2 1
..
```

See also **area_element_group_method**, **area_element_group_sequence_element_group** etc.

6.2 area_element_group_element *index name*

With **area_element_group_element** you select the name of the elements for which the **area_element_group** will be used; if this **area_element_group_element** is not specified then all elements will be used.

6.3 area_element_group_interface *index switch*

If *switch* is set to **-yes** the **area_element_group** record with the same index will also be used for interface elements. If *switch* is set to **-no** the **area_element_group** record with the same index will not be used for interface elements. Presently the *switch* can be only set to **-no**.

6.4 area_element_group_method *index method*

Set *method* to **-all** or **-any**. If *method* is set to **-all**, then the corresponding **area_element_group** is applied to elements for which all nodes are inside the specified geometry. If *method* is set to **-any**, then the corresponding **area_element_group** is applied to elements for which any of the nodes is inside the specified geometry. If *method* is set to **-any_but_not_all**, then the corresponding **area_element_group** is applied to elements for which any but not all of the nodes are inside the specified geometry. If *method* is set to a positive integer

number then the corresponding **area_element_group** is applied to elements for which at least such amount of the nodes is inside the specified geometry. Default *method* is **-all**.

6.5 area_element_group_node *index node_0 node_1 ... element_group*

Similar to **area_element_group**. Now, however, directly the global node numbers are specified.

6.6 area_element_group_time *index switch*

If *switch* is set to **-yes** the corresponding **area_element_group** is evaluated at all times (as opposed to only at the start of the calculation).

6.7 area_element_group_sequence *index element_0 element_1 ...*

See **area_element_group_sequence_element_group**.

6.8 area_element_group_sequence_element *index name*

See **area_element_group_sequence_element_group**.

6.9 area_element_group_sequence_element_group *index group_0 group_1 ...*

General description

This option works more or less the same as the **area_element_group** option. Read that description first.

With this option however, you can specify what the element group numbers of an area (geometry), or set of element numbers, will be in time. This allows for an easy modeling of change of material models.

This option works in combination with the **area_element_group_sequence_*** records (with the same index).

See also **control_mesh_change_element_group**.

Selection of elements for which the element group changes over time

With **area_element_group_sequence_geometry** you select the area (geometry) for which the time sequence of group numbers should be used.

With **area_element_group_sequence** you select the elements for which the time sequence of group numbers should be used.

You can use both **area_element_group_sequence_geometry** and **area_element_group_sequence** to select a combination of elements in a geometry and directly specified element numbers. As a completely separate option do not use any of **area_element_group_sequence_geometry** and **area_element_group_sequence** at all. Then at a time point *time_i* the elements which have group number *group_(i-1)* will get new group number *group_i*. So the previous group number of elements is used to set the current group number of elements (and geometries are not used to change the group numbers).

With **area_element_group_sequence_element** you select the name of the elements for which the sequence of time versus group will be used; if this **area_element_group_sequence_element** is not specified then all elements will be used.

Specification of new element group numbers in time

With **area_element_group_sequence_time** and **area_element_group_sequence_element_group** you select time points at which groups should become active; for example, group_0 becomes active at time_0 etc.

Remarks

Remark 1: If you want the stresses, strains, etc. to be reset to 0. when the element group changes, then use a **control_reset_geometry** record for that.

Remark 2: It is more convenient and clear to use the **start_define end_define** option to define the geometries.

Examples

Example:

```
area_element_group_sequence_geometry 0 -geometry_brick 1
area_element_group_sequence_element 0 -hex8
area_element_group_sequence_time 0 0. 2. 3.
area_element_group_sequence_element_group 0 1 5 4

group_type 1 ...
...
group_type 5 ...
...
group_type 4 ...
...
control_reset_geometry 10 -geometry_brick 1
```

...

In the selected geometry element group 1 will be used starting from time 0 for elements **-hex8**. Starting from time 2 element group 5 will be used, etc. Same example, now with defines however:

```
start_define
soil_empty_wall geometry_brick 1
end_define
...

area_element_group_sequence_geometry 0 -soil_empty_wall
area_element_group_sequence_element 0 -hex8
area_element_group_sequence_time 0 0. 2. 3.
area_element_group_sequence_element_group 0 1 5 4

group_type 1 ...
...
group_type 5 ...
...
group_type 4 ...
...
control_reset_geometry 10 -soil_empty_wall
...
```

Now an example of the separate option:

```
area_element_group_sequence_time 0 0. 2. 3.
area_element_group_sequence_element_group 0 1 5 4

element_group 77 1
element_group 78 1

group_type 1 ...
...
group_type 5 ...
...
group_type 4 ...
```

At time 0. elements 77 and 78 have group number 1. At time 2. the elements with group number 1 get group number 5. At time 3. the elements with group number 5 get group number 4.

6.10 area_element_group_sequence_geometry *index geometry_ entity_ item geometry_ entity_ index*

See **area_element_group_sequence_element_group**.

6.11 area_element_group_sequence_geometry_method *index method*

Set *method* to **-all** or **-any**. If *method* is set to **-all**, then the corresponding **area_element_group_sequence_ge** is applied to elements for which all nodes are inside the specified geometry. If *method* is set to **-any**, then the corresponding **area_element_group_sequence_geometry** is applied to elements for which any of the nodes is inside the specified geometry. Default *method* is **-all**.

6.12 area_element_group_sequence_interface *index switch*

If *switch* is set to **-yes** the **area_element_group_sequence_*** will be used for interface elements also. If *switch* is set to **-no** the **area_element_group_sequence_*** will not be used for interface elements. Default *switch* is set to **-no**.

6.13 area_element_group_sequence_time *index time_ 0 time_ 1 ...*

See **area_element_group_sequence_element_group**.

6.14 area_node_dataitem *index geometry_ entity_ item geometry_ entity_ index data_ item_ name*

This record is used to generate *data_ item_ name* records on all nodes located on the specified geometrical entity. The values for the *data_ item_ name* should be specified in the **area_node_dataitem_double** record for real precision values, or in the **area_node_dataitem_integer** record for integer values (or words).

6.15 area_node_dataitem_double *index value_ 0 value_ 1 ...*

See **area_node_dataitem**.

6.16 area_node_dataitem_integer *index value_ 0 value_ 1 ...*

See **area_node_dataitem**.

6.17 **axisymmetric** *switch*

If *switch* is set to **-yes**, the calculation becomes axi-symmetrical. If *switch* is set to **-no**, the calculation becomes not axi-symmetrical. In case a **group_axisymmetric** is specified for some group, that overrules this **axisymmetric** record.

6.18 **bounda_alternate** *index bounda_index_0 bounda_index_1 ...*

This option takes care that between successive iterations only one of the specified **bounda_dof** is not used. For example if **bounda_dof** records with index 10, 20 and 30 are present in the input file, and you use **bounda_alternate 10 20 30** then in subsequent iterations the following index is not used: 10, 20, 30, 10, 20, 30, 10, ... etc.

This option comes handy to allow for very large calculations on a computer with limited memory. By putting alternating bounday conditions on velocities, pressures or temperatures the system of active equations to be solved in each iterations is only of a limited size. And then using enough iterations the solutions for all dof's can slowly converge to the actual coupled solution.

As example consider a large 3d calculation where displacements and hydraulic pressure heads need to be solved:

```
solver_matrix_symmetric -yes
...
bounda_alternate 10 20 30 40
bounda_dof 10 -all -velx
bounda_dof 20 -all -vely
bounda_dof 30 -all -velz
bounda_dof 40 -all -pres
...
control_timestep 100 ..
control_timestep_iterations 100 20
```

The above **bounda_dof** records are additional to the normally present records, like fixing displacements at sides of the domain, boundary conditions on hydraulic pressure, etc. The **bounda_alternate** record instructs tochnog to subsequently neglect the record 10, 20, 30, 40, 10, ..., etc. When a record is neglected the corresponding solution field can be solved. For example in the first iteration the solution field for the x-displacement can be solved, while the y-displacement and z-displacement and hydraulic pressure head are kept fixed. And thus the total system of equations is much smaller, approximately 4 times less dof's need to be solved by the pardiso solver, which in fact is the bottleneck in computer memory usage for very large calculations. Notice that we asked tochnog to use the symmetric equation

solver, since the pressures and displacements are not used simultaneously, so we don't have the disadvantage of a non-symmetric matrix with displacement and pressure contributions.

As another example we use a classical staggered solution for displacements and water pressures:

```
solver_matrix_symmetric -yes
...
bounda_alternate 10 20
bounda_dof 10 -all -velx -vely -velz
bounda_dof 20 -all -pres
...
control_timestep 100 ..
control_timestep_iterations 100 20
```

You should not specify **bounda_time** records i.c.w. **bounda_dof** records which are used in **bounda_alternate**. The **bounda_time** records will not be used.

6.19 bounda_baseline_correction *time_start time_end*

If this record is specified baseline correction is performed after one of:

- reading SMC files with uncorrected accelerations in **bounda_dof** i.c.w. **bounda_time_smc**.
- direct specification of acceleration in **bounda_dof** i.c.w. **bounda_time**.

Such baseline correction is needed to suppress artificial drift in velocity signals following from the acceleration signal.

The correction actually is done by adding a parabolic acceleration signal to the specified accelerations, thus giving a corrected acceleration in time. The parabolic (second order) signal contains three constant coefficients. These are determined by demanding that the corrected acceleration signal leads to a minimal sum of squared velocities over the considered time interval.

This correction is done over the time interval from *time_start* up to *time_end*. Typically *time_start time_end* are the start time and the end time of the time interval in which you apply base excitation. You need to specify these times in units that you actually use in your Tochnog calculation (so not in the units of the SMC file).

If this **bounda_baseline_correction** is not specified the data will be used directly without a correction.

See also **bounda_baseline_correction_parameters**.

6.20 bounda_baseline_correction_parameters *index ...*

The parameters for the parabolic baseline correction are written in this record. In future calculations you can use the parameters yourself by setting this record in the input file; then the parameters will not be determined again by the baseline correction algorithm; the parameters in the specified record will be used instead.

6.21 bounda_constant *index switch*

This record can be used i.s.o. the **bounda_time** record. If *switch* is set to **-yes** the prescribed dofis kept constant. This is only available for velocities, pressures and temperatures. This is not available for time derivatives **ttemp**, **tpres** and **ttotal_pres**.

6.22 bounda_dof *index node_range dof_0 dof_1 ...*

States which dof's in which nodes get prescribed values by adjustment of the **node_dof** records. The item *node_range* represents a range of node numbers. In stead of a node range also, by example, **-geometry_line 1** can be used, indicating that the nodes on line 1 get the prescribed boundary values. The items *dof_0* etc. are one of the primary dof's listed at **dof_label**.

For a specific *index*, only one of **bounda_force** or **bounda_dof** can be specified (thus either Neumann conditions or Dirichlet conditions).

Example for discrete node forces in y-direction on the nodes on a line:

```
bounda_dof 0 -geometry_line 1 -vely
bounda_time 0 0. 0. 1. 1. 100. 1.
```

Normally you only should specify boundary conditions on principal dof's (like velocity, temperature, etc.) and not on strain, stresses, etc.!

Specially for velocity (displacement) dof's, you can prescribe that nodes should not move in a direction normal to a plane. For this, specify **-veln** for *dof_0* to indicate that the normal velocity to a plane is 0. The normal direction should be given with **bounda_normal**; if however a geometrical entity is used to specify the nodes, you do not necessarily need to specify the **bounda_normal**, thus the normal from the geometrical entity is then used instead. The **bounda_time** record should not be specified (it is irrelevant). Internally in Tochnog a multi-point-constraint will be generated to accomplish this condition of zero velocity in normal direction.

Specially for velocity (displacement) dof's, you can prescribe a rotation around either the x-axis, y-axis or z-axis. In 1D you cannot use this record. In 2D you can only specify a

rotation around the z-axis. In 3D you can specify each of the three axis. Example of an x-axis rotation of node 12 with angular velocity of 0.33 [degrees per unit time]:

bounda_dof 0 12 -rotation_x_axis
bounda_time 0 0.33

For the rotation 0.33 the rotation vector points in the positive x-axis direction.

Specially for the groundflow phreatic head h, you can prescribe the physical pore pressure **-total_pressure** and Tochnog will automatically calculate the corresponding hydraulic pressure head h. Also specially for the groundflow phreatic head h, you can prescribe the time rate of the physical pore pressure **-ttotal_pressure** and Tochnog will automatically calculate the corresponding hydraulic pressure head h. Also specially for the groundflow phreatic head h, you can prescribe the time rate of the hydraulic pressure head **-tpres**. Specially for the temperature you can prescribe the time rate of the temperature **-ttemp**.

As a special option you can specify also, for example, **-element_group 1** in stead of a node range. Then nodes of elements which have **element_group** set to 1 will get the prescribed boundary values.

As a special option you can specify also, for example, **-element_geometry 1** in stead of a node range. Then nodes of elements which have **element_geometry** set to 1 will get the prescribed boundary values.

As a special option you can specify also, for example, **-geometry_set 1** in stead of a node range. Then nodes of elements which have any of the elements belonging to **geometry_set 1** will get the prescribed boundary values.

Notice: if several **bounda_dof** records act on a node, only the record with the highest index will be used.

See also: **bounda_time**, **bounda_sine**, **bounda_constant**, **bounda_dof_radial**, **bounda_dof_cylindrical**, **force_edge** and **force_volume**.

6.23 bounda_dof_cylindrical *index x_first y_first z_first x_second y_second z_second*

Specially for velocity (displacement) dof's, you can prescribe velocities cylindrical to a line specified with the point x_first, y_first, z_first and x_second, y_second, z_second; in 1D only x values should be specified, and in 2D only x, y values should be specified. Example:

bounda_dof 10 -ra ...-ra -velx -vely -velz

bounda_dof_cylindrical 10 1.23 3.43 5.12 1.23 3.43 15.12
bounda_time 10 0. 0. 1. 1. 100. 1.

The velocity increases linearly in size away from the specified line (at unit distance away from the line the velocity has size 1; you can scale it by the **bounda_time** record).

6.24 bounda_dof_radial *index x y z*

Specially for velocity (displacement) dof's, you can prescribe velocities radial to a specified point x, y, z; in 1D only x should be specified, and in 2D only x, y should be specified. Example:

bounda_dof 10 -ra -ldots -ra -velx -vely -velz
bounda_dof_radial 10 1.23 3.43 5.12
bounda_time 10 0. 0. 1. 1. 100. 1.

A radial velocity is prescribed on nodes in a specified range, relative to point 1.23, 3.43, 5.12 and with the time table given by **bounda_time**. The velocity increases linearly in size away from the specified point x, y, z (at unit distance away from the specified point x, y, z the velocity has size 1; you can scale it by the **bounda_time** record).

6.25 bounda_factor *index* a_0 a_1 $\ldots a_n$

This data item defines a polynomial in space. This polynomial gives a factor which is used as a multiplication factor for **bounda_time** records (with the same index). In this way, you can obtain coordinate dependent boundary conditions.

In 1D the polynomial is $a_0 + a_1 x$ (specify 2 values). In 2D the polynomial is $a_0 + a_1 x + a_2 y$ (specify 3 values). In 3D the polynomial is $a_0 + a_1 x + a_2 y + a_3 z$ (specify 4 values).

6.26 bounda_factor_parabolic_x *index* a_0 a_1 a_2

This data item defines a quadratic polynomial in x-direction.

The polynomial is $a_0 + a_1 x + a_2 x^2$ (specify 3 values).

6.27 bounda_force *index node_range dof_0 dof_1 ...*

States which ones from the list of dof's in which nodes get prescribed nodal forces. The item *node_range* represents a range of node numbers. In stead of a node range also, for example, **-geometry_line 1** can be used, indicating that the nodes on line 1 get the prescribed nodal forces. The items *dof_0* etc. can be one of the items listed at **dof_label**. However, neither **-dis** and **-scal** can be used.

For a specific *index*, only one of **bounda_force** and **bounda_dof** can be specified; thus, either Neumann conditions or Dirichlet conditions can be applied to a particular node, but nor both.

Attention: with this option you get the same nodal force on all the specified nodes. If you want to apply a distributed force on a edge, however, you should use **force_edge**. That option gives forces consistent with the displacement field, so not necessarily the same for all nodes. For example the nodes on the side of linear elements on a edge get only half the force.

As a special option you can specify also, for example, **element_geometry 1** in stead of a node range. Then nodes of elements which have **element_group** set to 1 will get the prescribed nodal forces.

Notice: if several **bounda_force** records act on a node, the imposed forces are summed.

See also: **bounda_time**, **bounda_sine** and **force_edge**.

6.28 bounda_found *index found*

This record is meant for printing only. A value of **-yes** indicates that the corresponding **bounda_*** records are indeed used at some nodes. A value of **-no** indicates that the corresponding **bounda_*** records are not used at all at some nodes.

6.29 bounda_geometry_method *index node_type*

If boundary conditions are imposed on a geometry, you can set with this record which node type should be used. If *node_type* is set to **-node_start_refined** the values of **-node_start_refined** are used to determine if nodes are located on the geometry. If *node_type* is set to **-node** the values of **-node** are used to determine if nodes are located on the geometry. If *node_type* is set to **-plus_displacement** the values of **-node** plus nodal displacements are used to determine if nodes are located on the geometry.

6.30 bounda_normal *index normal_x normal_y normal_z*

This record specifies the components of a normal vector to a plane on which nodes should slide (the nodes are not allowed to move normal to the plane). In 3D you need to specify all of *normal_x normal_y normal_z*. In 2D you need to specify only *normal_x normal_y*. In 1D you need to specify only *normal_x*.

See also **bounda_dof**.

6.31 bounda_print_mesh_dof *dof_0 dof_1 ...*

See **print_mesh_dof**.

6.32 bounda_print_mesh_dof_geometry *geometry_item_name geometry_item_index*

See **print_mesh_dof**.

6.33 bounda_print_mesh_dof_values *value_dof_0 value_dof_1 ...*

See **print_mesh_dof**.

6.34 bounda_sine *index start_time end_time freq_0 amp_0 freq_1 amp_1 ...*

The **bounda_dof** or **bounda_force** record with the same *index* is imposed with the sum of the sine functions; the first sine function has frequency *freq_0* and amplitude *amp_0*, the second sine function has frequency *freq_1* and amplitude *amp_1*, etc.. More general behavior in time can be imposed by using **bounda_time** records. For a specific *index* only one of **bounda_time** and **bounda_sine** can be specified.

As a typical application the response due to the excitation with a frequency spectrum can be analyzed. Just print the relevant response by **control_print_history** and extract the frequency spectrum of that response signal.

The sine loads will be only imposed after *start_time*, and will not be imposed anymore after *end_time*. The sine functions start at time *start_time* (then they have value 0).

As a special option setting a frequency to 0 enforces tochnog to use a constant static value of the specified amplitude.

6.35 **bounda_time** *index time load time load ...*

This record specifies a multi linear time-load diagram for the **bounda_dof** or **bounda_force** record with the same *index*. Between two time points in the diagram, the load is interpolated linearly (ramp function between the two points).

At all times that an dofis not prescribed in such way, it is free and determined with the governing differential equations. For a specific *index* only one of **bounda_time**, **bounda_sine** and **bounda_time_user** can be specified.

As a special option, you can specify only one value in the **bounda_time** record if the load is constant over time (so not time-load sets but directly the constant load value).

As a further special option, you can specify no **bounda_time** and no **bounda_sine** at all; then a 0 value is assumed.

6.36 **bounda_time_factor** *index factor*

With this record you can specify an multiplication factor to be used for loads specified by **bounda_time**. This option comes handy when you import a time-load table from some external data source, which uses some other definition of the load as you do in the tochnog input file. For example, if you specify accelerations in metric units but the external source specifies the accelerations as part of the gravity acceleration, you can convert the load in the time-load table with this factor.

Default, if **bounda_time_factor** is not specified, the factor is set to 1.

6.37 **bounda_time_offset** *index time_offset*

With this record you can specify an offset to be used for times specified by **bounda_time**. The actual times will become time offset added to the specified times in **bounda_time**. This option comes handy when you import a time-load table from some external data source, but would like to apply the table at a different moment in time in the calculation. You need to specify *time_offset* in the units that you actually use in your calculation.

6.38 **bounda_time_increment** *index time_increment*

With this record you can specify that the data as specified in **bounda_time** is only the load data, so not time points anymore. The time points are automatically calculated from a fixed time increments (and optionally an initial offset as specified in **bounda_time_offset**). For example:

```
...
```

bounda_dof 10 -geometry_line -accx
bounda_time 10 0.2 0.78 1.33 ... (acceleration data only)
bounda_time_offset 10 1. (the accelerations start at time 1)
bounda_time_increment 10 0.05 (the increments in time are 0.05)
(thus the acceleration is spcified at times 1.0, 1.05., 1.10, 1.15, etc.)
...

In this example the acceleration is 0.2 at time 1, it is 0.78 at time 1.05, etc.

6.39 bounda_time_units *factor_time factor_length*

The specified times and data in **bounda_time** may have other units then you actually apply in your calculation. With *factor_time* you correct the time in **bounda_time** to get times consistent with your calculation. With *factor_length* you can correct the data **in bounda_time** to get data consistent with your calculation. For example, if **bounda_time** contains [sec] and [cm] and if your actual calculation uses [hour] and [m] then set *factor_time* to 3600. and set *factor_length* to 100. This option is presently only available for prescribed accelerations.

6.40 bounda_time_until_data *data_item_name data_item_index date_item_number*

With this option you can set how much the **bounda_time** record with the same index should be applied. Tochnog will look at the value of *data_item_name data_item_index date_item_number*. If that value is lower than *start* Tochnog will start to reduce the applied value in **bounda_time**. This reduced value will become 0 at the moment that the value of *data_item_name data_item_index date_item_number* reaches *wanted*.

A typical application is to slowly reduce prescribed velocities/displacements on a structure so that a mimimum force response of the structure is obtained. This would look like:

...
bounda_dof 210 ... -vely (apply velocity on structure)
bounda_time 210 ...
bounda_time_until_data 210 -post_node_result 10 -vely (monitor structure force response)
(reduce prescribed displacement when force response
is below 30 percent of initial value)
(the reduced velocity will become zero when the force response
reaches 10 percent of initial value)
bounda_time_until_value_minimum 210 0.1 0.3
...

6.41 bounda_time_until_value_minimum *wanted start*

See **bounda_time_until_data**.

6.42 bounda_time_smc *index switch*

If *switch* is set to **-yes** the SMC file *index*.smc will be read. Such Strong Motion CD file (SMC file) contains base acceleration time data. This option can be used to read SMC files strictly following the definition from **http://nsmp.wr.usgs.gov/smcfmt.html**. A typical input example for a SMC file looks like:

```
...
materi_velocity
materi_stress
...
end_initia
...
bounda_baseline_correction 1.  1.1 (correct acceleration for time 1
to 1.1
...
bounda_dof 10 -geometry_line -accx
bounda_time_smc 10 -yes
bounda_time_smc_offset 10 1. (the base excitation starts at time 1)
bounda_time_smc_units 10 3600. 100. (we use hours and meters)
...
control_timestep 10 1.e-2 1. (gravity from time 0 to 1)
...
control_timestep 20 1.e-6 0.1 (base excitation from time 1 to 1.1)
...
```

In case the SMC file does not strictly follow the definition from **http://nsmp.wr.usgs.gov/smcfmt.html**, the option **bounda_time_smc** cannot be used. In such case you can use the actual data lines in a **bounda_time** record as follows:

```
...
materi_velocity
materi_stress
...
end_initia
...
bounda_baseline_correction 1.  1.1 (correct acceleration for time 1
to 1.1
```

...
bounda_dof 10 -geometry_line -accx
include acceleration.dat (include file containing **bounda_time 10 ...**, the dots ... represent acceleration data)
bounda_time_offset 10 1. (the base excitation starts at time 1)
bounda_time_units 10 3600. 100. (we use hours and meters)
...
control_timestep 10 1.e-2 1. (gravity from time 0 to 1)
...
control_timestep 20 1.e-6 0.1 (base excitation from time 1 to 1.1)
...

Be sure that you take sufficient small time increments while performing the base acceleration steps. See also **http://nsmp.wr.usgs.gov/**.

6.43 bounda_time_smc_offset *index time_offset*

The times of the SMC file are incremented with *time_offset* , such that you can use the acceleration data starting from any time point in a calculation. If this record is not specified then *time_offset* is set to 0.

6.44 bounda_time_smc_units *factor_time factor_length*

The SMC files have units [cm] for length and [sec] for time. You input file may have other units however. With *factor_time* you correct the time read from the SMC file to get times consistent with your input file. With *factor_length* you can correct the data (acceleration, velocity or displacement) read from the SMC file to get data consistent with your input file. For example, if you use [hour] and [m] in your calculation then set *factor_time* to 3600. and set *factor_length* to 100.

6.45 bounda_time_user *index switch*

If *switch* is set to **-yes** a user supplied routine for the time-load diagram will be used.

See also the file **user.cpp** in the distribution.

6.46 bounda_water *index switch*

If *switch* is set to **-yes**, and you specify the pore pressure **-total_pressure** as dof, the pore pressure is actually determined from the height of the water column between the node and

the phreatic level. In fact the pore pressure is set to density_water g Δz where g is the gravitational acceleration, and Δz is the distance to the phreatic level.

The water density is given by **groundflow_density**. The gravity acceleration is given by the vertical component of **force_gravity**. The water height is relative to the water height is given by **groundflow_phreatic_level**.

In this case the record **bounda_time** does not contain the actual value of the pore pressure, but instead it only contains a multiplication factor for the static water pressure as calculated above.

This **bounda_water** is convenient when the phreatic level is located above the FE mesh. Then this option allows you to impose a pressure boundary condition for the nodes in the FE mesh at the top boundary of the mesh, automatically using a specified phreatic level record.

6.47 change_dataitem *index data_ item_ name data_ item_ index data_ item_ number_ 0 data_ item_ number_ 1 ... operat*

With this record you can specify a data item which should be changed over time. The time table should be given in the **change_dataitem_time** table as time-value sets; at least two sets should be specified.

The *operat* determines how the time-value sets are used. If *operat* is set to **-use**, then the value of the time-value sets is directly used. If *operat* is set to **-add**, then the value of the time-value sets is interpreted as a rate of change, so that the value is multiplied with the time step and then added to the old value.

Notice that you can change multiple numbers at once.

As a typical example you can use this to prescribe the displacement of a contact geometry over time. Below the y-coordinates of a geometry line which is used in the contact algorithm is changed over time:

```
contact_target_geometry 0 -geometry_line 1
...

geometry_line 1 0. 10. 2. 10.
...

change_dataitem 0 -geometry_line 1 1 -use
change_dataitem_time 0 0. 10. 100. 0.
change_dataitem 1 -geometry_line 1 3 -use
change_dataitem_time 1 0. 10. 100. 0.
...
```

The specified values are evauated at the start of each timestep.

6.48 change_dataitem_geometry *index geometry_entity_name geometry_entity_index*

For element group data **group_*** you can restrict the application for the **change_dataitem** to only those elements which are part of the geometry specified by *geometry_entity_name geometry_entity_index*.

6.49 change_dataitem_time *index time value ...*

See **change_dataitem** and **change_dataitem_time_user**.

6.50 change_dataitem_time_discrete *index switch*

If *switch* is set to **-yes** then the changes applied by the **change_dataitem** and **change_dataitem_time** records (with the same index), will be applied at the discrete time points given in **change_dataitem_time**. Between those time points, no interpolation is used.

More precise, the change of the data item will be applied directly after the time point has passed.

If you don't specify this **change_dataitem_time_discrete** record then interpolation is used.

6.51 change_dataitem_time_method *index method*

With this record you can require that the cosinus, sinus or tangent of a data value will be changed (in stead of the data value directly itself). The *method* can be set to either **-cosinus**, **-sinus** or **-tangent**. This is typically convenient for geotechnical safety factor calculations where you want that for a mohr coulomb law the cohesion and tangent of the friction angle are decreased at the same ratio in time.

Example:

```
...
group_materi_plasti_mohr_coul_direct 10 ...
...
```

(tangent of friction angle reduction)
change_dataitem 10 -group_materi_plasti_mohr_coul_direct 10 0 -use
change_dataitem_time 10 ... (specify tangent values here)
change_dataitem_time_method 10 -tangent
...
(cohesion reduction)
change_dataitem 20 -group_materi_plasti_mohr_coul_direct 10 1 -use
change_dataitem_time 20 ...
...

As an extra remark on such 'phi - c' reduction: if you want to calculate the safety factor of the initial geometry you should not use the **mesh -follow_material ...** option, since with that the soil would be able to deform to new stable configurations.

6.52 change_dataitem_time_user *index switch*

If *switch* is set to **-yes** a user supplied subroutine is used instead of the **change_dataitem_time** table.

See also the **user.cpp** routine included in the distribution.

6.53 check_data *switch*

If *switch* is set to **-yes** the in-core database is checked at some moments during the calculation. You can try this option in case you experience unexpected behavior.

6.54 check_error *switch*

Tochnog will does some error checking which you can suppress by setting *switch* to **-no**.

6.55 check_element_node *index switch*

Tochnog will check that elements do not have duplicate nodes. If you want to have duplicate nodes on purpose however, you can set *switch* to **-no** so that this checking is suppressed.

6.56 check_element_shape *index factor*

Isoparametric elements are mapped from the isoparametric space to the real coordinate space with shape functions. The determinant of the Jacobian of the mapping will have the same value in each integration point if elements are not distorted by the mapping. Thus the relative difference $\frac{det_{ip}-det_{average}}{det_{average}}$ in each integration point of an element measures the distortion.

Tochnog determines the average of the relative difference for all the integration points in an element.

If this average is larger then *factor* a warning message will be printed. Furthermore, if **check_element_shape** is specified the average will be stored in a record **element_shape** in the database dbs file; the average will be plotted in the GID post-processing files so that you can visually inspect where the elements are most distorted.

Perfectly non-distorted isoparametric elements have average 0.

Severely distorted elements have a high average, e.g. larger than 0.25.

6.57 check_memory *index switch*

If *switch* is set to **-yes**, Tochnog checks memory usage of the calculation. If *switch* is set to **-no**, Tochnog does not check memory usage of the calculation.

When checking memory usage Tochnog checks that the calculation fits in the computer RAM memory. Furthermore, on 32 bit systems Tochnog checks that array sizes do not exceed 2Gb.

Default, if **check_memory** is not specified, the *switch* is set to **-no**.

6.58 check_memory_usage *index switch*

If *switch* is set to **-yes** Tochnog keeps record of the highest memory used by the calculation. It will put that highest usage, expressed in GB, in the record **check_memory_usage_result**. This option comes convenient to keep an eye on the memory usage of a calculation, in case you are reaching the limit on your computer. You need to prevent that memory usage exceeds the amount of RAM memory, since swapping to disk is extremely slow.

This option is only available on 64 bit linux. Default, if **check_memory_usage** is not specified, then *switch* is set to **-yes**.

6.59 check_memory_usage_result *index memory*

See **check_memory_usage**.

6.60 check_nan *switch*

If *switch* is set to **-yes** some internal result (stresses, etc.) are check for being NAN. NAN represents Not A Number , meaning that the computer cannot represent the result by a number. This means that something is wrong: the solution may have diverged, or you may have a programming error in a user supplied routine, or etc.

6.61 check_solver *eps*

If this record is set the solver checks if diagonal terms are smaller than *eps*. That normally indicates some problem in your input file if *eps* is very small.

6.62 check_target *switch*

If you set switch to **-no**, any **target_*** records will be neglected. THis allows to run the input file without getting error messages in the log file, for example when testing variations of the input file.

6.63 check_used *switch*

If *switch* is set to **-yes**, Tochnog will check if input data is really used. It will give a message if some input data is not used. In fact, this option will only check if any index of a certain data item is used; thus if any index of a certain data item in the input file has been used in the calculation, all indices of that data item are considered to be used, and no message will be given.

This option comes handy when looking for errors in input files.

Default, when **check_used** is not specified, *switch* is set to **-no**.

6.64 check_warning *switch*

Tochnog will does some warning checking which you can suppress by setting *switch* to **-no**.

6.65 condif_convection_edge_normal *index* α_c T_r

Convection coefficient and convection environmental temperature. Also the record **condif_convection_edge_normal_geometry** should be specified.

Attention: this option is only available for linear and quadratic isoparametric elements.

6.66 condif_convection_edge_normal_element *index element_0 element_1 ...*

Selects the elements for which the **condif_convection_edge_normal** record with the same *index* should be applied.

6.67 condif_convection_edge_normal_element_group *index element_group_0 element_group_1 ...*

Selects the element groups for which the **condif_convection_edge_normal** record with the same *index* should be applied.

6.68 condif_convection_edge_normal_element_node *index element node_0 node_1 ...*

Selects the element and local node numbers for which the **condif_convection_edge_normal** record with the same *index* should be applied.

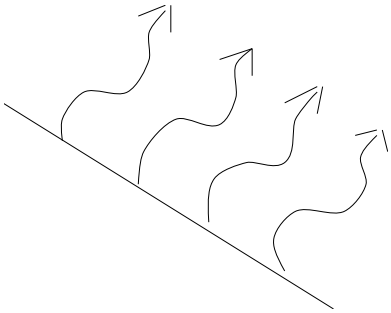
6.69 condif_convection_edge_normal_element_side *index element_0 element_1 ... side*

Selects the elements and local side number for which the **condif_convection_edge_normal** record with the same *index* should be applied.

6.70 condif_convection_edge_normal_geometry *index geometry_entity_name geometry_entity_index*

Selects the area for which the **condif_convection_edge_normal** record with the same *index* should be applied.

Instead of a number of nodes also, for example, **-geometry_line 1** can be used in 2D, indicating that the nodes on line 1 start to convect. The total edge of an element must be inside



the geometry for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges. See also: **condif_convection_edge_normal**.

6.71 condif_convection_edge_normal_node *index node_0 node_1 ...*

Selects the nodes for which the **condif_convection_edge_normal** record with the same *index* should be applied. The *node_0* etc. specifies the global node numbers.

6.72 condif_heat_edge_normal *index heat*

Distributed prescribed heat flux normal normal to the edge of a element. This distributed heat is translated into equivalent nodal heat on the edges of elements. Also the record **condif_heat_edge_normal_geometry** should be specified, and optionally the record **condif_heat_edge_normal_time** can be specified.

Attention: this option is only available for linear and quadratic isoparametric elements.

Attention: if this option is used INSIDE a FE mesh, then the elements on each side will get the distributed heat. So the total heat flux will normally become zero since the normals of the elements at the side of the geometry are opposite.

6.73 condif_heat_edge_normal_element *index element_0 element_1 ...*

Restricts the elements to which the **condif_heat_edge_normal** record with the same *index* should be applied.

6.74 **condif_heat_edge_normal_element_group** *index element_group_0 element_group_1 ...*

Restricts the element groups to which the **condif_heat_edge_normal** record with the same *index* should be applied.

6.75 **condif_heat_edge_normal_element_node** *index element node_0 node_1 ...*

Selects the element and local node numbers for which the **condif_heat_edge_normal** record with the same *index* should be applied.

6.76 **condif_heat_edge_normal_element_node_factor** *index* $factor_0$ $factor_1$ ...

Nodal multiplication factors with which the **condif_heat_edge_normal** will be applied to the element of **condif_heat_edge_normal_element_node**. You need to specify a factor for each node on the side. Here $factor_0$ is the multiplication factor for the first node on the side, etc.

6.77 **condif_heat_edge_normal_element_side** *index element_0 element_1 ... side*

Selects the elements and local side number for which the **condif_heat_edge_normal** record with the same *index* should be applied.

6.78 **condif_heat_edge_normal_factor** *index* a_0 a_1 ... a_n

This data item defines a polynomial in space. This polynomial gives a factor which is used as a multiplication factor for **condif_heat_edge_normal** records (with the same index). In this way, you can obtain coordinate dependent heat fluxes.

In 1D the polynomial is $a_0 + a_1 x$ (specify 2 values). In 2D the polynomial is $a_0 + a_1 x + a_2 y$ (specify 3 values). In 3D the polynomial is $a_0 + a_1 x + a_2 y + a_3 z$ (specify 4 values).

6.79 condif_heat_edge_normal_geometry *index geometry_ entity_ name geometry_ entity_ index*

Selects the area for which the **condif_heat_edge_normal** record with the same *index* should be applied. For example, **-geometry _line 1** can be used in 2D, indicating that the nodes on line 1 get the distributed heat. The total edge of an element must be inside the geometry for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges.

6.80 condif_heat_edge_normal_node *index node_ 0 node_ 1 node_ 2 ...*

Selects the nodes for which the **condif_heat_edge_normal** record with the same *index* should be applied. The *node_ 0* etc. specify global node numbers.

6.81 condif_heat_edge_normal_sine *index start_ time end_ time freq_ 0 amp_ 0 freq_ 1 amp_ 1 ...*

Similar to **force_edge_sine**, now for heat flux however.

6.82 condif_heat_edge_normal_time *index time load time load ...*

This record specifies a diagram which contains the factors with which the **condif_heat_edge_normal** record with the same index is applied. Linear interpolation is used to extend the *time load* values to the intervals between these pairs. Outside the specified time range a factor 0 is used.

If this record is not specified, the heat flux is applied at all times with a factor 1.

6.83 condif_heat_volume *index heat*

Distributed volume heat source. Here *heat* is the distributed heat source value.

See also **condif_heat_volume_factor**, **condif_heat_volume_geometry**, and **condif_heat_volume_time**.

6.84 condif_heat_volume_element *index element_ 0 element_ 1 ...*

Specifies the elements for which the **condif_heat_volume** record with the same *index* should be applied.

6.85 condif_heat_volume_element_group *index element_ group*

Specifies the element group for which the **condif_heat_volume** record with the same *index* should be applied.

6.86 condif_heat_volume_factor *index* a_0 a_1 $\ldots a_n$

This polynomial gives a factor which is used as a multiplication factor for **condif_heat_volume** records (with the same index). In this way, you can obtain coordinate dependent forces.

In 1D the polynomial is $a_0 + a_1 x$ (specify 2 values). In 2D the polynomial is $a_0 + a_1 x + a_2 y$ (specify 3 values). In 3D the polynomial is $a_0 + a_1 x + a_2 y + a_3 z$ (specify 4 values).

6.87 condif_heat_volume_geometry *index geometry_ name geometry_ index*

Specifies the geometry for which the **condif_heat_volume** record with the same *index* should be applied.

6.88 condif_heat_volume_sine *index start_ time end_ time freq_ 0 amp_ 0 freq_ 1 amp_ 1 ...*

Similar to **force_edge_sine**, now for volume heat source however.

6.89 condif_heat_volume_time *index time load time load ...*

This record specifies a multi-linear diagram which contains the factors with which the **condif_heat_volume** record with the same index is applied.

If this record is not specified, the heat source is applied at all times with a factor 1.

6.90 condif_heat_volume_user *index switch*

Set *switch* to **-yes** if you want to call the user supplied routine for heat.

6.91 condif_heat_volume_user_parameters *index ...*

Specify the parameters for the user supplied routine for heat.

6.92 condif_radiation_edge_normal *index* α_r T_r

Radiation coefficient and radiation environmental temperature. Also the record **condif_radiation_edge_norma** should be specified.

Attention: this option is only available for linear and quadratic isoparametric elements.

6.93 condif_radiation_edge_normal_element *index element_0 element_1 ...*

Selects the elements for which the **condif_radiation_normal_edge** record with the same *index* should be applied.

6.94 condif_radiation_edge_normal_element_node *index element node_0 node_1 ...*

Selects the element and local node numbers for which the **condif_radiation_edge_normal** record with the same *index* should be applied.

6.95 condif_radiation_edge_normal_element_group *index element_group_0 element_group_1 ...*

Selects the element groups for which the **condif_radiation_normal_edge** record with the same *index* should be applied.

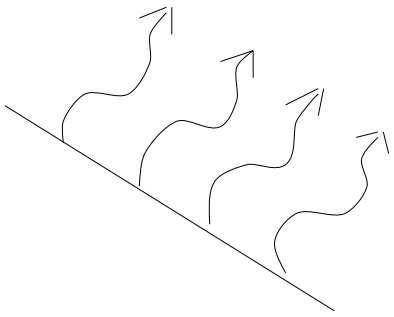
6.96 condif_radiation_edge_normal_element_side *index element_0 element_1 ... side*

Selects the elements and side number for which the **condif_radiation_edge_normal** record with the same *index* should be applied.

6.97 condif_radiation_edge_normal_geometry *index geometry_entity_name geometry_entity_index*

Selects the area for which the **condif_radiation_edge_normal** record with the same *index* should be applied.

In stead of a number of nodes also, for example, **-geometry_line 1** can be used in 2D, indicating that the nodes on line 1 radiate heat. The total edge of an element must be inside



the geometry for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges. See also: **condif_radiation_edge_normal**.

6.98 condif_radiation_edge_normal_node *index node_0 node_1 ...*

Selects the nodes for which the **condif_radiation_edge_normal** record with the same *index* should be applied. This is only available for linear elements. The *node_0* etc. specifies the global node numbers.

6.99 contact_apply *index switch*

If *switch* is set to **-yes**, the contact algorithm is used. If *switch* is set to **-no**, the contact algorithm is not used. This is done for all timestep records.

See also **control_contact_apply**.

6.100 contact_heat_generation *factor*

This *factor* specifies how much of the frictional energy is transformed into heat (this only makes sense if *friction* in **contact_plasti_friction** is not zero, and if **condif_temperature** is initialized). The *factor* should be between 0 and 1. See also **contact_target_geometry**.

6.101 contact_penalty_pressure *pressure_penalty*

The *pressure_penalty* should be given some high value if the pressure is freely linked at the surfaces of contactor and target. See also **contact_target_geometry**.

6.102 contact_penalty_temperature *temperature_penalty*

The *temperature_penalty* should be given some high value if free heat exchange between contactor and target is possible. See also **contact_target_geometry**.

6.103 contact_penalty_velocity *velocity_penalty*

The **velocity_penalty** essentially puts a spring between the contactor and the target if penetration occurs. Iterations (see **control_timestep_iterations**) are needed; more iterations are needed if the penalty factor is higher. See also **contact_target_geometry**.

6.104 contact_plasti_friction *friction*

See **contact_target_geometry**.

6.105 contact_target_element_group *element_group_0 element_group_1 ...*

This records defines the element groups for which the elements function as target in a contact analysis. It is advised to use different element groups for the contacting and target elements, so that the contact algorithm can distinguish between both. The target element group should consist of more than 1 layer of elements in contact direction (so only one layer of target elements is not allowed). The contacter should be smaller of size than the target.

See also **contact_target_geometry**.

6.106 contact_target_geometry *index geometry_entity_item geometry_entity_index*

Attention: the contact algorith is experimental up to now, and may not work for all calculations.

This record specifies a contact geometry. Contacting nodes are forced to stay at the outward normal side of the contact geometry.

The allowed geometries and their material outward normals are listed below

- If a **geometry_point** is used in 1D, the normal is in positive x-direction.
- If a **geometry_line** is used in 2D, the normal is the outer product of 3-direction and the line direction (from point 0 to point 1).
- If a **geometry_circle** is used in 2D, the normal is the outward direction at the circle.

- If a **geometry_circle** is used in 3D, the normal is the outward direction on the circle surface.
- If a **geometry_ellipse** is used in 2D, the normal is the outward direction at the ellipse.
- If a **geometry_sphere** is used in 3D, the normal is the outward direction at the sphere.
- If a **geometry_polynomial** is used in 2D, the normal is in positive y-direction.
- If a **geometry_polynomial** is used in 3D, the normal is in positive z-direction.
- If a **geometry_triangle** is used in 3D, the normal is in direction of the outer product v01 $*$ v02 where v01 is the vector from node 0 to node 1 and v02 is the vector from node 0 to node 2.
- If a **geometry_quadrilateral** is used in 3D, the normal is in direction of the outer product v01 $*$ v02 where v1 is the vector from node 0 to node 1 and v02 is the vector from node 0 to node 2. Only non-distorted quadrilaterals should be used.

This normal can be switched sign by setting the **contact_target_geometry_switch** with the same *index* to **-yes**.

In stead of geometries, also contact with target elements will be checked. Only contact with the elements **-bar2**, **-quad4**, and **-hex8** can be detected. Specify **contact_target_element_group** for this.

The time steps should be such small, that contacting nodes penetrate the other elements only in small steps.

If a **contact_target_geometry** is used, then the contacting node should also be within the tolerance of the geometrical entity to be noticed!

If contact is detected, normal contact forces of size *contact_penalty_velocity* $*$ penetration are generated between the contacting node and the other element. Moreover, also a frictional force of size *friction* $*$ normal force is generated (see **contact_plasti_friction**).

With contact you need more iterations the normal, say 5 or more. See **control_timestep_iterations** how to define the number of iterations.

6.107 contact_target_geometry_switch *index switch*

See **contact_target_geometry**.

6.108 control_bounda_relax *index switch*

With this **control_bounda_relax** you can require Tochnog to store the nodal right-hand-sides; for example external nodal forces for nodes with prescribed velocities. These

stored nodal right-hand-sides can later be used to relax prescribed boundary conditions; for example a prescribed velocity is removed and substituted by the stored external right-hand-side (external force) and slowly set to zero by multiplication with a time function as specified with **bounda_force** in combination with **bounda_time**. With the **control_bounda_relax_geometry** record with the same index you can select a specific geometry for which the storing will be done.

A typical example can be found in the **relax1.dat** file in your distribution.

6.109 control_bounda_relax_geometry *index geometry_item_name geometry_item_index*

See **control_bounda_relax**.

6.110 control_change_dataitem_apply *index switch*

If *switch* is set to **-no**, any **change_dataitem*** data in the input file will be ignored. This is done for timestep records with the same index.

6.111 control_check_data *index switch*

If *switch* is set to **-yes** the in-core database is checked at some moments during the calculation, for the specified control index. You can try this option in case you experience unexpected behavior.

6.112 control_contact_apply *index switch*

If *switch* is set to **-yes**, the contact algorithm is used. If *switch* is set to **-no**, the contact algorithm is not used. This is done for timestep records with the same index.

Default *switch* is set to **-yes**. See also **contact_apply**.

6.113 control_convection_apply *index switch*

If *switch* is set to **-yes**, the convection of a material with respect to the mesh is allowed. If *switch* is set to **-no**, the convection of a material with respect to the mesh is not allowed. This is done for timestep records with the same index. See also **convection_apply**.

6.114 control_data_activate *index data_item_name_0 data_item_name_1 ... switch*

With this record you can set data items to become activated if *switch* is set to **-yes** or de-activated if *switch* is set to **-no**. The *data_item_name* specifies a data record name.

6.115 control_data_arithmetic *index data_item_name data_item_index data_item_number operat*

This record allows you to change a data item. With *data_item_name data_item_index data_item_number* you select which data item to change. It will be changed with value *val* as specified in the corresponding **control_data_arithmetic_double** record. With *operat* you select how to change the data item; possibilities are **-plus**, **-minus**, **-multiply** and **-divide**.

In stead of a specific index *data_item_index* you can also specify a range **-ra ... -ra**.

In case you specify **-all** for *data_item_number* the specified value will be used for all numbers of the record.

6.116 control_data_arithmetic_double *index val*

See **control_data_arithmetic**.

6.117 control_data_copy *index data_item_from data_item_to*

Copy data item *data_item_from* to *data_item_to*. The user is responsible to apply only logic copy actions.

Normally the *data_item_from* and *data_item_to* should have the same length. As a special option however, you can copy **node_inertia** to **node_force** records , while using a **control_data_copy_factor** of -1. This allows you to substitute material mass inertia by static nodal forces, for the remainder of the calculation. This in fact is the d'alembert principle.

6.118 control_data_copy_factor *index factor*

Multiplication factor for **control_data_copy**.

6.119 control_data_copy_index *index data_item_from index_from data_item_to index_to*

Copy data item *data_item_from* with index *index_from* to *data_item_to* with *index_to*. The user is responsible to apply only logic copy actions.

6.120 control_data_copy_index_factor *index factor*

Multiplication factor for **control_data_copy_index**.

6.121 control_data_delete *index data_item_name index_range*

Delete one or more data items. The *index_range* is a number (e.g. 3) or a range (**-ra ... -ra**, or **-all**).

If *index data_item_name* is a nodal item (for example **node** or **node_dof**) then *index_range* can also be a geometrical entity (for example **-geometry_line 1** or so), and the item will be deleted for nodes located on the geometrical entity.

If *index data_item_name* is a element item then *index_range* can also be a geometrical entity (for example **-geometry_line 1** or so), and the item will be deleted for elements with all nodes located on the geometrical entity.

In the example below element 1-10 and nodes 1-100 are deleted after some time in the calculation; this simulates dismantling a part of a structure somewhere in its lifetime. First, time steps with the total structure are taken; then a part of the structure is dismantled; then time steps with the remaining part of the structure are taken.

```
...
control_timestep 10 ...
...
control_data_delete 20 -element -ra -from 1 -to 10 -ra
control_data_delete 21 -node -ra -from 1 -to 100 -ra
...
control_timestep 30 ...
...
```

If an element or node is deleted, then also the corresponding records will be deleted. See also **control_data_put**.

6.122 control_data_put *index data_item_name index_range number_0 number_1 ...*

Puts one or more data items.

The *index_range* is a number (e.g. 3) or a range (**-ra ... -ra**, or **-all**). The **-all** option for *index_range* is only available for nodal data items (like **node** or **node_dof**). If *data_item_name* is a nodal item then *index_range* can also be a geometrical entity (for example **-geometry_line 1** or so), and the item will be put for nodes located on the geometrical entity. If *data_item_name* is a element item then *index_range* can also be a geometrical entity (for example **-geometry_line 1** or so), and the item will be put for elements with all nodes located on the geometrical entity.

With *number_0 number_1* etc. you can set which value should be put. For example only using 3 for *number_0* then you only want to set the fourth value for the data item (remember that numbering starts at 0). To specify the numbers for dof's you can also specify names like **-velx**, **-sigxx**, etc. In case you specify **-all**, then all values should be given in **control_data_put_double** or **control_data_put_integer**.

The values to be put should be specified in a **control_data_put_double** record for real data or in a **control_data_put_integer** record otherwise. You should specify a value for each and every specified number.

If the data item already exists it is overwritten; else a new record will be generated.

See also **control_data_delete**.

6.123 control_data_put_double *index ...*

See **control_data_put**.

6.124 control_data_put_integer *index ...*

See **control_data_put**.

6.125 control_data_save *index switch*

If *switch* is set to **-yes** save the status of strains, stresses, displacements, etc. At a later point in the calculation you can plot with gid data relative to these saved data with **control_print_gid_save_difference**.

...

control_timestep 10 ...
...
control_data_save 20 -yes
...
control_timestep 30 ...
...
control_print_gid 40 -separate_sequential
control_print_gid_save_difference 40 -yes
...

6.126 control_dependency_apply *index switch*

If *switch* is set to **-yes**, dependencies as specified with **dependency_diagram** and **dependency_item** are included in the calculation. If *switch* is set to **-no**, these dependencies are not included. This is done for timestep records with the same index.

Default, if **control_dependency_apply** is not specified, then **dependency_apply** will be used.

6.127 control_distribute *index distribution_type data_item_name data_item_index data_item_number*

Apply a random number, based on a **-lognormal** or **-normal** distribution, to the *data_item_name* records. This is done for the index *data_item_index* and the *data_item_number* value in those records (0 for the first value, 1 for the second value, etc.). The *data_item_index* can optionally be set to **-all** in stead of a specific index, so that the distribution will be applied to all existing indices.

The *distribution_type* should be set to **-lognormal** or **-normal**. Use the **control_distribute_parameters** record to set the mean value and standard deviation.

The *data_item_name* can be one of **group_*** or **node_***. If you specify a **group_***, for example **group_materi_elasti_young** or so, then not the group item record self will be changed, but the item will be changed for the elements which use this record; in this way you can give a random distribution to group data like Young modulus, plastic properties, etc.

It is optionally possible to require a distribution that is correlated in space. To obtain such a correlated distribution , you need to specify the **control_distribute_correlation_length** record. If the specified correlation length is larger than 1.e12 then Tochnog uses a constant G (all components have the same value). As a special option, you can specify a different distribution length in each space direction (in 2D specify 2 values, and in 3D specify 3 values).

With **control_distribute_correlation_distance** you can set the maximum distance

below which data will be correlated. Above that distance tochnog will not correlate the data. Default, if **control_distribute_correlation_distance** is not specified it will be taken to be 4 times the correlation length.

With **control_distribute_minimum_maximum** you can set the minimum and maximum value which the random numbers are allowed to take. Numbers outside that range will be cutoff to the minimum or maximum value. A typical application would be limiting the void ratio to a range which is needed by a hypoplasticity law.

In the first example, an lognormal distribution with average 100 and standard deviation 1.2 is used to the nodal temperatures:

```
...
materi_velocity
condif_temperature
...
control_distribute 10 -lognormal -node_dof -all -temp
control_distribute_parameters 10 100. 1.2
...
```

In the second example, a normal distribution with average 1 and standard deviation 1.e-3 is used to the y coordinate of the nodes:

```
...
control_distribute 10 -normal -node -all 1
control_distribute_parameters 10 1. 1.e-3
...
```

In the third example, a normal distribution with average 10 and standard deviation 1. is used to the young's modulus of group 7:

```
...
control_distribute 10 -normal -group_materi_elasti_young 7 0
control_distribute_parameters 10 10. 1.
...
```

This **control_distribute_*** is presently only available on linux computers. The **control_distribute_*** should be before all **control_reset_dof** (thus have a higher index).

6.128 control_distribute_correlation_distance *index maximum_distance*

6.129 control_distribute_correlation_length *index correlation_length ...*

See **control_distribute**.

6.130 control_distribute_minimum_maximum *index minimum maximum*

See **control_distribute**.

6.131 control_distribute_parameters *index mean_value standard_deviation*

See **control_distribute**.

6.132 control_distribute_seed *index seed*

For experts only. With this record you can specify the seed which will be used to start the random series of numbers. Use a positive integer value.

As a special option you can set *seed* to **-new** then Tochnog will self choose a seed. As a special option you can set *seed* to **-old** then Tochnog will use the previous seed.

6.133 control_element_group *index switch*

If *switch* is set to **-yes** the records **area_element_group** with be evaluated for the current control index. This option should not be used if the control index is also used for timesteps.

6.134 control_element_group_apply *index number*

See **element_group_apply**.

6.135 control_geometry_moving *index* -initialise

Initialise all **geometry_moving** records. That is, determine for all elements at which time they will be excavated by the **geometry_moving** entities in the remainder of the calculation.

6.136 control_groundflow_consolidation_apply *index switch*

If *switch* is set to **-no**, then the material divergence part in the groundflow equation is skipped.

Attention: If you want consolidation in geotechnics then set the *switch* to **-yes**. If you do not want consolidation in geotechnics then set the *switch* to **-no**.

This is done for timestep records with the same index.

Default, if **control_groundflow_consolidation_apply** is not specified, then **groundflow_consolidation_apply** will be used.

6.137 control_groundflow_nonsaturated_apply *index switch*

If *switch* is set to **-no**, then nonsaturated groundflow data (eg van Genuchten) will not be applied; only saturated data will be used.

Default, if **control_groundflow_nonsaturated_apply** is not specified, then **groundflow_nonsaturated_apply** will be used.

6.138 control_inertia_apply *index switch_0 switch_1 ...*

If *switch_0* is set to **-yes**, the corresponding inertia term is included (material mass, heat capacity, ..). The same for the other switches. A switch should be specified for each of the principal dof's. See the 'input file - data part - introduction - types of dof's' section for an explanation about principal dof's. The sequence of the principal dof's is in the order as initialised in the **initia** ... **end_initia** part.

As a special option you can specify only one switch, and then the specified value will automatically be used for all principal dof's.

This **control_inertia_apply** record is applied for timestep records with the same index.

Default, if **control_inertia_apply** is not specified, then **inertia_apply** will be used.

6.139 control_input *index switch*

If *switch* is set to **-yes** Tochnog reads an extra piece of input from the file *index***.dat**. The piece of input needs to be closed by two **end_data** statements. Comments (...) are not allowed. All defines and arithmetics cannot be used.

6.140 control_materi_damage_apply *index switch*

If *switch* is set to **-no**, any damage data in the input file will be ignored. This is done for timestep records with the same index.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with damage data. See also **materi_damage_apply**.

6.141 control_materi_dynamic *index factor*

Same as **materi_dynamic** but now only for timesteps with the same control index.

6.142 control_materi_elasti_k0 *index switch*

See **group_materi_elasti_k0**.

6.143 control_materi_failure_apply *index switch*

If *switch* is set to **-no**, any damage data in the input file will be ignored. This is done for timestep records with the same index.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with failure data. See also **materi_failure_apply**.

6.144 control_materi_plasti_hypo_masin_ocr_apply *index switch*

If *switch* is set to **-yes** the OCR will be applied. If *switch* is set to **-no** the OCR will not be applied.

Default *switch* is **-no**.

6.145 control_materi_plasti_hypo_masin_clay_ocr_apply *index switch*

If *switch* is set to **-yes** the OCR will be applied. If *switch* is set to **-no** the OCR will not be applied.

Default *switch* is **-no**.

6.146 control_materi_plasti_hardsoil_gammap_initial *index switch*

See theory section on hardsoil.

6.147 control_materi_plasti_hypo_pressure_dependent_void_ratio *index switch*

If *switch* is set to **-yes** the initial void ratio is corrected for pressure dependency; see the theory section. This is done for the first timestep in the corresponding **control_timestep** record with the same *index*. Default *switch* is set to **-no**.

6.148 control_materi_plasti_hypo_niemunis_visco_ocr_apply *index switch*

If *switch* is set to **-yes** the OCR will be applied. If *switch* is set to **-no** the OCR will not be applied.

Default *switch* is **-no**.

6.149 control_materi_plasti_hypo_substepping *index switch*

If *switch* is set to **-yes** substepping will be applied in hypoplasticity routines. If *switch* is set to **-no** substepping will not be applied in hypoplasticity routines.

If this record is not specified the record **materi_plasti_hypo_substepping** will be used.

6.150 control_materi_plasti_tension_apply *index switch*

If *switch* is set to **-no**, any tension-plasticity data in the input file will be ignored. This is done for timestep records with the same index.

See also **materi_plasti_tension_apply**.

6.151 control_materi_plasti_visco_apply *index switch*

If *switch* is set to **-no**, any visco-plasticity data in the input file will be ignored. This is done for timestep records with the same index. See also **materi_plasti_visco_apply**.

6.152 control_materi_updated_apply *index switch*

If *switch* is set to **-no**, any **-updated** material memory will be set to **-updated_linear**. If *switch* is set to **-yes**, any non-specified material memory will be set to **-updated**. This is done for timestep records with the same index.

6.153 control_materi_undrained_apply *index switch*

See **group_materi_undrained_capacity**. Default, if **control_materi_undrained_apply** is not specified, *switch* is set to **-yes**.

6.154 control_materi_viscosity_apply *index switch*

If *switch* is set to **-no**, any viscosity in the input file will be ignored. This is done for timestep records with the same index.

6.155 control_mesh_activate_gravity_apply *index index_0 index_1 ...*

With this record you can specify which of the **mesh_activate_gravity_*** records should be applied, by specifying the indices of the records that should be applied. In case this **control_mesh_activate_gravity_apply** is not given, all **mesh_activate_gravity_*** records will be applied. As a special option you can use **-all** indicating that all of the **mesh_activate_gravity_*** records should be applied (this is the same as not specifying the **control_mesh_activate_gravity_apply** record at all). As another special option you can use **-none** indicating that none of the **mesh_activate_gravity_*** records should be applied.

See also **mesh_activate_gravity_time**.

6.156 control_mesh_adjust_geometry *index geometry_entity_item_0 geometry_entity_index_0 geometry_entity_item_1 geometry_entity_index_1*

The nodes of the geometry entity 0 are replaced such that they neatly follow the boundary of geometry 1. In this way, it is easy to make a mesh with elements precisely in specific regions, if this is required to give separate **element_group** data (e.g. materials) to the geometry and it is too difficult to make the mesh at once OK for this.

The created mesh may be quite distorted.

6.157 control_mesh_change_element_group *index element_group_0 element_group_1*

Change the group number **element_group** of elements from *element_group_0* to *element_group_1*. The index should not be equal to a timestep index.

6.158 control_mesh_convert index *switch*

If *switch* is set to **-yes**, tochnog will automatically convert elements:

- **-bar2** in 2D to **-quad4** if the element is an interface
- **-bar3** in 2D to **-quad6** if the element is an interface
- **-tria3** in 3D to **-prism6** if the element is an interface
- **-tria6** in 3D to **-prism12** if the element is an interface
- **-quad4** in 3D to **-hex8** if the element is an interface
- **-quad8** in 2D to **-quad6** if the element is an interface
- **-quad8** in 3D to **-hex18** if the element is an interface
- **-quad9** in 2D to **-quad6** if the element is an interface
- **-quad9** in 3D to **-hex18** if the element is an interface
- **-hex20** in 3D to **-hex18** if the element is an interface
- **-hex20** in 3D to **-hex27** if the element is not an interface
- **-prism15** in 3D to **-prism12** if the element is an interface
- **-prism15** in 3D to **-prism18** if the element is not an interface

For an interface you need to specify interface data in the **group_interface...**. For example the **-bar2** is connected to two nodes, whereas the converted **-quad4** is connected to four nodes. In a similar manner all other converted elements also get extra nodes. This options makes it easy to obtain a mesh with interface elements. For example generate with GID in a 2d mesh bar elements, insert group data, and use **control_mesh_convert** to generate the interface elements. This generation of interfaces only works properly if certain conditions are satisfied:

- Each interface needs to have only isoparametric neighbours which have a total side in common with the interface. For example a **-hex8** interface should only have **-hex8** neighbours.

- Surfaces with interface elements should not intersect with another surface with interface elements.

The new generated nodes will be connected to existing neighbouring element at the interfaces. The **control_mesh_convert** tries to do that automatically correct. You can help however by specifying in the record **control_mesh_convert_element_group** element groups which are located at one side of the interfaces (for example the groups of a pile in soil when an interface is generated between pile and soil).

Example in which a **-bar2** interface becomes a **-hex8** interface:

```
...
number_of_space_dimension 3
...
end_initia
...
element 1 -bar2 101 102
element_group 1 10
...
group_interface 10 -yes
...
control_mesh_extrude 100 ...
...
control_mesh_convert 110 -yes
...
```

If *switch* is set to **-no**, tochnog will not convert elements.

6.159 control_mesh_convert_element_group index *element_group_0 element_group_1 ...*

See **control_mesh_convert**.

6.160 control_mesh_convert_quad9_quad6 *index dir*

Convert **quad9** into **quad6** is a 2D calculation. With *dir* you can decide in which isoparametric direction of the **quad9** nodes should be deleted (so that becomes the linear direction in the **quad6** element). Set *dir* either to **-x** or to **-y**.

6.161 control_mesh_convert_tria6_tria3 *index switch*

Convert **tria6** into **tria3** is a 2D calculation. This is done if *switch* is set to **-yes**.

6.162 control_mesh_copy index *move_x move_y move_z*

This option copies the mesh. Thus you get twice as much elements and nodes. Each new node is moved *move_x move_y move_z* relative to the corresponding old node. In 1d you only should specify *move_x*. In 2d you only should specify *move_x move_y*.

6.163 control_mesh_cut_geometry *index geometry_item_name geometry_item_index*

This command cuts away a part of the mesh, as defined by *geometry_item_name geometry_item_index*. The cut away mesh can be substituted by its nodal forces. Actually, with **control_mesh_cut_force** you can set for each direction if the nodal force of the cut away mesh should be applied to the remaining mesh. This will be done if you set the corresponding *switch* in **control_mesh_cut_force** to **-yes**. In 2D you should set two switches, and in 3D you should set 3 switches.

See **mesh_cut_1.dat** and **mesh_cut_2.dat** in the test directory for examples. See **earthquake_2.dat** how this **control_mesh_cut_geometry** command can save you computing time in dynamic calculations with many timesteps.

6.164 control_mesh_cut_force *index switch_0 switch_1 switch_2*

See **control_mesh_cut_geometry**.

6.165 control_mesh_delete_element *index number_0 number_1 ...*

The elements with numbers *number_0 number_1* will be deleted. Otherwise the same as **control_mesh_delete_geometry**.

6.166 control_mesh_delete_geometry *index geometry_entity_item geometry_entity_index*

All elements which are part of the geometry item are deleted. In this way, it is easy to make a mesh with holes, tunneling systems in ground, etc. Remaining nodes in the geometry, are moved onto the edge of the geometry if the corresponding **control_mesh_delete_geometry_move_node**

record with the same index is set to **-yes**; (otherwise, the remaining nodes are left inside the geometry).

For a **geometry_point**, elements inside the tolerance distance of the point will be deleted. For a **geometry_circle**, elements in the total inner area of the circle radius plus its tolerance will be deleted. Likewise for other geometries.

If you combine this record with a **control_timestep** record, then the element will be slowly deleted, starting from a complete element at the start of the timestep up to no element at the end of the timestep. This is accomplished by reducing the nodal forces of the elements slowly to zero; at the end of the timestep, the element is deleted completely. This might be useful for a better convergence behavior of the iterative process.

If an element is being deleted, **element_empty** is automatically set to **-empty**, even if the element is not completely deleted yet. This allows you to look with GID 'behind elements that are being deleted' (see also **element_empty** and **control_print_gid_empty**).

See also **control_mesh_delete_geometry_move_node**, **control_mesh_delete_geometry_element** and **control_mesh_delete_geometry_element_group**.

6.167 control_mesh_delete_geometry_direct *index switch*

If *method* is set to **-yes** the elements inside the geometry will be deleted direct, as opposed to slowly over the timesteps.

6.168 control_mesh_delete_geometry_element *index element_name_0 element_name_0 ...*

Only elements with names *element_name_0* etc. will be deleted if the **control_mesh_delete_geometry** (with the same index) is used. For example, *element_name_0* is **-quad4**, **-beam**, etc.

If this record is not specified all elements in the geometry will be deleted.

6.169 control_mesh_delete_geometry_element_group *index element_group_0 element_group_1 ...*

Only elements from group *element_group_0* etc. will be deleted if the **control_mesh_delete_geometry** (with the same index) is used.

6.170 control_mesh_delete_geometry_factor *index factor_0 factor_1 ...*

The elements deleted by **control_mesh_delete_geometry** (with the same index), will be deleted by a factor *factor_0* at the start of the timesteps up to a factor *factor_1* at the end of the timesteps. If the **control_mesh_delete_geometry** is not used in combination with timesteps, then directly *factor_1* will be applied.

If *factor_1* exceeds $1.-1.e-10$ an element will be completely deleted from the calculation, that is the **element** record will be removed and cannot be reactivated in any way later in the calculation.

If this record is not specified then *factor_0* = 0 and *factor_1* = 1.

6.171 control_mesh_delete_geometry_method *index method*

Determines the condition on which an element will be considered part of the geometry to be deleted. If *method* is set to **-all** then all element nodes should be part of the geometry. If *method* is set to **-any** then any of the element nodes should be part of the geometry. If *method* is set to **-average** then the average element coordinate should be part of the geometry.

Default this record is **-all**.

See also **control_mesh_delete_geometry**.

6.172 control_mesh_delete_geometry_move_node *index switch*

Determines if remaining nodes inside a deleted geometry, are moved onto the edge of the geometry (**-yes**) or not (**-no**). Moving nodes makes that the element mesh exactly fits the deleted geometry, but may also lead to heavily distorted elements. Default this record is **-no**.

See also **control_mesh_delete_geometry**.

6.173 control_mesh_delete_geometry_projection_type *index type*

This record allows you to control what geometry will actually be deleted. Set *type* to **-project_inside** or **-project_exact**. For example if the geometry is a **geometry_circle** then **-project_inside** means that everything inside the circle will be deleted, whereas **-project_exact** means that everything within a tolerance from the circle edge will be deleted. Default *type* is **-project_exact**.

6.174 control_mesh_delete_geometry_stop *index switch*

If *switch* is set to **-yes**, any deleting of elements in geometries will be stopped. That is, all remaining delete factors from **control_mesh_delete_geometry_factor** will be destroyed and all elements will become fully active again.

In combination with **global_element_dof_apply -yes**, the elements which become active again will take their strains, stresses etc. of the moment just before being deleted! If you want to lower the stresses or strains or so, then consider using **control_reset_dof**.

In combination with **global_element_dof_apply -no**, the elements which become active again will take their strains, stresses etc. from the nodes.

6.175 control_mesh_delete_geometry_stop_geometry *index geometry_entity_name geometry_entity_index*

Only do the **control_mesh_delete_geometry_stop** for elements part of the geometrical entity specified in this **control_mesh_delete_geometry_stop_geometry**.

6.176 control_mesh_delete_small *index eps*

At the end of a timestep, an element will be deleted when its volume has become smaller than *eps*.

6.177 control_mesh_duplicate_element_group *index element_group_old element_group_new*

Use this command to duplicate elements from group *element_group_old* to new elements with group *element_group_new*. The new elements get the same nodes as the old original elements.

6.178 control_mesh_element_group_apply *index group_0 group_1 ...*

If you specify this record, only the element groups specified will be evaluated in the timesteps with the same index. Default, if **control_mesh_element_group_apply** is not specified, all elements groups will be used.

6.179 control_mesh_extrude *index z0 z1 z2 ...*

Option to extrude a 2D mesh to 3D. The 2D mesh has x,y,z coordinates, with z=0. The 3D mesh will have x,y,z coordinates. You need to specify in the initialisation part **number_of_space_dimensions** to 3.

With z0, z1, z2 etc. you specify the coordinates of the layers to which the 2D coordinates will be extruded. With n0, n1, n2 you specify the number of elements that will be generated in each layer; n0 specifies the number of elements between z0 and z1, n1 specifies the number of elements between z1 and z2, etc.; for the last n-value you always should use a 1 (this is a dummy value, that is not used for any layer at all).

Extrusion must be done before doing mesh refinements, mesh splitting, etc.

6.180 control_mesh_extrude_direction *index dir*

Default extrusion is done in the global z-direction. Optionally you can set *dir* to **-y** and then extrusion is done in global y-direction.

6.181 control_mesh_extrude_element *index name*

If you extrude **-tria6** elements, you can set *name* either to **-prism12** or **-prism18**. Then either the 12 node or 18 node prismatic elements will be generated. Default, if this **control_mesh_extrude_element** is not set, then **-prism18** is used for *name*.

See also **control_mesh_extrude_n**.

6.182 control_mesh_extrude_contact_spring_element_group *index element_group_0 element_group_1 ...*

See **control_mesh_extrude_contact_spring_element_group_new**.

6.183 control_mesh_extrude_contact_spring_element_group_new *index element_group_new_0 element_group_new_1 ...*

If this record is specified, then a contact spring is generated between each start node and end node in the extrude direction. This option comes handy, when you want to use these contact springs to enforce that the nodes on the start plane get the same displacements as the nodes on the end plane, which models that the extruded mesh is in fact part of a very long domain with no variations in the longitudinal direction of the domain.

The contact springs get group number *element_group_new_0* when its node is attached to an element with old group *element_group_0*. The contact springs get group number *element_group_new_1* when its node is attached to an element with old group *element_group_1*. Etc. The old groups are specified in the **control_mesh_extrude_contact_spring_element_** record. If the contact spring's node is attached to more than one old group, the first specified old group, and corresponding new group, will be used.

As a special option, if you specify in **control_mesh_extrude_contact_spring_element_group_new** only one new element group number, then all contact springs will be placed on that group.

6.184 control_mesh_extrude_element_group_new *index element_group_old_0 element_group_old_1 ... element_group_new_00 element_group_new_01 ... element_group_new_10 element_group_new_11 ...*

With this option you set the element_group number of the new extruded elements.

With *element_group_old_0*, *element_group_old_1* etc. you specify the old element_group numbers of the 2D elements (which will be extruded). For these old groups, you specify for each layer in z-direction what the new element_group numbers of the extruded 3D elements should be. For example, *element_group_new_00* , *element_group_new_01* etc. give for *element_group_old_0* what the element_group numbers of the new extruded elements will be (for each z layer).

You need to specify element_group numbers for each and every z layer.

If a new element group is set to a negative number in this **control_mesh_extrude_element_group_new** the elements will not be generated.

See also **control_mesh_extrude**.

6.185 control_mesh_extrude_n *index n0 n1 n2 ...*

See **control_mesh_extrude**.

6.186 control_mesh_generate_beam *index element_group geometry_entity_item geometry_entity_index*

The same as **control_mesh_generate_truss**, now for beams however.

6.187 control_mesh_generate_contact_spring *index element_group geometry_entity_item geometry_entity_index*

Generate **-contact_spring2** springs for nodes which have the same position in space. This can be used to connect these nodes with spring elements, so to model a contact area. Only nodes located on the specified geometry entity will be used.

The generated springs will get an **element_group** record with value *element_group*. So in that element group you can put the properties of the contact springs.

With the **control_mesh_generate_contact_spring_element** record you can set between which elements the contact_springs should be generated. For example use **-quad4** and **-truss_beam** if you want to generate contact_springs between those elements.

If **control_mesh_generate_contact_spring_element_group** (with the same index) is used, contact springs will only be generated between elements of the groups *element_group_0*, *element_group_1* etc.

6.188 control_mesh_generate_contact_spring_element *index element_0 element_1*

See **control_mesh_generate_contact_spring**.

6.189 control_mesh_generate_contact_spring_element_group *index element_group_0 element_group_1 ...*

See **control_mesh_generate_contact_spring**.

6.190 control_mesh_generate_interface *index element_group_0 element_group_00 element_group_01 element_group_1 element_group_10 element_group_11 ...*

With this record you can generate interface elements.

The interface elements will be given an **element_group** record *element_group_0* if the interface is between *element_group_00* and *element_group_01*. The interface elements will be given an **element_group** record *element_group_1* if the interface is between *element_group_10* and *element_group_11*. The interface elements will be given an **element_group** record *element_group_2* if the interface is between *element_group_20* and *element_group_21*. Etc, etc.

The groups *element_group_00*, *element_group_10*, *element_group_20*, etc. should be on one side. The groups *element_group_01*, *element_group_11*, *element_group_21*, etc.

should be on the opposite side.

Between two linear 2d elements **-quad4** interfaces will be generated. Between two quadratic 2d elements **-quad6** interfaces will be generated. Between two **-hex8** elements a **-hex8** interface will be generated. Between two **-hex27** elements a **-quad18** interface will be generated. Between two **-tet4** elements a **-prism6** interface will be generated. Between two **-tet10** elements a **-tria12** interface will be generated. Between two **-prism6** elements a **-prism6** interface will be generated on sides with 3 nodes. Between two **-prism6** elements a **-hex8** interface will be generated on sides with 4 nodes. For other situations no interface element will be generated.

Crossing interfaces are not allowed, eg in 2d you should not have locally two connecting lines with interfaces and in 3d you should not have locally two connecting surfaces with interfaces.

Interfaces can only be generated between exactly two elements. You cannot generate interface where three elements connect; for example ypu cannot generate an interface at the common side of two quad4 elements if there is also a truss along that common side.

If you want the interface to connect, you really should do for example:

```
...
control_mesh_generate_interface 10 20 30 31 20 40 41
...
```

which takes care that the interfaces generated by this command are connected together. If you would have used the following:

```
...
control_mesh_generate_interface 10 20 30 31
control_mesh_generate_interface 11 20 40 41
...
```

The interfaces generated by the two commands will not connect.

See also **control_mesh_generate_interface_geometry** and **control_mesh_generate_interface_metho**

6.191 control_mesh_generate_interface_geometry *index geometry_item_name geometry_item_index*

Restrict the generation of interfaces for the **control_mesh_generate_interface** record with the same index to the geometry specified in this **control_mesh_generate_interface_geometry** record.

6.192 control_mesh_generate_interface_method *index method_select method_generate*

If you set *method_select* to **-element_geometry** the **control_mesh_generate_interface** will select with **element_geometry** between which elements interfaces will be generated.

If you set *method_generate* to **-element_geometry** the **control_mesh_generate_interface** will generate **element_geometry** records for the interface elements, in stead of **element_group** records.

So for example using **-element_geometry -element_geometry** tells that the **control_mesh_generate_interface** in fact is *index element_geometry_0 element_geometry_00 element_geometry_01 element_geometry_1 element_geometry_10 element_geometry_11* ....

Default, if **control_mesh_generate_interface_method** is not specified, it is set to **-element_group -element_group**.

6.193 control_mesh_generate_spring1 *index element_group geometry_entity_item geometry_entity_index*

Generate **-spring1** springs for nodes. Only nodes located on the specified geometry entity will be used.

The generated springs will get an **element_group** record with value *element_group*. So in that element group you can put the properties of the springs (see **group_spring_stiffness** etc.).

6.194 control_mesh_generate_spring2 *index element_group geometry_entity_item geometry_entity_index*

Generate **-spring2** springs for nodes which have the same position in space. This can be used to connect these nodes with spring elements. Only nodes located on the specified geometry entity will be used.

The generated springs will get an **element_group** record with value *element_group*. So in that element group you can put the properties of the springs (see **group_spring_stiffness** etc.).

Typically you can use this option to connect meshes which were generated with different **control_mesh_macro** records or so.

If you need interfaces, then afterwards use a **control_mesh_convert** to turn the generated surface elements into real interface elements.

6.195 control_mesh_generate_truss *index element_group geometry_entity_item geometry_entity_index*

Generate trusses for nodes which are neighbor in space (that is, for nodes which are connected by an isoparametric finite element). Only nodes located on the specified geometry entity will be used.

The generated trusses will get an **element_group** record with value *element_group*. So in that element group you can put the properties of the trusses (see **group_truss_elasti_young** etc.).

Typically you can use this option to put easy trusses somewhere in a mesh with isoparametric elements.

6.196 control_mesh_generate_truss_beam *index element_group geometry_entity_item geometry_entity_index*

The same as **control_mesh_generate_truss**, now for truss_beams however.

6.197 control_mesh_generate_truss_beam_loose *index switch*

This record works together with the **control_mesh_generate_truss**, **control_mesh_generate_beam** and **control_mesh_generate_truss_beam** records.

If *switch* is set to **-yes**, the truss or beam of truss_beam will not be connected to the existing nodes, but new nodes will be generated for the generated element.

Afterwards you can typically connect the truss or beam of truss_beam to the existing mesh with constactsprings, so that the end result is that you can model frictional slip between isoparametric elements and structural elements.

See also **control_mesh_generate_contact_spring**.

6.198 control_mesh_generate_truss_beam_macro *index macro_0 macro_1 ...*

This record works together with the **control_mesh_generate_truss**, **control_mesh_generate_beam** and **control_mesh_generate_truss_beam** records.

With *macro_0* etc. you can specify the indices of **control_mesh_macro_*** records. Then the trusses (or beams or truss_beams) will only be generated for nodes coming from the mesh generated by the macro records with the specified indices.

This is handy in case you generate two neighboring meshes with macro's, and want to

generate the elements (trusses or beams or truss_beams) in between these two meshes. Normally, both the meshes would get the extra truss (or ..) in case you use a geometry_line or so to specify that the new elements should be generated between the two meshes (this is so, since the nodes of both meshes are located on the geometry_line). With the present **control_mesh_generate_truss_beam_macro** record however you can specify that the new elements should only be generated by looking at the nodes of some of the meshes, and so no double new elements will be generated in between the two meshes.

6.199 control_mesh_generate_truss_beam_separate *index switch*

This record works together with the **control_mesh_generate_truss**, **control_mesh_generate_beam** and **control_mesh_generate_truss_beam** records.

If *switch* is set to **-yes**, the truss or beam of truss_beam will be generated for separate regions, not necessary connected by isoparametric finite elements.

A typical example is the generation of exactly one truss between two end points (thus no trusses along all of the isoparametric elements between the end points). For this, put the end points in a geometry set, and also use **-yes** for this **control_mesh_generate_truss_beam_separate** record.

6.200 control_mesh_gid_batch *index switch*

If *switch* is set to **-yes** all **mesh_gid_*** records are used to generate elements using GiD as preprocessor. In fact, the GiD program is called from inside Tochnog as batch. This makes it convenient to do everything that you need from inside the Tochnog input file, without even opening GiD as preprocessor. A simple example is as follows:

```
echo -yes
number_of_space_dimensions 2
end_initia

( define points )
mesh_gid_point_coord 1 0. 0.
mesh_gid_point_coord 2 1. 0.
mesh_gid_point_coord 3 0. 1.
mesh_gid_point_coord 4 1. 1.

( define lines, each line connects to two points )
mesh_gid_line_point 1  1 2
mesh_gid_line_point 2  2 4
mesh_gid_line_point 3  4 3
mesh_gid_line_point 4  3 1

( define closed surfaces, each surfaces connects to multiple lines )
```

```
mesh_gid_surface_line 1  1 2 3 4
( define that the elements in this surface get a group number )
mesh_gid_surface_element_group 1  -yes

( size of elements to be generated )
mesh_gid_size 0.1

( call gid in batch, this generates an extra file index.dat so 10.dat in this example )
control_mesh_gid 10  -yes
( read the mesh in 10.dat )
control_input 10 -yes

( add extra data )
( ... )

end_data
```

A more complex example which creates a circular hole in a rectangular zone is as follows:

```
echo -yes
number_of_space_dimensions 2
end_initia

( the circle will be used hollow )
mesh_gid_circle_coord  1  0.5 0.5
mesh_gid_circle_radius 1  0.3
mesh_gid_circle_hollow 1  -yes

mesh_gid_point_coord 1 0. 0.
mesh_gid_point_coord 2 1. 0.
mesh_gid_point_coord 3 0. 1.
mesh_gid_point_coord 4 1. 1.

mesh_gid_line_point 1  1 2
mesh_gid_line_point 2  2 4
mesh_gid_line_point 3  4 3
mesh_gid_line_point 4  3 1

( the surface edges are the line of the circle and the 4 specified lines )
mesh_gid_surface_line 1  1 2 3 4 5
mesh_gid_surface_element_group 1  1

mesh_gid_size 0.05

control_mesh_gid 10  -yes
control_input 10 -yes

target_item  0   -node 10 1
```

```
target_value 0   0.8715 1.e-2
end_data
```

For more examples see in your distribution **test/other/mesh_gid_*.dat**.

Attention: Please realise that when generating gid objects (circle, cylinder, etc) also automatically points, lines, surfaces and volumes are generated. So you get more points, lines, surfaces and volumes then you specify yourself with **mesh_gid_point_coord**, **mesh_gid_line_point**, **mesh_gid_surface_line** and **mesh_gid_volume_surface**. Thus, you need to pay attention to which point, line, surface and volume numbers you specify in **mesh_gid_line_point**, **mesh_gid_surface_line** and **mesh_gid_volume_surface**. To help you, this option **control_mesh_gid_batch** will print for all **mesh_gid_*** data the points, lines, surfaces and volumes numbers that it generates. So for each thing that you specify you get the corresponding point, line and surface numbers. It is these printed numbers you should use in the records which need these numbers: **mesh_gid_line_point**, **mesh_gid_surface_line** and **mesh_gid_volume_surface**!

Attention: When you specify group numbers for **mesh_gid_..._group** records, you should apply the numbers 1, 2, 3, etc for the groups, and don't use gaps in the numbers.

Attention: For this option to work you need to have GiD (of CIMNE) installed on your computer. Take care that the GiD path where the GiD executable is stored is set in your PATH environment symbol. Also take care that the **tochnog.gid** directory from your Tochnog distributions is copied to the GiD **problemtypes** directory.

6.201 control_mesh_interface_triangle *index switch*

See **mesh_interface_triangle_coordinates**.

6.202 control_mesh_keep_element *index element_0 element_1 ...*

With this option you can delete all elements except for the elements with numbers *element_0*, *element_1*, etc. This enables you to clearly view some specific elements and nodes in a plot.

6.203 control_mesh_keep_element_group *index element_group_0 element_group_1 ...*

With this option you can delete all elements except for the elements with group numbers *element_group_0*, *element_group_1*, etc. This enables you to clearly view some specific elements and nodes in a plot.

6.204 control_mesh_keep_geometry *index geometry_item_name geometry_item_index*

With this option you can delete all elements except for the elements present in the specified geometry. This enables you to clearly view some specific elements and nodes in a plot.

6.205 control_mesh_keep_node *index node_0 node_1 ...*

With this option you can delete all nodes except for the nodes with numbers *node_0*, *node_1*, etc. This enables you to clearly view some specific elements and nodes in a plot.

6.206 control_mesh_macro *index macro_item element_group n ...*

With this record and the **control_mesh_macro_parameters** record you define a macro region. The macro region will automatically be divided into finite elements.

The type of macro region is defined by *macro_item*. You can set *macro_item* to a **-sphere** (3D), **-cylinder** (3D), **-cylinder_hollow** (3D), **-brick** (3D), **-rectangle** (2D/3D), **-circle (2D)**, **-circle_hollow** (2D), **-truss** (1D/2D/3D), **-truss_beam** (1D/2D/3D) and **-bar** (1D).

The elements to be generated will get **element_group** *element_group*.

With *n ...* you define how much nodes and elements will be generated. For a **-cylinder**, you need to specify the number of nodes in the length direction, the number of nodes in radial direction and the number of nodes in circ. direction (there is always only one element in radial direction). For a **-cylinder_hollow**, you need to specify the number of nodes in the length direction, the number of nodes over the wall thickness and the number of nodes in circ. direction. For a **-brick**, you need to specify the number of nodes in x-direction, the number of nodes in y-direction and the number of nodes in z-direction. For a **-circle** and **-sphere**, you need to specify 'fineness' of the mesh, which is a number 0, 1, 2, 3, ...; a higher number gives a higher fineness; typically use 3 or so. For a **-circle_hollow**, you need to specify the number of nodes over the wall thickness, the number of elements in tangential direction. For a **-rectangle**, you need to specify the number of nodes in first direction and the number of nodes in second direction. For a **-bar**, you need to specify the number of nodes. For a **-truss**, you need to specify the number of nodes. For a **-truss_beam**, you need to specify the number of nodes.

In the following example a sphere is generated

```
...
number_of_space_dimension 2
```

...
end_initia
...
control_mesh_macro 20 -sphere ...
control_mesh_macro_parameters 20 ...
...

6.207 control_mesh_macro_concentrate *index ...*

For the **-rectangle** macro you can specify with this **control_mesh_macro_concentrate** record a mesh fineness concentration factor in the first direction and in the second direction. In each direction give a mesh fineness factor at the beginning and at the end (so two factors per direction). A smaller factor means smaller elements. The relative size of the factor determines where elements are concentrated, at the start or at the end.

6.208 control_mesh_macro_element *index element_type*

With this option you can set the element type which will be generated with **control_mesh_macro** (with the same index). This option is only available in 2d and 3d.

For **element** you can use **-tria3**, **-tria6**, **-quad4** and **-quad9** in 2d. For **element** you can use **-tet4**, **-tet10**, **-hex8** and **-hex27** in 2d.

If this record is not specified then **-bar2** (1d), **-quad4** (2d) or **-hex8** (3d) will be generated.

Attention: in case you choose a quadratic element the macro geometry may not be exactly followed. In this case, leave the default linear elements, and use a global mesh refinement to quadratic elements afterwards, including the geometry to follow.

6.209 control_mesh_macro_parameters *index x y ...*

With this record you can specify the dimensions of the **control_mesh_macro** region.

For a **-sphere**, you need to specify the x, y, z coordinates of the middle of the sphere and the radius of the sphere. For a **-cylinder**, you need to specify the x, y, z coordinates at the start of the cylinder, the x, y, z coordinates at the end of the cylinder, the radius, the start angle and the end angle in degrees (which allows for an open section). For a **-cylinder_hollow**, you need to specify the x, y, z coordinates at the start of the cylinder, the x, y, z coordinates at the end of the cylinder, the middle radius, the wall thickness, the start angle and the end angle in degrees (which allows for an open section). For a **-brick**, you need to specify the x, y, z coordinates at the middle, the length in x-direction, the length in y-direction, and the length in z-direction. For a **-circle**, you need to specify the x, y coordinates of the middle and also the radius. For a **-circle_hollow**, you need to specify the same as for the **circle**

and additionally the wall thickness, the start angle and the end angle in degrees (which allows for an open section). For a **-rectangle**, you need to specify the x, y coordinates of the middle, the width and the height respectively. For a **-bar**, you need to specify the x coordinate of the middle and the length respectively. For a **-truss**, you need to specify the coordinates of the start and of the end respectively.

6.210 control_mesh_map *index switch*

A typical piece of input file is

. . .
global_element_dof_apply -no
. . .
. . . (input file with quadratic elements -hex20 or -hex27 or -tet10 or -prism15)
. . .
control_mesh_map . . . -yes (map to linear elements -hex8 or -prism6 or -tet4)
. . .
control_timestep . . . (calculate with linear elements)
control_solver . . . -matrix_pardiso (with pardiso solver)
. . .
control_mesh_map -yes (map back to quadratic elements)
. . .
control_timestep . . . (calculate with quadratic elements)
control_solver . . . -matrix_iterative_bicg (with bicg solver)
. . .

In this way, the last calculation with the quadratic elements gets as first guess for the bicg solver the solution field of the linear elements with the pardiso solver. This saves much computing time for bicg, especially in very large calculations. This strategy normally should only be used for large linear calculations. For this option always set **global_element_dof_apply -no**.

6.211 control_mesh_merge *index switch*

If *switch* is set to **-yes**, then nodes with the same coordinates are merged into one node.

6.212 control_mesh_merge_eps_coord *index epsilon*

Distance below which nodes will be merged. Default some small value.

6.213 control_mesh_merge_macro_generate *index macro_0 ...*

This record works together with the **control_mesh_merge** record.

With *macro_0* etc. you can specify the indices of **control_mesh_macro_*** or **control_mesh_generate_*** records. Then the merging will only be done for nodes coming from the mesh generated by the macro or generate records with the specified indices.

6.214 control_mesh_merge_geometry *index geometry_entity_item geometry_entity_index*

The mesh merging from **control_mesh_merge**, with the same index, will only be used for nodes in the geometry specified by *geometry_entity_item geometry_entity_index*.

6.215 control_mesh_merge_geometry_not *index geometry_entity_item geometry_entity_index*

The mesh merging from **control_mesh_merge**, with the same index, will not be used for nodes in the geometry specified by *geometry_entity_item geometry_entity_index*.

6.216 control_mesh_mirror index *axis*

This option mirrors the mesh. Thus you get twice as much elements and nodes. The *axis* should either be set to **-x**, **-y** or **-z**.

6.217 control_mesh_move index *move_x_constant move_x_linear_x move_x_linear_y move_x_linear_z move_y_constant move_y_linear_x move_y_linear_y move_y_linear_z move_z_constant move_z_linear_x move_z_linear_z move_y_linear_z*

This option movies the mesh. Thus you get the same amount of elements and nodes, but just moved in space.

In the x-direction a node is moved over *move_x_constant* + *move_x_linear_x* * x + *move_x_linear_y* * y + *move_x_linear_z* * z.

Specify only data for the number of space dimensions.

6.218 control_mesh_multiply *index number_of_multiplications*

The mesh is multiplied *number_of_multiplications* times. In each multiplication the mesh gets double the amount of elements, because for each element a new element is generated with the same nodes.

6.219 control_mesh_refine_globally *index refinement_type*

This record activates global mesh refinement or global mesh coarsening. This is not available for **-tria3** and **-tet4** elements. Either *refinement_method* is **-h_refinement** (more of the same elements) or *refinement_method* is **-p_refinement** (higher order elements).

As a special option for the **-h_refinement** method, the format **refine_globally** *index* **-h_refinement** *switch_ξ switch_η switch_ζ* can be used. For example in 1D, only **refine_globally** *index* **-h_refinement** *switch_ξ* should be specified. For example in the **-hex8** element, ξ is the isoparametric coordinate running from the first node to the second node, η runs from the first node the third node and ζ runs from the first node to the fifth node. A isoparametric direction will be refined if the corresponding switch is set to **-yes**. This option allows for refinement in specific directions. It should be used with care however, and only gives proper results if the ξ,η and ζ directions of the elements match.

The **control_mesh_refine_globally** will automatically merge nodes which have the same position in space.

Rules for old and new:

- A new generated element inherits its data items from the old element it is generated from.
- If a new generated node is placed on an old element edge it inherits those data items of the old nodes on that old edge that have a property in common; then arbitrarily the data item of one of the old nodes is taken.
- If a new generated node is placed inside an old element it inherits those data items of the old nodes of that old element that have a property in common; then arbitrarily the data item of one of the old nodes is taken.
- For all new nodes the **node_dof** records are interpolated from the old element nodes **node_dof** records by using the old element interpolation functions.

See also **control_mesh_refine_globally_geometry**.

6.220 control_mesh_refine_globally_geometry *index geometry_ entity_ item geometry_ entity_ index*

This record can be used together with the **control_mesh_refine_globally** record with the same index. If all nodes of an element edge is part of the geometrical entity, the new generated nodes are also placed on that geometrical entity. This typically is used to follow curved edges of the domain.

The **control_mesh_refine_locally** will automatically merge nodes which have the same position in space.

6.221 control_mesh_refine_locally *index percentage*

An elements will be refined depending on the size of a solution variable. The solution variable can be chosen via **control_mesh_refine_locally_dof**.

The percentage of elements which will be refined is specified by *percentage*. Typically *percentage* is 10 or so.

This local mesh refinement is only available for **-bar2**, **-bar3**, **-tria3**, **-tria6**, **-tet4** and **-tet10** elements; there should be no other elements in the mesh.

See the rules for old and new at **control_mesh_refine_globally**.

6.222 control_mesh_refine_locally_dof *index dof*

With *dof* you can set which dofwill be used for deciding if an element should be refined. The size of the doffield will be used.

Possibilities for *dof* are: **-materi_damage**, **-materi_displacement**, **-materi_plasti_kappa**, **-materi_plasti_kappa_shear**, **-materi_strain_elasti**, **-materi_strain_plasti**, **-materi_strain_total**, **-materi_stress**, **-materi_velocity**, **-materi_void_fraction** and

As a special option you can set *dof* to **-nothing**; then an element is refined always.

For finding localization zones (e.g. shear bands) choosing **-materi_strain_plasti** or **-materi_damage** seems to be most robust.

See also **control_mesh_refine_locally_geometry**.

6.223 control_mesh_refine_locally_geometry *index geometry_ entity_ item geometry_ entity_ index*

This record can be used together with the **control_mesh_refine_locally** record with the same index. If all nodes of an element edge is part of the geometrical entity, the new generated nodes are also placed on that geometrical entity. This typically is used to follow curved edges of the domain.

6.224 control_mesh_refine_locally_minimal_size *index minimal_ size*

Element with minimal size below the specified *minimal_ size* will not be refined. The minimal element size is defined as the largest node distance between nodes of the element. Default the minimal allowed size is 0.

6.225 control_mesh_refine_locally_not *index geometry_ entity_ 0 geometry_ entity_ index_ 0*

The refinement as specified in the **control_mesh_refine_locally** record with the same index, will not be applied on the geometry specified by *geometry_ entity_ 0 geometry_ entity_ index_ 0*.

6.226 control_mesh_refine_locally_not_method *index method*

Set *method* to **-all** or **-any**. If *method* is set to **-all**, then the corresponding **control_mesh_refine_locally_not** is applied to elements for which all nodes are inside the specified geometry. If *method* is set to **-any**, then the corresponding **control_mesh_refine_locally_not** is applied to elements for which any of the nodes is inside the specified geometry. Default *method* is **-all**.

6.227 control_mesh_refine_locally_only *index geometry_ entity_ 0 geometry_ entity_ index_ 0*

The refinement as specified in the **control_mesh_refine_locally** record with the same index, will only be applied on the geometry specified by *geometry_ entity_ 0 geometry_ entity_ index_ 0*.

6.228 control_mesh_refine_locally_only_method *index method*

Set *method* to **-all** or **-any**. If *method* is set to **-all**, then the corresponding **control_mesh_refine_locally_only** is applied to elements for which all nodes are inside the specified geometry. If *method* is set to **-any**, then the corresponding **control_mesh_refine_locally_only** is applied to elements for which any of the nodes is inside the specified geometry. Default *method* is **-all**.

6.229 control_mesh_remove *index method element_group_0 element_group_1 element_group_2 ...*

With *method* set to **-method1** you can remove elements of *element_group_0* if they are completely located inside a elements of groups *element_group_1*, *element_group_2* etc.

With *method* set to **-method3** you can remove elements if all nodes of these elements have an mpc (that is, **node_mpc** exists for all nodes of an element). Thus for *method* set to **-method3** you do not need to specify *element_group_0*, *element_group_1*, *element_group_2* etc.

6.230 control_mesh_remove_geometry *index geometry_item_name geometry_item_index*

With this record you can restrict to which geometry the **control_mesh_remove** will be applied.

6.231 control_mesh_remove_keep_geometry *index geometry_item_name geometry_item_index*

If elements are being removed once with the **control_mesh_remove** command, they keep on being removed in the future if they are part of the geometry as specified in this **control_mesh_remove_keep_geometry** command.

6.232 control_mesh_remove_really *index switch*

If *switch* is set to **-yes** elements removed by the **control_mesh_remove** command are really removed. If *switch* is set to **-no** elements removed by the **control_mesh_remove** command are not really removed; they are made inactive instead, and will become active again at the moment that they are no longer being removed by the **control_mesh_remove** command.

6.233 control_mesh_remove_really_activate_all *index switch*

See **control_mesh_remove_really_activate_factor**.

6.234 control_mesh_remove_really_activate_factor *index factor*

When an element becomes active again, after being removed before, we need to decide what the stresses and pore pressures are in nodes of the activated element.

For nodes of the element which were connected to already active elements nothing extra is done.
For nodes of the element which were not connected to already active elements, the average value of the stresses and pore pressures from already active nodes (connected to already active elements) are taken. However, with this *factor*, you can specify to which part the stresses and pore pressures of already nodes will actually be used. Set *factor* to 0 if you want to reactivate the nodal stresses and pore pressures with 0. Set *factor* to 1 if you want to reactivate the nodal stresses and pore pressures completely with the stresses and pore pressures from already active neighbour nodes. Or set a *factor* between 0 and 1 if you do something in between.

As an extra option you can set the *switch* in **control_mesh_remove_really_activate_all** to **-yes**. Then the stresses and pore pressures in ALL nodes of the activated element will be reactivated using the *factor* (so not only the nodes which were not active before).

Default, if **control_mesh_remove_really_activate_factor** is not specified, the *factor* is set to 1.

6.235 control_mesh_renumber *index lowest_element lowest_node*

The element numbers are made strictly sequential starting from *lowest_element* and the node numbers are made strictly sequential starting from *lowest_node*. Beware using **control_renumber** in combination with, for example, node numbers in printing of **node_dof** records; use **post_point** records instead.

6.236 control_mesh_renumber_element_geometry_offset *index offset*

While renumbering elements the element geometry number will be offset with *offset*.

6.237 control_mesh_renumber_element_group_offset *index offset*

While renumbering elements the element group number will be offset with *offset*.

6.238 control_mesh_rotate *index n*

After rotation n is the number of elements in rotational direction for a rotation over 360 degrees. After rotation the old y direction becomes the new z direction. The following data is transferred in the rotation process: **element**, **element_group**, **node** and **node_dof**. A 2D **-tria3** element becomes a 3D **-prism6** element and a 2D **-quad4** element becomes

a 3D **-hex8** element; other 2D elements can presently not be rotated. All data that is not valid in 3D, like for example a 2D line etc, will be deleted in the rotation process.

This **control_mesh_rotate** is convenient when the first part of calculation is axisymmetric, for example loading a pile vertically in a soil, and the second part of the calculation is 3D, for example loading the top of the pile in some horizontal direction. Then first an axi-symmetric calculation can be performed, and the results can be used to start a 3D calculation.

If a **-quad4** elements has a side on the y-axis in the 2D mesh, the element is rotated to a **-prism6** element; the **-quad4** element should have the side with local node numbers 0 and 1 on the y-axis, which is the case if you generated the elements with a **control_mesh_macro** You should not use other elements with a side on the y-axis when rotating the mesh.

This **control_mesh_rotate** deletes all data, except **element**, **element_group**, **node**, **node_dof**, **element_interface_strain** and **element_interface_stress** will be rotated to 3D. Furthermore, **control_input** will available afterwards, so that all 3d data can be set in an extra input file, which is read after the mesh rotation.

If you use any history variables in the model, these should be scalars (and thus not vectors or matrices); otherwise rotation will not go ok for the history variables.

6.239 control_mesh_rotate_angle *index angle*

With *angle* you can specify an angle in degrees up to which the mesh rotation should be done for the **control_mesh_rotate** with the same index. Typically you could use 90 degrees or 180 degrees for *angle*. Default, if this **control_mesh_rotate_angle** is not specified, *angle* will be set to 360.

6.240 control_mesh_split *index switch*

If *switch* is set to **-yes** then each **-quad4** element is split into four **-tria3** elements and each **-hex8** element is split into twelve **-tet4** elements. Further, each **-quad9** element is split into four **-tria6** elements and each **-hex27** element is split into six **-tet10** elements. Further, each **-tria6** element is split into four **-tria3** elements.

See the rules for old and new at **control_mesh_refine_globally**. See also **control_mesh_split_element_to** and **control_mesh_split_only**.

Splitting a 3D mesh will only work correctly on certain regular grids; you need to check the splitted mesh.

6.241 control_mesh_split_element_from *index name*

Split only elements with the specified *name*.

6.242 control_mesh_split_element_to *index name*

If you are splitting **-hex8** elements, then you can set **name** either to **-tet4** or **-prism6**. Default, if **control_mesh_split_element_to** is not specified, **-tet4** is used.

If you are splitting **-hex27** elements, then you can set **name** either to **-tet10** or **-prism18**. Default, if **control_mesh_split_element_to** is not specified, **-tet10** is used.

6.243 control_mesh_split_only *index geometry_ entity geometry_ entity_ index*

If this record is used, the corresponding **control_mesh_split** record will only be applied on elements which have at least one node on the geometry specified by *index geometry_ entity_ name geometry_ entity_ index*.

6.244 control_mesh_switch index *dir0 dir1*

With this option you can switch x, y and z values for all nodal coordinates. Each of *dir0* and *dir1* can be set to either **-x**, **-y** or **-z**. Then the specified coordinates *dir0* and *dir1* will be switched for all nodes.

6.245 control_mesh_truss_distribute_mpc *index switch*

If *switch* is set to **-yes** the nodes of truss elements are fixed with multi point constraints (mpc's) to the isoparametric elements through which the trusses run. This typically can be used for modeling reinforcement bars in a concrete embedment, where the bars follow the displacements (and temperatures if present) of the concrete.

If **control_mesh_truss_distribute_mpc_exact** *switch* is set to **-yes**, truss elements are redistributed (that is, more small truss elements will be made), in such way that each truss gets a node when it enters an isoparametric element or ends internally in an isoparametric element. This **control_mesh_truss_distribute_mpc_exact** comes handy when you initially have large trusses relative to the isoparametric elements.

Truss below a minimum length as specified in **control_mesh_truss_distribute_mpc_exact_minimal_leng**
will not be generated; default the minimal length *tolerance* is set to some small value. With **control_mesh_truss_distribute_mpc_exact_minimal_length_connect** you can determine if the generated trusses jumping a space below the minimal length will be connected or will be not-connected (loose); set the *switch* to **-yes** if you want the truss to be

connected in such case. Please realise that the connection is ensured only for the trusses generated from 1 old truss; connection is not ensured for trusses generated from different old truss elements.

This **control_mesh_truss_distribute_mpc** option is done for truss groups as specified in **control_mesh_truss_distribute_mpc_element_group_truss** or in **control_mesh_truss_distribute_mpc_geometry_truss**.
Only one of **control_mesh_truss_distribute_mpc_element_group_truss** and **control_mesh_truss_distribute_mpc_geometry_truss** can be specified.
If none of **control_mesh_truss_distribute_mpc_element_group_truss** and **control_mesh_truss_distribute_mpc_geometry_truss** is specified the distribution will be done for all trusses.

Default Tochnog will look for all isoparametric elements how to distribute the trusses. To save computer time you can restrict the geometry or element group of the isoparametric elements where Tochnog will look with **control_mesh_truss_distribute_mpc_element_group_isoparamet**
end **control_mesh_truss_distribute_mpc_geometry_isoparametric**.

Please notice that if you are using geometries in **control_mesh_truss_distribute_mpc_geometry_truss** or
control_mesh_truss_distribute_mpc_geometry_isoparametric these can in fact be a **geometry_set**.

In case you specify both of the above ***_truss** and ***_isoparametric**, the number of specified values (groups or geometries) should be the same. Then the first value specified for the truss will be combined with the first value specified for the isoparametric elements, the second value specified for the truss will be combined with the second value specified for the isoparametric elements, etc. For example, if you specify two groups for **control_mesh_truss_distribute_mpc_element_group_truss** and
two groups for **control_mesh_truss_distribute_mpc_element_group_isoparametric** the first specified truss group will be distributed over the first specified isoparametric group, and the second specified truss group will be distributed over the first specified isoparametric group.

If *switch* in **control_mesh_truss_distribute_mpc_air** is set to **-yes**, trusses will also be generated in the center of the truss is not inside an isoparametric element. If *switch* in **control_mesh_truss_distribute_mpc_air** is set to **-no**, trusses will not be generated in the center of the truss is not inside an isoparametric element. Default *switch* is **-yes**.

A typical input file looks like:

control_mesh_truss_distribute_mpc 10 -yes
control_mesh_truss_distribute_mpc_exact 10 -yes
control_mesh_truss_distribute_mpc_geometry 10 -element_geometry
123

Only one **control_mesh_truss_distribute_mpc** record is allowed in the input file. As a special option you can also generate **truss_beam** elements in stead of **truss** elements.

6.246 control_mesh_truss_distribute_mpc_air *index switch*

See **control_mesh_truss_distribute_mpc**.

6.247 control_mesh_truss_distribute_mpc_dof *dof_0 dof_1 ...*

The *dof_0 dof_1 ...* specify the dof's that should be set equal, e.g. **-velx**, **-vely** etc.

6.248 control_mesh_truss_distribute_mpc_element_group_truss *index element_group_0 element_group_1 ...*

See **control_mesh_truss_distribute_mpc**.

6.249 control_mesh_truss_distribute_mpc_element_group_isoparametric *index element_group_0 element_group_1 ...*

See **control_mesh_truss_distribute_mpc**.

6.250 control_mesh_truss_distribute_mpc_exact *index switch*

See **control_mesh_truss_distribute_mpc**.

6.251 control_mesh_truss_distribute_mpc_exact_minimal_length *index tolerance*

See **control_mesh_truss_distribute_mpc**.

6.252 control_mesh_truss_distribute_mpc_exact_minimal_length_connect *index switch*

See **control_mesh_truss_distribute_mpc**.

6.253 control_mesh_truss_distribute_mpc_geometry_truss *index geometry_entity_name_0 geometry_entity_index_0 geometry_entity_name_1 geometry_entity_index_1 ...*

See **control_mesh_truss_distribute_mpc**.

6.254 control_mesh_truss_distribute_mpc_geometry_isoparametric *index geometry_entity_name_0 geometry_entity_index_0 geometry_entity_name_1 geometry_entity_index_1 ...*

See **control_mesh_truss_distribute_mpc**.

6.255 control_mpc_apply *index switch*

If *switch* is set to **-yes** then mpc conditions will be used for the control index. If *switch* is set to **-no** then mpc conditions will not be used for the control index. Default, if **control_mpc_apply** is not specified, *switch* is set to **-yes**.

6.256 control_mpc_element_group *index switch*

If *switch* is set to **-yes** the **mpc_element_group** records will be evaluated at all timesteps for the current control index. If *switch* is set to **-no** the **mpc_element_group** records will only be evaluated when the mesh has been changed. This option can only be used if there are only mpc's coming from this option, and not from other mpc data.

Default, if **control_mpc_element_group** is not specified, the *switch* is set to **-no**.

6.257 control_plasti_apply *index switch*

If *switch* is set to **-no**, any plasticity data in the input file will be ignored. This is done for timestep records with the same index.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with plasticity data. See also **plasti_apply**.

6.258 control_post *index switch*

If *switch* is set to **-yes** all post processing commands are evaluated for index *index*. This enforces evaluation of post processing command even if no timesteps are performed or so.

6.259 control_post_apply *index switch*

Setting *switch* to **-no** prevents post processing commands to be evaluated for control commands with the same index. Postprocessing commands have **post** in the name (only the **post_node_rhside_ratio** will be evaluated always, independent of **control_post_apply**).

6.260 control_post_element_force *index switch*

You can save CPU time in timesteps with the same index by setting *switch* to **-no**, which prevents **post_element_force** commands to be evaluated in timesteps with the same index.

6.261 control_print *index data_item_name_0 data_item_name_1 ...*

The is the normal printing command. A **control_print** record causes the data items with name *data_item_name_0*, etc. to be printed. Example

control_print 1 -node -node_dof

See also: **print_filter**.

6.262 control_print_beam_force_moment *index switch*

This option prints the beam forces and moments through a set of beams starting at place x_{start}, y_{start}, z_{start} and ending at x_{end}, y_{end}, z_{end} as specified in **control_print_beam_force_moment_coord**
In 2D only x and y coordinates need to be specified. The forces and moments are printed in the file beam_force_moment.*index*. In fact, if the element contains a truss (either a truss element or a truss-beam element), the truss force will be used for the axial force. The first column in the file is the distance from the start point. The following columns contain in the local beam axes force_x_first_node force_y_first_node force_z_first_node moment_x_first_node moment_y_first_node moment_z_first_node force_x_second_node force_y_second_node force_z_second_node moment_x_second_node moment_y_second_node moment_z_second_node . The *switch* needs to be set to **-separate_index** or **-separate_sequential**.
See also **control_print_beam_force_moment_switch**.

6.263 control_print_beam_force_moment_coordinates *index* x_{start} y_{start} z_{start} x_{end} y_{end} z_{end}

See **control_print_beam_force_moment**.

6.264 control_print_beam_force_moment_switch *index switch*

If you set *switch* to **-yes**, the definition of the beam forces and moments is changed (multiplied with a -1). So you can get exactly the definition that you want.

6.265 control_print_database *index switch*

If *switch* is set to **-separate_index**, the complete database is be printed. See the example below

control_print_database 6 -separate_index

This database contains the complete status of the calculation. For example if *index* is 6, the data base is printed in the file input_file_name6.dbs. As a special option, you can print databases with sequential numbers by setting *switch* to **-separate_sequential**.

If tochnog exists with an error, for example due to non-convergence, a complete database is printed in **input_file_name_error.dbs**. Otherwise, a complete database will be printed at the end of the calculation.

6.266 control_print_database_method *index method*

If *method* is set to **-all** then all database base records will be printed in the database. If *method* is set to **-size_tot** then the size of all database base records will be printed in the database. If *method* is set to **-size_tot_large** then the size of database base records larger then 1 Mb will be printed in the database.

When using **-size_tot** or **-size_tot_large** also the size of the system matrix is printed in the database.

Default, if **control_print_database_method** is not specified, the *method* is set to **-all**.

6.267 control_print_data_versus_data *index data_item_name_0 index_0 number_0 data_item_name_1 index_1 number_1 ...*

This option prints columns of data for each time step. Print in the first column the *number_0* value of *data_item_name_0* with index *index_0*. Similar in the second column for *data_item_name_1 index_1 number_1*. Etc. (for all values). All results will be printed in the file *problemname*.dvd.

Typically, the data item names can be **-node_dof** such that dof's can be printed against each other in time. If the data item names are **-node_dof**, then *number_0* and *number_1*, etc. can be names of **dof_label** (eg **-velx**).

Also typically, the data item names can be **-node_dof_calcul** such that post calculation results can be printed against each other in time. If the data item names are **-node_dof_calcul** or **post_point_dof_calcul** or so, then *number_0* and *number_1*, etc. can be names of **post_calcul_label** (eg **-aept**).

Otherwise, for example, if *number_0* is 3 then the fourth value of *data_item_name_0* is printed.

Example:

control_print_data_versus_data 0 -node_dof 2 -temp
-node_dof 2 -sigxx -node_dof 2 -sigxx

Another example:

post_point 0 0.0 1.0
post_calcul -materi_stress -average -materi_stress -size_dev

control_print_data_versus_data 20
-time_current 0 0
-post_point_dof_calcul 0 0 -post_point_dof_calcul 0 1

In the last example, the **-post_point_dof_calcul 0 0** stands for 'the **post_point_dof_record** with index 0 and the 0'th number which is the first value so the average of the stresses'.

For data that is not present Tochnog will print a 0.

See also: **control_print**.

6.268 control_print_data_versus_data_factor *index factor_0 factor_1 ...*

Optionally specify a multiplication factor for each of the data item of **control_print_data_versus_data**. This can, by example, be convenient if you want to change to sign or so. If you specify this record, a factor should be given for each data item.

6.269 control_print_dof *index switch*

Results for the primary dof's will be printed, including also the coordinates at which the results hold. Also results for **node_dof_calcul** records will be printed. The printed files will contain lines like x, y, z and *dof* (where *dof* is the dof, e.g. **temp**). In 1D only x will be printed, etc.

As extra also the coordinates themselves are printed in files.

If *switch* is set to **-separate_index** the filenames will be like *dof.index*.

If *switch* is set to **-separate_sequential** then the filenames will be sequentially numbered, like *dof.0*, *dof.1*, etc.

6.270 control_print_dof_id *index switch*

This record works in combination with the **control_print_dof** record. If *switch* is set to **-yes** also the node number ('identity') is written. So for example in 3D the file will contain lines with x, y, z, *dof* and node number.

Default, if **control_print_dof_id** is not specified, *switch* is set to **-yes**.

6.271 control_print_dof_smooth_dof *index dof_0 dof_1 ...*

This option allows you to smooth results for **control_print_dof**. With *dof_0 dof_1 ...* you specify the dof's to be smoothed. As a special option you can specify **-all** so that all dof's will be smoothed.

The smoothing is done a number of times, with increasing smooth results. You can specify this number of times with the optional **control_print_dof_smooth_n**; if you don't specify this optional number of smoothings it is done 10 times.

6.272 control_print_dof_smooth_n *index number_of_smoothings*

See **control_print_dof_smooth_dof**.

6.273 control_print_dof_line *index switch*

This **control_print_dof_line** record together with
the **control_print_dof_line_coordinates** and
control_print_dof_line_n records print values of the **node_dof** records and **node_dof_calcul** records along a line in space to files.

The start point of the first line segment is given by *x_0 y_0 z_0*, and the end point of the first line segment is given by *x_1 y_1 z_1*, the start point of the second line segment is given by *x_1 y_1 z_1*, and the end point of the second line segment is given by *x_2 y_2 z_2*, etc.

In 1D only the x-coordinates of the start point and end point need to be specified, etc. The parameter *n* determines how many points will be printed along the line.

The printed files will contain lines like *x*, *y*, *z* and *dof* (where *dof* is the dof, e.g. **temp**). In 1D only *x* will be printed, etc.

If *switch* is set to **-separate_index** the filenames will be like *dof.index*.

If *switch* is set to **-separate_sequential** then the filenames will be sequentially numbered, like *dof.0*, *dof.1*, etc.

In **control_print_dof_line_method** you can set *node_type* either to **-node** or **-node_start_refined**. Then the coordinates in the printed file will contain either the values of **node** or the values of **node_start_refined**. In case you use an updated lagrange formulation where the mesh nodes follow the material the values of **node** and **node_start_refined** will differ; in case you do a geometrically linear analysis the values will not differ. Default *node_type* is set to **-node_start_refined**.

With **control_print_dof_line_element_group** you can set a specific element groups for which the printing should be done.

With **control_print_dof_line_eps_iso** you set the tolerance with which a point of the specified line is accepted to be part of an element. The default value is 1.e-3. You can increase the default value if if the mesh is not exactly adjusted to the line.

6.274 control_print_dof_line_coordinates *index x_0 y_0 z_0 x_1 y_1 z_1 x_2 y_2 z_2 ...*

See **control_print_dof_line**.

6.275 control_print_dof_line_element_group *index element_group_0 element_group_1 ...*

See **control_print_dof_line**.

6.276 control_print_dof_line_eps_iso *index eps_iso*

See **control_print_dof_line**.

6.277 control_print_dof_line_method *index node_type*

See **control_print_dof_line**.

6.278 control_print_dof_line_move *index switch*

If *switch* is set to **-yes** the **control_print_dof_line_coordinates** with the same index will be moved along with the velocity field. Thus, with this option you can follow with a **control_print_dof_line** the dof's of material particles.

Please realise that this option should only be used if **materi_velocity** is initialised in the initialisation part.

6.279 control_print_dof_line_n *index n*

See **control_print_dof_line**.

6.280 control_print_dof_line_time *index switch*

If *switch* is set to **-yes** the first line of each file will specify the **time_current** at which the file is written (in gnuplot comment format).

6.281 control_print_dof_point *index switch*

This **control_print_dof_point** record prints values of the **node_dof** records and **node_dof_calcul** records in a point in space to files.

The point is given by x y z,

In 1D only the x-coordinates of the start point and end point need to be specified, etc.

The printed files will contain lines like x, y, z and *dof* (where *dof* is the dof, e.g. **temp**). In 1D only x will be printed, etc.

If *switch* is set to **-separate_index** the filenames will be like *dof.index*.

If *switch* is set to **-separate_sequential** then the filenames will be sequentially numbered, like *dof.0*, *dof.1*, etc.

6.282 control_print_dof_point_coordinates *index x y z*

See **control_print_dof_line**.

6.283 control_print_dof_point_time *index switch*

If *switch* is set to **-yes** the first line of each file will specify the **time_current** at which the file is written (in gnuplot comment format).

6.284 control_print_dof_rhside *index switch*

If *switch* is set to **-yes** then results for right-hand-side for the primary dof's will be printed, including also the coordinates at which the results hold.

For example, for the file temp_rhside.*index* will contain lines containing x, y, z and right-hand-side of **-temp** (that is, heat flux). In 1D only x will be printed, etc.

6.285 control_print_element *index data_item_name*

With this option you can print values from element data versus coordinates. Select either **-element_truss_force** or **-element_beam_force_moment** for *data_item_name*.

The normal truss forces of the **-element_truss_force** records will be printed in the file **element_truss_force_n**.*index*. This file will contain lines containing x, y, z and normal truss force. In 1D only x will be printed, etc.

The lateral beam shear forces of the **-element_beam_force_moment** records will be printed in the file **element_beam_force_moment_q**.*index*. This file will contain lines containing x, y, z and lateral beam shear force. In 1D only x will be printed, etc. The shear force will always be calculated as an absolute value.

The beam moments of the **-element_beam_force_moment** records will be printed in the file **element_beam_force_moment_m**.*index*. This file will contain lines containing x, y, z and beam moment. In 1D only x will be printed, etc.

How the data is printed depends on how *method* is set in **control_print_element_method**. If method is set to **-middle** then only the average value of the element data and the coordinate of the middle of the element is printed for each element. If method is set to **-node** then the two nodal values and nodal coordinates are printed for each element.

6.286 control_print_element_method *index method*

Set *method* to **-middle** or *-node*. If **control_print_element_method** is not specified then **-middle** is used. See also **control_print_element**.

6.287 control_print_filter *index print_filter_ index_ 0 print_filter_ index_ 1 ...*

See **print_filter**.

6.288 control_print_frd *index switch*

Activate printing of results in Calculix output format **frd**. Only results for 2D and 3D isoparametric elements are printed presently. For structural elements (trusses, beams, ...) nothing is printed.

For example if the input file name is **excavation.dat** and *index* is 100 and *switch* is set to **-separate_index** then results are printed in the file is **excavation_100.frd**.

For example if the input file name is **excavation.dat** and *switch* is set to **-separate_sequential** then results are printed in the files is **excavation_0.frd**, **excavation1.frd**, etc.

For example if the input file name is **excavation.dat** and *switch* is set to **-yes_sequential** then results are printed in the files is **excavation.frd**.

The frd files can be plotted by the **prepomax** pre- and postprocessor, see **http://lace.fs.uni-mb.si/wordpress/borovinsek/?page_id=41**. Since prepomax presently cannot plot 2d elements, Tochnog extrudes 2d calculations to a fictive thickness of 1 when printing the frd files.

You also can use the CGX postprocessor of calculix itself , see **http://www.bconverged.com/download.php**.

Since Freecad and Prepomax like specific names of results we write the following names:

- **DISP** for **materi_displacement** or **materi_velocity_integrated**
- **STRESS** for **materi_stress**
- **TOSTRAIN** for **materi_strain_total**
- **NDTEMP** for **condif_temperature**
- **PEEQ** for **post_calcul -groundflow_pressure -total_pressure** (if **print_frd_freecad** is **-yes**)

For other results the Tochnog names are used, up to the allowed 8 characters in frd files.

Freecad presently only reads frd files which contain displacements and stresses and total strains. Thus, if these are not initialised in your tochnog input file and if **print_frd_freecad** is **-yes** then tochnog will not write the frd file for freecad.

See also **control_print_frd_prepomax**.

6.289 control_print_frd_freecad *index switch*

If *switch* is set to **-yes** the frd files are written specifically suited for the **freecad** program. This is done for the **control_print_frd** command with the same index. If *switch* is set to **-no** the frd files are not written specifically suited for the **freecad** program. See also **print_frd_freecad**.

6.290 control_print_frd_prepomax *index switch*

If *switch* is set to **-yes** the frd files are written specifically suited for the **prepomax** program. This is done for the **control_print_frd** command with the same index. If *switch* is set to **-no** the frd files are not written specifically suited for the **prepomax** program. See also **print_frd_prepomax**.

6.291 control_print_frequency_timeinterval *index timeinterval*

This **control_print_frequency_timeinterval** record causes **control_print_*** other than **control_print**, **control_print_history** and **control_print_data_versus_data** to be done each time after a time interval has passed, and always also at the end of the time increment. This **control_print_frequency_timeinterval** record should only be used in combination with **control_timestep** (with the same index). All **control_print_*** printing will be influenced except **control_print**, **control_print_history** and **control_print_data_versus_data** printing.

Example:

```
control_timestep 10 0.04 0.41
control_print_gid 10 -yes
control_print_frequency_timeinterval 10 0.15
```

In this example gid data is written at times 0.16, 0.32, 0.41

6.292 control_print_frequency_timestep *index timestep*

This **control_print_frequency_timestep** record causes **control_print_*** other than **control_print**, **control_print_history** and **control_print_data_versus_data** to be done each time after a number of time timesteps has passed, and always also at the end of the time increment. This **control_print_frequency_interval** record should only be used in combination with **control_timestep** (with the same index). All **control_print_*** printing will be influenced except **control_print**, **control_print_history** and **control_print_data_versus_data** printing.

Example:

control_timestep 10 0.04 0.41
control_print_gid 10 -yes
control_print_frequency_timestep 10 5

In this example gid data is written at times 0.20, 0.40, 0.41

6.293 control_print_gid *index switch*

Print the mesh and the dof's in a file which can be plotted with the GID pre-post processor if *switch* is set to **-yes**. For example, if the input file is called turbine.dat then the mesh is written in the turbine_flavia.msh file. The results are written in the turbine_flavia.res.

The mesh and results for dof's will always be written at the end of the calculation.

Since GID gets confused when the number of elements changes between several **control_print_gid** records, Tochnog will only print GID results for the last mesh used.

Coordinates for nodes will be written in the original configuration. If **materi_velocity** is initialized, also a vector **mesh_deform** will be written for GID which contains the deformation between the original mesh configuration and the deformed mesh configuration. Use the **deform mesh** menu in GID, to draw the deformed configuration by applying the vector **mesh_deform** with a factor 1. If **materi_displacement** is initialised the **mesh_deform** contains the nodal displacements. If **materi_velocity_integrated** is initialised the **mesh_deform** contains the integrated nodal velocities. Else **mesh_deform** contains the current value of **node** minus the start value of the nodal coordinates.

For 2D interface elements which have strains and stresses, the normal stress **interface_sign**, the tangential shear stress **interface_sigt**, the normal strain **interface_epsn** and the tangential shear strain **interface_epst**, are written to the GID results file.

The following data is written also to the gid file and can serve as a help to check the validity of your input file. This data is only available after one or more time steps are taken.

- **condif_bounda_dof**, boundary conditions on temperature.
- **condif_heat_edge_normal**, distributed prescribed heat flow on an edge.
- **condif_convection_edge_normal**, distributed convection heat flow on an edge.
- **condif_radiation_edge_normal**, distributed convection heat flow on an edge.
- **groundflow_bounda_dof**, boundary conditions on groundflow hydraulic pressure head.
- **materi_bounda_force**, discrete forces on nodes.
- **materi_force_edge**, distributed forces on nodes.
- **materi_force_edge_normal**, distributed normal forces on nodes.
- **materi_force_edge_projected**, distributed projected forces on nodes.
- **materi_force_edge_water**, distributed water forces on nodes.
- **materi_force_volume**, distributed volume forces on nodes.
- **materi_force_gravity**, distributed gravity forces on nodes.
- **materi_bounda_dof**, boundary conditions on materi velocity on nodes.
- **materi_support_edge_normal**, distributed support forces on nodes.
- **materi_rhside_free**, unbalance forces for **materi_velocity** (for free displacements) on nodex.
- **materi_rhside_fixed**, reaction forces for **materi_velocity** (for fixed displacements) on nodex.
- **element_materi_force_edge**, norm of distributed forces on elements.
- **element_materi_force_edge_normal**, norm of distributed normal forces on an edge on elements.
- **element_materi_force_edge_water**, norm of distributed water forces on an edge on elements.
- **plasti_reduction_factor**, reduction factor for plasticity parameters from **group_materi_plasti_eleme** etc.

If you have specified **print_node_geometry_present** then the gid files will contain **geometry_...** values which are 1 on nodes present in a geometry.

The **materi_bounda_dof** you can view in gid with **View results**, **Display vectors**, **materi bounda dof**, **All**. The other data you can view in GID for example with **View results**, **Display vectors**, **force edge normal**, | **force edge normal** | . Above with 'distributed' we mean that results are per unit area.

For isoparametric elements the element group number will be printed.

For all **post_point** a point will be plotted in the gid files, with element group number 1000 + the index of the post point.

As a special option, you can set *switch* to **-separate_index**. Then the mesh and results will be printed in separate files for GID, numbered with *index*. The option comes handy when the mesh changes during the calculation; GID cannot plot that if the mesh and results are in the same file.

As a further special option, you can set *switch* to **-separate_sequential**. Then the mesh and results will be printed in separate files for GID, number sequentially.

6.294 control_print_gid_batch *index switch*

If *switch* is set to **-yes** Tochnog calls GiD as batch program to generate some typical png files of results. This works i.c.w. a **control_print_gid** with the same index.

The following files are generated: mesh_*index*.png, element_group_*index*.png, element_group_*index*.png, materi_velocity_integrated_veliy_*index*.png, materi_stress_sigyy_*index*.png and groundflow_pressure_total_pressure_to_pres_*index*.png.

For this GiD needs to be installed on your computer. You also need to take care that GiD can be found, so you need to adjust your PATH environment symbol.

6.295 control_print_gid_beam_vectors *index switch*

If *switch* is set to **-yes**, force and moment vectors will be plotted for **-beam** and **-truss_beam** elements. The force and moment vectors will be plotted perpendicular to the length direction and a user specified plane-normal vector, see **control_print_gid_beam_vectors_normal**. The length of the plotted vectors measures the size of the forces and moment.

The vectors will be plotted as element result, so not as nodally averaged result.

Attention: this **control_print_gid_beam_vectors** is a special plotting option, to get each beam force and moment result as vector plot, with the possibility to influence the direction of the vectors with **control_print_gid_beam_vectors_normal**. Default Tochnog plots the beam result already as scalar values for each beam element.

6.296 control_print_gid_beam_vectors_normal *index normal_x normal_y normal_z*

This record gives you the possibility to influence the plane in which the moment vectors generated by the **control_print_gid_beam_vectors** will be plotted. In fact this **control_print_gid_beam_vectors_normal** specifies the normal to the plotting plane. If this **control_print_gid_beam_vectors_normal** is not specified then **0 0 1** is taken

as normal.

6.297 control_print_gid_contact_spring2 *index number_of_nodes*

Set *number_of_nodes* to 2 if you want to draw **contact_spring2** with two nodes, and to 1 if you want to draw **contact_spring2** with one node. Default, if **control_print_gid_contact_spring2** is not specified, then 1 node is used.

6.298 control_print_gid_coord *index switch*

If *switch* is set to **-yes** the coordinates of nodes is plotted in gid. If *switch* is set to **-no** the coordinates of nodes is not plotted in gid. Default *switch* is set to **-yes**.

6.299 control_print_gid_dof *index initialisation_name_0 initialisation_name_1 ...*

When you specify this record only the solution fields *initialisation_name_0*, *initialisation_name_1* etc will be printed to the gid files. So the files become smaller in size. This is especially convenient for very large calculations. The names *initialisation_name_0*, *initialisation_name_1* are names from the initialisation part like **-condif_temperature**, **-materi_velocity**, **-materi_stress** etc. In case you do not want any field to be printed in the gid file use **control_print_gid_dof** *index* **-none**.

See also **control_print_gid_other**.

6.300 control_print_gid_dof_calcul *index calcul_0 calcul_1 ...*

When you specify this record only the post fields *calcul_0*, *calcul_1* etc will be printed to the gid files. So the files become smaller in size. This is especially convenient for very large calculations. See **post_calcul_label** for the allowed names of *calcul_0*, *calcul_1* etc. In case you do not want any post field to be printed in the gid file use **control_print_gid_dof_calcul** *index* **-none**.

See also **control_print_gid_other**.

6.301 control_print_gid_element_group *index element_group_0 element_group_1 ...*

Select specific element groups for the gid files. If this record is not specified all element groups will be used.

6.302 control_print_gid_element_mpc *index switch*

If *switch* is set to **-yes** also elements which have mpc'd nodes will be printed in the gid files. If *switch* is set to **-no** aelements which have mpc'd nodes will not be printed in the gid files. Default, if **control_print_gid_element_mpc** is not specified, *switch* is set to **-yes**.

6.303 control_print_gid_empty *index switch*

If *switch* is set to **-yes**, empty elements will be show in GID plots. If *switch* is set to **-no**, empty elements will not be shown. Default *switch* is set to **-no**.

See also **element_empty**.

6.304 control_print_gid_group *index switch*

If *switch* is set to **-yes** the element groups are plotted in gid as result field; in gid you can do a **contour_fill** to visualize this result field. If *switch* is set to **-no** the element groups are not plotted in gid as result. Default *switch* is set to **-yes**.

6.305 control_print_gid_mesh_activate_gravity *index switch*

See also **mesh_activate_gravity_time**.

6.306 control_print_gid_method *index method*

If *method* is set to **-node**, results will be written for global nodes to the gid files. Gid will interpolate between the nodes, to fill contour plots, etc. Hence, you get continuous plots fields.

If *method* is set to **-element**, results will be written element-by-element to the gid files, so that any discontinuity in fields can be seen. The results will be written using the integration point values.

If *method* is set to **-element_average**, results will be written element-by-element to the gid files, so that any discontinuity in fields can be seen. The results will be written using the average of the integration point values.

If *method* is set to **-node_elemen**, results will be written with continuous fields to the gid files, but at group jumps discontinuous fields are allowed.

For **-element** and **-node_elemen** gid cannot plot some results like 'contour fill' for all elements if there are several type of elements (quad4, tria3, ...) in the mesh. You can only

select on specific element type for the plot.

If this **control_print_gid_method** record is not specified then *method* is set to **-node**. If **global_element_dof** is set to **-no** the element-by-element stresses are not available, so then **-element_average** and **-node_elemen** should not be used.

6.307 control_print_gid_node_method *index method*

If *method* is set to **-node**, these coordinates are written. If *method* is set to **-node_start_refined**, these coordinates are written. If *method* is set to **-node_deformed_mesh**, these coordinates are written. Default *method* is **-node_start_refined**.

6.308 control_print_gid_other *index switch*

If *switch* is set to **-yes** also other things like boundary conditions, mesh deformation etc. are printed in the gid files. If *switch* is set to **-no** these other things are not printed in the gid files. Default *switch* is set to **-yes**.

6.309 control_print_gid_save_difference *index switch*

If *switch* is set to **-yes** then data differences relative to a saved status will be plotted. See **control_data_save**.

6.310 control_print_gid_safety_slip_critical *index switch*

If *switch* is set to **-yes**, then for a safety analysis with **control_safety_slip** only the critical slip surface will be plotted. Default, if *switch* is not set, all evaluated slip surfaces will be plotted. The critical surface is either determined over all safety surfaces, or otherwise in case sets are specified a critical surface is determined for each set.

Furthermore, always the normal stresses and shear stresses on the slip surfaces will be plotted.

6.311 control_print_gid_smooth_dof *index dof_0 dof_1 ...*

This option allows you to smooth results in gid files. With *dof_0 dof_1 ...* you specify the dof's to be smoothed. As a special option you can specify **-all** so that all dof's will be smoothed.

The smoothing is done a number of times, with increasing smooth results. You can specify this number of times with the optional **control_print_gid_smooth_n**; if you don't

specify this optional number of smoothings it is done 10 times.

6.312 control_print_gid_smooth_n *index number_of_smoothings*

See **control_print_gid_smooth_dof**.

6.313 control_print_gid_spring2 *index number_of_nodes*

Set *number_of_nodes* to 2 if you want to draw **spring2** with two nodes, and to 1 if you want to draw **spring2** with one node. Default, if **control_print_gid_spring2** is not specified, then **print_gid_spring2** is used.

6.314 control_print_gid_truss_vector *index switch*

Same as **control_print_gid_beam_vector**, however now for the normal force in **-truss** and **-truss_beam** elements.

Attention: this **control_print_gid_truss_vector** is a special plotting option, to get the truss force result as vector plot, with the possibility to influence the direction of the vectors with **control_print_gid_truss_vector_normal**. Default Tochnog plots the truss force result already as scalar values for each truss element.

6.315 control_print_gid_truss_vector_normal *index normal_x normal_y normal_z*

Same as **control_print_gid_beam_vectors_normal**, however now for the normal force in **-truss** and **-truss_beam** elements.

6.316 control_print_gmsh *index switch*

We discuss as an example the printed file naming convention if the input file name is **excavation.dat**

If *switch* is set to **-yes** the results are printed into the **excavation.msh** file. In case the mesh (elements and nodes) have not been printed before in this file, the file will be emptied, and the mesh will be printed. This will also be done if the mesh is changed.

If *index* is 100 and *switch* is set to **-separate_index** then the mesh and results are printed in the file is **excavation_100.msh**.

If *switch* is set to **-separate_sequential** then the mesh and results are printed in the files **excavation_0.msh**, **excavation_1.msh**, etc. So each time that a **control_print_gmsh** with **-separate_sequential** is evaluated a new file is generated with number increased by one.

A dummy point element is put in each node in the gmsh file. Gmsh needs that for plotting vector fields in the nodes. The dummy element group 1234 is used for these dummy point elements. You can suppress these dummy point elements by setting **control_print_gmsh_dummy** to **-no**.

All element data starts with **element_** in the plots. All node data starts with **node_** in the plots.

Scalar data with more then one value is given the extension **_0**, **_1** etc. for each of the values. For example the record **node** (which contains coordinates in each space direction) is plotted as scalar **node_0**, **node_1** and **node_2** which contain the x-coordinate, y-coordinate and z-coordinate respectively. For example the record **group_groundflow_permeability** (which contains permeability in each space direction) is plotted as scalar **group_groundflow_0**, **group_groundflow_1** and **group_groundflow_2** which contain the x-permeability, y-permeability and z-permeability respectively.

For nodes the presence in geometries is plotted as **node_geometry_***. For elements the presence in geometries is plotted as **element_geometry_***.

You can plot this file with the program **gmsh** ; see http://www.geuz.org/gmsh . You can also plot this file with the program **mecway** ; see https://mecway.com/ .

See also **input_gmsh**.

6.317 control_print_gmsh_dummy *index switch*

See **control_print_gmsh**.

Default, if this record is not set and **print_gmsh_dummy** is not specified, *switch* is set **-yes**.

6.318 control_print_gmsh_element_data *index switch*

If you set *switch* to **-yes** data for elements (like element strains, stresses, etc.) is written averaged over the element; this corresponds to **ElementData** in the gmsh format.

If you set *switch* to **-no** this data is written for all element nodes; this corresponds to **ElementNodeData** in the gmsh format.

Default, if this record is not set, *switch* is set **-yes**.

6.319 control_print_gmsh_node_method *index method*

If *method* is set to **-node**, these coordinates are written. If *method* is set to **-node_start_refined**, these coordinates are written. If *method* is set to **-node_deformed_mesh**, these coordinates are written.

6.320 control_print_history *index data_item_name_0 data_item_index_0 number_0 ...*

Print the time history for each of the sets *data_item_name_0 data_item_index_0 number_0 ....*

For example, if **-node_dof** is used, *number_0* is one of the names of **dof_label** (eg **-velx**).

For example, if **-node_dof_calcul** is used, *number_0* is one of the names of **post_calcul_label** (eg **-aept**).

Otherwise, *number_0* should be an integer specifying the number of the value in the record (for instance number 2 means the third value).

The following history is printed in the file node_dof_112_temp.his

control_print_history 0 -node_dof 112 -temp

6.321 control_print_history_factor *index factor_0 factor_1 ...*

Optionally specify a multiplication factor for each of the data item of **control_print_history**. This can, by example, be convenient if you want to change to sign or so. If you specify this record, a factor should be given for each data item.

6.322 control_print_history_relative_time *index tr*

If you specify this record, the time printed in the history files will not be the actual time, but instead the actual time minus the relative time *tr*. This is especially convenent when something happens suddenly after a long time, in which case the time-axis in the history plot would be not clear. Using this relative time the time-axis in the plots will become clear (since the long initial time is not part of the time axis).

6.323 control_print_history_smooth *index smooth_0 smooth_1 ...*

You can smooth history results with this option. Each of *smooth_0smooth_1* etc. represent an integer number for each data value printed with **control_print_history**. By example if *smooth_0* is 10, for the first data value the average of the last 10 values will be printed (as opposed to the current value). You should specify an integer for each of the data values being printed. As a special option you can specify one integer only which then will be used for all data values being printed. The smoothed results will be printed in a separate history file starting with **smooth**.

6.324 control_print_interface_stress *index switch*

2D analysis

This option prints in 2D the interface stresses through a set of interfaces starting at place x_{start}, y_{start} and ending at x_{end}, y_{end} as specified in **control_print_interface_stress_coordinates**. The *switch* needs to be set to **-separate_index** or **-separate_sequential**. The stresses are printed in the file interface_stress.*index*. The first column in the file is the distance from the start point. The following columns contain interface_sign and interface_sigt. A line is written for each node of each interface element. Crossing interfaces are not allowed. From the start point up to the end point the interfaces needs to be connected without gaps.

3D analysis

This option prints in 3D the average interface stresses in the middle of interface elements. The *switch* needs to be set to **-separate_index** or **-separate_sequential**. The interface element middles and average stresses are printed in the file interface_stress.*index*. The first three columns in the file are the coordinates of the middle of the interface element. The following columns contain interface_sign and interface_sigt1 and interface_sigt2. A line is written for each interface element. If you specify **control_print_interface_stress_3d_geometry** then only interfaces elements located on the geometry will be printed. If you don't specify **control_print_interface_stress_3d_geometry** then all interfaces elements will be printed. You can specify the order of printing of the interfaces in the file with *method* in **control_print_interface_stress_3d_order**. If you set *order* to **-x** the interfaces will be ordered according to x-coordinate. If you set *order* to **-y** the interfaces will be ordered according to y-coordinate. If you set *order* to **-z** the interfaces will be ordered according to z-coordinate. If you don't use **control_print_interface_stress_3d_order** the interfaces will be ordered according to element number.

6.325 control_print_interface_stress_2d_coordinates *index* x_{start} y_{start} x_{end} y_{end}

For 2D only. See **control_print_interface_stress**.

6.326 control_print_interface_stress_3d_geometry *index geometry_item_name geometry_item_index*

For 3D only. See **control_print_interface_stress**.

6.327 control_print_interface_stress_3d_order *index order*

For 3D only. See **control_print_interface_stress**.

6.328 control_print_materi_stress_force *index method*

This option prints forces and moments as calculated by **post_calcul_materi_stress_force**. It prints in special purpose ascii files, convenient for further external postprocessing. For example, the name of the file will be **materi_stress_force.100** if the *index* is 100. The files themselves will contain comments explaining the detailed structure of the files.

The *method* can be set either to **-all** if all results should printed in the file (so including the averaged results) or to **-primary** if only the primarily calculated results should be printed in the file (so not including the averaged results).

6.329 control_print_mesh_dof *index switch*

See **print_mesh_dof**.

6.330 control_print_node *index data_item_name number_0 number_1 ...*

With this record you can print nodal data like **node_dof**, **node_dof_calcul** etc. to files. As an example in 2D you can use **control_print_node index -node_dof -velx -velx** to get the files **velx**.*index* and **vely**.*index*; these files contain in columns for all nodes x y velx and x y vely.

For *data_item_name* you can apply any nodal data record for which the name starts with **node**. For *number_0 number_1* you can specify which parts of the data record should be printed; you can either specify numbers 0, 1, etc. or for **node_dof** you can specify the names of **dof_label** like **-vely**, **-vely** etc., or for **node_dof_calcul** you can specify the names of **post_calcul_label** like **-to_pres**, **-dy_pres** etc.

6.331 control_print_node_angular *index switch_x switch_y switch_z*

With this record you can specify that an angle will be included in the files (in stead of coordinates). With *switch_x switch_y switch_z* set to **-yes -yes -no** the angle will measure the number of degrees from the positive global x-coordinate directed to the positive global y-direction. With *switch_x switch_y switch_z* set to **-no -yes -yes** the angle will measure the number of degrees from the positive global y-coordinate directed to the positive global z-direction. With *switch_x switch_y switch_z* set to **-yes -no -yes** the angle will measure the number of degrees from the positive global x-coordinate directed to the positive global z-direction. In 1D you cannot use this **control_print_node_angular** record. In 2D you should not specify *switch_z* and you can only use **-yes -yes**.

The middle point of the axes in which the angle is determined should be specified with **control_print_node_angular_middle**. For example in 2D the angle follows from $tan(angle) = \frac{y-y\_middle}{x-x\_middle}$. In 1D you cannot use this **control_print_node_angular_middle** record. In 2D you should not specify *z_middle* and you should only specify *x_middle y_middle*.

See also **control_print_node**.

6.332 control_print_node_angular_middle *index x_middle y_middle z_middle*

See **control_print_node_angular**.

6.333 control_print_node_geometry *index geometry_item_name geometry_item_index*

With **control_print_node_geometry** you can restrict the printing to be done only on nodes located on the specified geometry. See also **control_print_node**.

6.334 control_print_node_sort *index sort_method*

With **control_print_node_sort** you can set if the printed results should be sorted. In case you use **-angular** for **control_print_node_method**, you can set the *sort_method* to **-angle**. Otherwise you can set the sort method to **-x**, **-y** or **-z** (**-y** is only allowed for 2D or 3D, and **-z** is only allowed for 3D). The results will be sorted starting from small values (of the **-angle**, **-x**, **-y** or **-z**) up to high values.

6.335 control_print_node_zero *index switch*

With **control_print_node_zero** you can can suppress or activate printing of results with value zero. If you set *switch* to **-yes** then zero valued results will also be printed. If you set *switch* to **-no** then zero valued results will not be printed. Default *switch* is **-yes**. See also **control_print_node**.

6.336 control_print_number_iterations *index switch*

If *switch* is set to |bf -yes , Tochnog will print the iteration number while doing equilibrium iterations in a time step. This comes convenient in very large calculations, where you want to monitor the evolution of the calculation.

6.337 control_print_partialname *index data_item_name_0 data_item_name_1 ...*

This printing command is similar to the normal **control_print** command. With this record, however, all records starting with *data_item_name_0*, *data_item_name_1*, etc. will be printed. Thus, for example, **control_print_partialname 10 -element** will print all records stating with **element** (as opposed to **control_print 10 -element** will only print the **element** record).

6.338 control_print_tecplot *index switch*

If *switch* is set to **-yes** a tecplot plot file is printed, and each time results are added to the same file. You can also set *switch* to **-separate_index**; then a new file using the index number will be printed. And also you can set *switch* to **-seperate_sequential**; then sequential tecplot files will be printed.

These files contain:

- the primary doffields from **node_dof**
- post calculated results from **node_dof_calcul**

Tecplot uses **zones** to collect data. Zones with nodal results are given names **nodal_...**. Zones with element averaged results are given names **element_averaged_...**. Tecplot uses a strandid integer to select which data is visualised. Tochnog generates in the tecplot file this strandid as follows:

- for nodal results the strandid is the group number and extra 1 is placed at the end

- for element averaged results the strandid is the group number and extra 2 is placed at the end

For example for group 100, the strandid is 1001 for nodal results, and the strandid is 1002 for element averaged results.

Tecplot files are less complete as GID files and GMSH files. Tecplot files can be plotted with the tecplot program, a trademark of Amtec Eng., Inc.

6.339 control_print_vtk *index switch*

Activate printing of results in the Visual Toolkit unstructured grid format, which can be plotted by the **paraview** plotting program. See **www.paraview.org**.

For example, if the input file name is **excavation.dat** and *index* is 100 and *switch* is set to **-separate_index** then results are printed in the file is **excavation100.vtk**.

For example, if the input file name is **excavation.dat** and *switch* is set to **-separate_sequential** then results are printed in the files is **excavation0.vtk**, **excavation1.vtk**, etc.

In **paraview** elements are called 'cells' and nodes are called 'points'.

How to get a nice contour plot for the yy-stress:

- **File open .....** choose file and hit apply button
- **Coloring .....** choose node_materi_stress and set 4 in stead of magnitude
- **Edit** hit the **Choose preset** button and select something nice.
- **Edit** set **number of table values** to e.g. 80
- **Color Legend** change legend text etc.
- **File Save Screenshot** save picture

How to get a vector plots for velocities:

- **File open .....** choose file and hit **apply** button
- **Glyph** add glyphs for vectors
- **Glyph type** choose **arrow**
- **Scale mode** choose **vectors**
- **Set scale factor** choose factor to get nice vector lengths
- **Coloring** choose node_materi_velocity and choose magnitude

How to find the number of elements depicted in the plot:

- Split the screen at the top right of the layout window, and select spreadsheet view on the second screen
- **View** and then **Selection display inspector**
- In the inspector select **ID** for **Cell labels** and **Point labels**
- Activate the small **select cells on** button in the layout
- With the left mouse button click and drag to select the cells

How to see only elements of a certain groups:

- In **Filters** select **Common** and then select **Threshold**
- In **Scalars** select **element_group**
- In **Minimum** set the mininum group number that you want to see
- In **Maximum** set the maximum group number that you want to see
- In **Coloring** select the data that you want to see

6.340 control_print_vtk_coord *index switch*

If *switch* is set to **-yes** the coordinates of nodes is plotted in vtk. If *switch* is set to **-no** the coordinates of nodes is not plotted in vtk. Default *switch* is set to **-yes**.

6.341 control_print_vtk_dof *index initialisation_name_0 initialisation_name_1 ...*

When you specify this record only the solution fields *initialisation_name_0*, *initialisation_name_1* etc will be printed to the vtk files. So the files become smaller in size. This is especially convenient for very large calculations. The names *initialisation_name_0*, *initialisation_name_1* are names from the initialisation part like **-condif_temperature**, **-materi_velocity**, **-materi_stress** etc. In case you do not want any field to be printed in the vtk file use **control_print_vtk_dof** *index* **-none**.

See also **control_print_vtk_other**.

6.342 control_print_vtk_dof_calcul *index calcul_0 calcul_1 ...*

When you specify this record only the post fields *calcul_0*, *calcul_1* etc will be printed to the vtk files. So the files become smaller in size. This is especially convenient for very large calculations. See **post_calcul_label** for the allowed names of *calcul_0*, *calcul_1* etc. In case you do not want any post field to be printed in the vtk file use **control_print_vtk_dof_calcul** *index* **-none**.

See also **control_print_vtk_other**.

6.343 control_print_vtk_empty *index switch*

If *switch* is set to **-yes**, empty elements are included in the vtk file. If *switch* is set to **-no**, empty elements are not included in the vtk file. Default, if **control_print_vtk_empty** is not specified, *switch* is set to **-yes**.

6.344 control_print_gid_group *index switch*

If *switch* is set to **-yes** the element groups are plotted in vtk as result field. If *switch* is set to **-no** the element groups are not plotted in vtk as result. Default *switch* is set to **-yes**.

6.345 control_print_vtk_node_method *index node_type*

If *method* is set to **-node**, these coordinates are written. If *method* is set to **-node_start_refined**, these coordinates are written. If *method* is set to **-node_deformed_mesh**, these coordinates are written.

6.346 control_print_vtk_other *index switch*

If *switch* is set to **-yes** also other things like boundary conditions, mesh deformation etc. are printed in the vtk files. If *switch* is set to **-no** these other things are not printed in the vtk files. Default *switch* is set to **-yes**.

6.347 control_repeat *index number_of_repeats control_index*

If *number_of_repeats* is larger than 0 the calculation repeats from the *control_index*. The value of *number_of_repeats* is decreased by 1.

A first application is to do many time steps, but print only once in a while:

control_timestep 10 1. 100. ...
control_print 20 -node_dof ...
control_repeat 30 80 10

In the latter example, first 100 timesteps are taken, then results for **node_dof** are printed; this is repeated 80 times.

Also, this **control_repeat** can typically be used to perform a number of refinements combined with time stepping to a new, refined, solution. This is done a fixed number of times.

In case the repeat jumps back to a **control_timestep** record for which the index equals *control_index*, then that the previous timestep will be used (instead of the timestep specified by the **control_timestep** record).

See also **control_repeat_until_item**.

6.348 control_repeat_save *index data_item_name_0 data_item_index_0 data_item_number_0 data_item_name_1 data_item_index_1 data_item_number_1 ...*

This record specifies data that should be saved while repeats are performed with **control_repeat**. The saved results are stored in the records **repeat_save_result** (subsequent repeats write in subsequent indices of repeat_save_result).

6.349 control_repeat_save_calculate *index switch*

Perform a statistical analysis on data of **repeat_save_result**. The statistical results are placed in **repeat_calculate_result**. The average value and variance will be calculated.

6.350 control_reset_dof *index dof_0 dof_1 ...*

The dof's as specified in this record are set to a some new value. For example, *dof_0* is **-sigxx**, etc. As a special option you can use **-all** to reset all dof's.

With **control_reset_value_constant** you can specify the new value to which the dof's should be set. Additionally you can specify values depending on space coordinates with **control_reset_value_linear** etc. The records **control_reset_value_constant**, **control_reset_value_linear** etc. can be arbitrarily combined so that complex dependency of the value of space coordinates is possible. If none of these records is specified then a new value 0 is used.

As a typical example, you can set displacements and strains to zero in a geotechnical calculation, with an **-updated** material description, after the gravity load has been applied. In

this way the strains for further deformations can de distinguished more clearly.

The dof's will be reset on all nodes of elements which are completely inside the geometry specified in **control_reset_geometry**, or of elements which have all their nodes specified in **control_reset_node**.

As a special option for groundflow calculations, you can set an dof to **-total_pressure** to reset the physical groundflow pore pressure (total pressure) .

Attention: this **control_reset_dof** should not be used to reset displacements (or velocity integrated) if also **support_edge_normal** is present. This is because those **support_edge_normal** supports calculate forces directly from total displacements, and so you would in fact set the support forces also to zero. Also in the presence of interface elements the displacements (or velocity integrated) should not be reset. Normal isoparametric elements use an incremental formulation for stresses however (new stress = old stress + incremental stress from stiffness), so that resetting displacements to zero does not influence the stresses.

Attention: with this **control_reset_dof** option you cannot reset the strains, stresses, forces, etc. in structural elements (springs, interfaces, trusses, ...) This option only works for isoparametric elements.

6.351 control_reset_element_dof *index switch*

If *switch* is set to **-yes** only dofs in **element_dof** and **element_intpnt_dof** will be set; dofs in **node_dof** will not be set.

6.352 control_reset_element_group *index element_group_number_0 element_group_number_1 ...*

Specifies the specific element groups on which the **control_reset_dof** record with the same index should be applied. If this record is not specified, the **control_reset_dof** record will be done for all element groups (in the specified geometry).

6.353 control_reset_geometry *index geometry_item_name geometry_item_index*

Specifies the geometry on which the **control_reset_dof** record with the same index should be applied.

6.354 control_reset_interface *index geometry_item_name geometry_item_index*

Reset all interface data like strains, stresses, etc. to 0 for interface elements located in the geometry with name *geometry_item_name* and index *geometry_item_index*.

6.355 control_reset_interface_strain *index geometry_item_name geometry_item_index*

Reset all interface strains to 0 for interface elements located in the geometry with name *geometry_item_name* and index *geometry_item_index*. The interface stresses at this moment of resetting will be remembered by Tochnog. In the next time steps the new interface strains start with 0, and change when the interfaces deform further. And in the next time steps the new interface stresses are calculated from the interface stresses at this moment of resetting plus stress due to additional deformation (from the specified stiffness properties).

6.356 control_reset_node *index node_0 node_1 ...*

Specifies nodes on which the **control_reset_dof** record with the same index should be applied.

6.357 control_reset_value_constant *index value*

Specifies the value to which dof's of the **control_reset_dof** record are reset. A constant *value* will be used.

6.358 control_reset_value_dof *index dof*

This record allows you to make the dofs of **control_reset_dof** dependent on a specified *dof* of this **control_reset_value_dof** record. The dependency should be given in table form with **control_reset_value_dof_diagram**.

By example you can make a **-hyhis0** in the hypo laws dependent on the vertical stress **-sigyy**:

- **control_reset_dof 10 -hyhis0**
- **control_reset_value_dof 10 -sigyy**
- **control_reset_value_dof_diagram 10 -1.e2 0.4 -2.e2 0.38 -1.e3 0.3**

This specifies that for vertical stress -1.e2 the void ratio is 0.4, for vertical stress -2.e2 the void ratio is 0.38, etc.

6.359 control_reset_value_dof_diagram *index ....*

See **control_reset_value_dof**.

6.360 control_reset_value_exponent *index* $a_x b_x c_x d_x e_x a_y b_y c_y d_y e_y a_z b_z c_z d_z e_z$

Specifies the exponential space distribution to which dof's of the **control_reset_dof** record are reset. The dependency $a_x e^{\frac{b_x+c_x x}{d_x+e_x x}} + a_y e^{\frac{b_y+c_y y}{d_y+e_y y}} + a_z e^{\frac{b_z+c_z z}{d_z+e_z z}}$ will be used. In 1D only $a_x b_x c_x d_x e_x$ should be specified. In 2D only $a_x b_x c_x d_x e_x a_y b_y c_y d_y e_y$ should be specified.

6.361 control_reset_value_linear *index* $a_x a_y a_z$

Specifies the linear space distribution to which the dof's of the **control_reset_dof** record are reset. The dependency $a_x x + a_y y + a_z z$ will be used. In 1D only a_x should be specified. In 2D only $a_x a_y$ should be specified.

6.362 control_reset_value_logarithmic_first *index* $a_x b_x c_x d_x e_x a_y b_y c_y d_y e_y a_z b_z c_z d_z e_z$

Specifies the logarithmic space distribution to which dof's of the **control_reset_dof** record are reset. The dependency $a_x \ln(\frac{b_x+c_x x}{d_x+e_x x}) + a_y \ln(\frac{b_y+c_y y}{d_y+e_y y}) + a_z \ln(\frac{b_z+c_z z}{d_z+e_z z})$ will be used. In 1D only $a_x b_x c_x d_x e_x$ should be specified. In 2D only $a_x b_x c_x d_x e_x a_y b_y c_y d_y e_y$ should be specified.

6.363 control_reset_value_logarithmic_second *index* $a_x b_x c_x d_x e_x f_x g_x a_y b_y c_y d_y e_y f_y g_y a_z b_z$

Specifies the logarithmic space distribution to which dof's of the **control_reset_dof** record are reset. The dependency $(a_x + b_x)(e^{c_x \ln(d_x(x+e_x)/f_x)}) + g_x + (a_y + b_y)(e^{c_y \ln(d_y(y+e_y)/f_y)}) + g_y + (a_z + b_z)(e^{c_z \ln(d_z(z+e_z)/f_z)}) + g_z$ will be used. In 1D only $a_x b_x c_x d_x e_x f_x g_x$ should be specified. In 2D only $a_x b_x c_x d_x e_x f_x g_x a_y b_y c_y d_y e_y f_y g_y$ should be specified.

6.364 control_reset_value_multi_linear *index* $z_0 value_0 z_1 value_1 \ldots$

Specifies the multi-linear space distribution in vertical direction to which the dof's of the **control_reset_dof** record are reset. A multilinear table of value versus z coordinate should be given; at z_0 the value is $value_0$ etc. The z_0, z_1 etc. should have increasing values from low to high; the values should cover all coordinates in the FE mesh for with the reset is done. In 1D not a z coordinate but x coordinate is used instead. In 2D not a z coordinate but y coordinate is used instead.

6.365 control_reset_value_power *index* $a_x b_x a_y b_y a_z b_z$

Specifies the power space distribution to which the dof's of the **control_reset_dof** record are reset. The dependency $a_x x^{b_x} + a_y y^{b_y} + a_z z^{b_z}$ will be used. In 1D only $a_x b_x$ should be specified. In 2D only $a_x b_x a_y b_y$ should be specified.

6.366 control_reset_value_method *index method*

If *switch* is set to **-multiply** the values as specified by **control_reset_value** etc. are used as relative factor by which the dof's are changed. So for example if 0.1 is given in **control_reset_value_constant**, then the dof's will be multiplied with 0.1.

If *switch* is set to **-add** the values as specified by **control_reset_value** etc. are used as additional values by which the dof's are changed. So for example if 0.1 is given in **control_reset_value_constant**, then the dof's will be added with 0.1.

6.367 control_reset_value_square_root *index* $a_x b_x c_x a_y b_y c_y a_z b_z c_z$

Specifies the power space distribution to which the to which dof's of the **control_reset_dof** record are reset. The dependency $a_x\sqrt{b_x + c_x x} + a_y\sqrt{b_y + c_y y} + a_z\sqrt{b_z + c_z z}$ will be used. In 1D only $a_x b_x$ should be specified. In 2D only $a_x b_x a_y b_y$ should be specified.

6.368 control_restart *index switch*

If *switch* is set to **-yes** then the calculation continues with the undeformed mesh. The dof's (in the **node_dof** records) are reset to the initial values. And **time_current** is set to the initial time.

This allows you to calculate some path dependent behavior completely from the start with a refined mesh.

6.369 control_safety_slip *index switch*

If *switch* is set to **-yes** a slip safety factor calculation will be performed with the method as described in [4]. The calculated safety factor F_s is:

$$F_s = \frac{\int \tau_{mc} dA}{\int \tau dA}$$

where τ_{mc} is the maximum possible shear stress according to the mohr-coulomb condition using the actual normal stress, τ is the actual shear stress and dA is the surface area in

the integral. The advantage of this safety factor definition is that it can be evaluated at any stress state, for example the gravity stress state, without any further timesteps with friction angle and cohesion reduction. The definition simply compares the actual current shear stress relative to the maximum possible shear stress following from mohr-coulomb and the current normal stresses.

The user needs to specify over which surface the integration of the safety factor needs to be performed. See **safety_slip_circle_grid_***, etc.

A critical slip surface will be calculated for each set of **safety_slip_circle_grid_***, etc. (thus for each separate index of these a critical surface will be calculated). You can specify also **safety_slip_set** however, which defines the indices of **safety_slip_circle_grid_***, etc. belonging to a specific set. The overall minimal safety factor will be determined for all safety geometries belonging to the set.

This **control_safety_slip** is available for **group_materi_plasti_mohr_coul**, **group_materi_plasti_mohr_coul_direct**, **group_materi_plasti_druck_prag** and **group_materi_plasti_hypo_wolffersdorff**.

As a special option you can set the *switch* not to **-yes** but to a number 1, 2, 3, .. instead. Then this number 1, 2, 3, ... is used by tochnog as the number of automatic safety calculations of the critical slip surface. For example if you use slip circles (specified by middle points and radii) after the first safety calculations a specific middle point and radius will have the lowest safety factor. Then in the next safety calculation tochnog will reduce the area of middle points and the set of radii to a smaller zone around that critical middle point and radius. With this smaller zone a new safety analysis will lead to a new critical middle point and radius somewhere in the reduced zone. Then again a smaller zone will be used, leading to again a new critical middle point and radius, etc. etc. This repetition of reducing the zone of middle points and radii with will done such many times as set in the number, so 1, 2, 3, ... Typically the number 2 could be used.

Slip surfaces will be drawn in GID plots (see **control_print_gid** for GID plotting). For each slip surfaces the safety factor can be plot. Moreover, also a local safety factor can be plot, which is the local ratio of shear stress and maximum possible shear stress.

Slip surfaces crossing a boundary with prescribed displacements (or velocities) non valid since the slip velocities are in general not compatible with the prescribed velocities on such boundary.

6.370 control_slide_damping_apply *index switch*

If *switch* is set to **-yes** then any **slide_damping** records will be applied. If *switch* is set to **-no** then any **slide_damping** records will be not applied. Default if **control_slide_damping_apply** is not specified then *switch* is **-yes**.

6.371 control_slide_plasti_apply *index switch*

If *switch* is set to **-yes** then any **slide_plasti_*** records will be applied. If *switch* is set to **-no** then any **slide_plasti_*** records will be not applied. Default if **control_slide_plasti_apply** is not specified, **plasti_apply** or **control_plasti_apply** will be used.

6.372 control_slide_stiffness_apply *index switch*

If *switch* is set to **-yes** then any **slide_stiffness** records will be applied. If *switch* is set to **-no** then any **slide_stiffness** records will be not applied. Default if **control_slide_stiffness_apply** is not specified then *switch* is **-yes**.

6.373 control_solver *index solver_type*

If *solver_type* is set to **-diagonal** then only the main diagonal of the system matrix will be used for the solution of all dof's. This gives the program an explicit like structure. In fact, if **control_timestep_iterations** is set to 1, then a classical explicit finite element program is obtained.

If *solver_type* is set to **-matrix_iterative_bicg** then the complete system matrix will be used for solution of the principal dof's (see the initialization section for an explanation on principal dof's). A diagonal Preconditioned Biconjugate Gradient method is applied.

If *solver_type* is set to **-matrix_pardiso** then the pardiso solver will be used for solution of the principal dof's.

If *solver_type* is set to **-none** then only the matrices and right-hand sides are setup, but the equations are not really solved.

6.374 control_solver_bicg_error *index error*

With *error* you set the termination error ratio between the initial and final error in the bicg iterations. Default *error* is set to **1.e-13**.

See also **solver_bicg_error**. This **control_solver_bicg_error** record overrules **solver_bicg_error** if both are specified.

6.375 control_solver_bicg_restart *index nrestart*

With *nrestart* you set the number of restarts in the bicg iterations. Default *nrestart* is set to 0.

See also **solver_bicg_restart**. This **control_solver_bicg_restart** record overrules **solver_bicg_restart** if both are specified.

6.376 control_solver_bicg_stop *index switch*

If *switch* is set to **-yes**, the calculation is stopped if the bicg solver does not converge. If *switch* is set to **-no**, the calculation is not stopped if the bicg solver does not converge. Default *switch* is set to **-yes**.

See also **solver_bicg_stop**. This **control_solver_bicg_stop** record overrules **solver_bicg_stop** if both are specified.

6.377 control_solver_matrix_save *index switch*

If *switch* is set to **-yes**, the solver saves and applies the decomposed matrix, but not in case Tochnog thinks for some reason that the matrix needs to be decomposed at each timestep. This can save CPU time, since further decompositions of the matrix are not required anymore (only backsubstitution to find the solution vector).

If *switch* is set to **-no**, the solver does not save the decomposed matrix.

If *switch* is set to **-always**, the solver saves and applies the decomposed matrix, even in case Tochnog thinks for some reason that the matrix needs to be decomposed at each timestep.

This option is only available in combination with the pardiso solver.

Side remark: Tochnog mostly uses a linear matrix in iterations (no plasticity effect in the matrix). Only in special cases like hypoplasticity, user supplied routines, etc. the current stiffness matrix is used.

6.378 control_solver_pardiso_out_of_core *index switch*

If *switch* is set to **-yes** the pardiso solver is called with a 'out of core' option. See for further the pardiso solver in the the intel mkl library. Default *switch* is **-no**.

6.379 control_solver_pardiso_ordering *index ordering*

Set the number *ordering* to one of the following:

- 0 The minimum degree algorithm.
- 2 The nested dissection algorithm from the METIS package.

- 3 The parallel (OpenMP) version of the nested dissection algorithm.

Default *ordering* is **3**. For more information see pardiso info at intel.

6.380 control_support_edge_normal_damping_apply *index switch*

If *switch* is set to **-yes** then all **support_edge_normal_damping** records will be applied. If *switch* is set to **-no** then all **support_edge_normal_damping** records will not be applied. Default, if **control_support_edge_normal_damping_apply** is not specified, then *switch* is set to **-yes**.

6.381 control_support_edge_normal_stiffness_freeze *index switch*

If *switch* is set to **-yes**, tochnog freezes the stiffness forces generated by **support_edge_normal**. The stiffness forces remain at their present value and will not change anymore. A typical application is earthquake or vibration analysis where you first impose gravity including stiffness at supports, then freeze the forces at the supports, and then in the earthquake or vibration analysis use only damping at the supports to model absorbing boundaries which absorb further force changes at the boundaries.

(support properties)
support_edge_normal 10 ...
support_edge_normal_damping 10 ...
...
(calculate gravity stresses)
control_timestep 10 ...
control_support_edge_normal_damping_apply 10 -no
...
(freeze stiffness forces at boundary)
control_support_edge_normal_stiffness_freeze 20 -yes
...
(calculate earthquake or vibrations)
control_timestep 30 ...
control_support_edge_normal_damping_apply 30 -yes
control_inertia_apply 30 -yes

6.382 control_system_call *index integer_value*

Specifying this record tochnog calls a system command. You need to program that command yourself. On linux provide a **tochnog_system_call.sh** file which is executable. On MS Windows provide a **tochnog_system_call.bat** file.

In the command you can place commands that you want to be executed. For example, if you put in the linux file the command **date >> system_call.out** you get the output of the **date** command appended to **system_call.out**. Another example is sending you an automatic email indicating that the calculation reached a certain point or is almost finished.

The command is called with *integer_value* as first argument. You can use this integer value in your command (eg by using $1 in the linux shell script command).

This command is executed at the end of each timestep and also at the end of each control index.

6.383 control_timestep *index step_size time_increment step_size time_increment ...*

These records define sets of time steps of size *step_size* which are to be taken till the time is increased by *time_increment*. In the example below time steps of 0.1 are taken from time 0.0 up to time 1.0. Then time steps of 0.2 are taken up to time 2.0

control_timestep 0 0.1 1. 0.2 1.

6.384 control_timestep_adjust_minimum_iterations *index switch*

If *switch* is set to **-yes** Tochnog will increase the minimum number of iterations in a timestep if it thinks that is helpful for the specific input file that you are running; this is done in combination with **control_timestep_iterations_automatic**. If *switch* is set to **-no** Tochnog will not do so, and keep 2 as the minimum number of iterations. Default, if **control_timestep_adjust_minimum_iterations** is not specified, *switch* is set to **-yes**.

6.385 control_timestep_iterations *index number_of_iterations*

This sets a fixed number of equilibrium iterations in each time step (for time steps of the **control_timestep** record with the same index). For many iterations, the time stepping is Euler implicit. For few iterations the time stepping becomes explicit. Default *number_of_iterations* is 2.

In dynamic analysis, with the default number of 2 iterations you gain numerical stability, at the expense of numerical damping however. To prevent this numerical damping use 1 iteration instead.

As an alternative, you can use **control_timestep_iterations_automatic**.

6.386 control_timestep_iterations_automatic *index ratio_criterium minimal_timestep maximum_timestep*

After specification of this record, iterations will be performed until *ratio* in **post_node_rhside_ratio** is less than *ratio_criterium*. Typically, set *ratio_criterium* to 0.001.

The time step size is increased if the number of iterations is substantially lower then the wished (preferred) number of iterations. The time step size is decreased if the number of iterations is substantially larger then the wished (preferred) number of iterations.

The time step specified in **control_timestep** is used as initial step. The time step is not allowed to become higher then *maximum_timestep*. The time step is not allowed to become lower then *maximum_timestep*.

The initial step as specified in **control_timestep**, should be sufficient small so that this automatic algorithm can fulfill the *ratio_criterium* in that initial step.

After the iterations in a step are finished, Tochnog performs one extra iterations to update strains, stresses, etc with the last velocity fields. In this extra iteration also the **post_node_rhside_ratio** will be recalculated, and thus may become different from the previous value that was used to determine if the iterations should be stopped.

See also **control_timestep_iterations_automatic_stop**, and **control_timestep_iterations_automatic**

6.387 control_timestep_iterations_automatic_minimum_maximum_wished *index minimum_iterations maximum_iterations wished_iterations*

This sets the minimum number of allowed iterations, the maximum number of allowed iterations, and the wished (preferred) number of iterations for the automatic time stepping mechanism as specified by **control_timestep_iterations_automatic** with the same index. The default for this record is 2 8 4. The maximum number of allowed iteration should be 2 or larger.

6.388 control_timestep_iterations_automatic_stop *index switch*

If you set *switch* in **control_timestep_iterations_automatic_stop** to **-yes** then the calculation does stop if the minimal timestep size is reached. If you set *switch* in **control_timestep_iterations_automatic_stop** to **-no** then the calculation does not stop if the minimal timestep size is reached, and the present timestepping will be finished.. If you set *switch* in **control_timestep_iterations_automatic_stop** to **-continue** then the calculation does not stop if the minimal timestep size is reached, and the present timestepping will not be finished.. Default, if **control_timestep_iterations_automatic_stop** is not specified, then *switch* is set to **-yes**.

6.389 control_timestep_multiplier *index multiplier maximum_timestep*

If this record is specified, each new time step size is *multiplier* * old time step size. The *step_size* as specified in **control_timestep** will only be used as the initial time step.

The timestep is not allowed to exceed the maximum specified timestep *maximum_timestep*.

This option is handy to study physical processes which develop more slowly when time proceeds. A typical example is consolidation analysis in geotechnics.

6.390 control_timestep_until_data *index data_item_name_0 data_item_index_0 data_item_number_0 data_item_name_1 data_item_index_1 data_item_number_1 ...*

With this record you can specify conditions for which the timesteps with the same index should be stopped. For each specified data item name, index and number you can specify a mnimum value in **control_timestep_until_minimum** and a maximum value in **control_timestep_until_maximum**. A typical example:

```
control_timestep 10 ...
control_timestep_until_data 10 -post_point_dof 3 -velx
control_timestep_until_minimum 10 -120.
control_timestep_until_maximum 10 +120.
```

6.391 control_timestep_until_maximum *index maximum_0 maximum_1 ...*

See **control_timestep_until_data**.

6.392 control_timestep_until_minimum *index minimum_0 minimum_1 ...*

See **control_timestep_until_data**.

6.393 control_truss_rope_apply *index switch*

If *switch* is set to **-no**, any truss rope data in the input file will be ignored. This is done for timestep records with the same index.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with truss rope data. See also **truss_rope_apply**.

6.394 control_zip *index switch*

If *switch* is set to **-yes** all ***flavia***, ***msh**, **vtk**, ***.plt** and ***dbs** files are zipped with the **gzip** program. The **gzip** program should be installed on your computer.

This comes convenient in large calculation with lots of output, where you want to use results later and save disk space during the calculation.

6.395 convection_apply *switch*

If *switch* is set to **-yes**, the convection of a material with respect to the mesh is allowed. If *switch* is set to **-no**, the convection of a material with respect to the mesh is not allowed. This is done for all timesteps.

Default *switch* is set to **-no**. See also **control_convection_apply**.

6.396 convection_stabilization *switch*

Because of finite discretisation sometimes unrealistic results may be obtained (wiggles, etc.). If *switch* is set to **-yes** results are stabilized with a minimal amount of artificial diffusion. If *switch* is set to **-maximal** results are stabilized with a maximal amount of artificial diffusion. If *switch* is set to **-no** results are not stabilized.

Default, if **convection_stabilization** is not specified, *switch* is set to **-yes**.

6.397 data_activate *index data_item_name_0 data_item_name_1 ... switch*

With this record you can set data items to become activated if *switch* is set to **-yes** or de-activated if *switch* is set to **-no**. The *data_item_name* specifies a data record name.

6.398 data_activate_time *index time*

Time point at which the record **data_activate** with the same index is evaluated. If this record is not specified, the **data_activate** is evaluated at the start of the calculation.

6.399 data_delete *index data_item_name index_range*

Similar to **control_data_delete**, but now not as control record however.

6.400 data_delete_time *index time*

Time point at which the record **data_delete** with the same index is evaluated. If this record is not specified, the **data_delete** is evaluated at the start of the calculation.

6.401 data_ignore *data_item_name*

With this option Tochnog will ignore all data items with name *data_item_name*. This **data_ignore** can also be set as environment symbol. As a typical example you can set the environment symbol **data_ignore** to **-print_apply**. Then when you run the tochnog example tests all **-print_apply -no** in the tests will be ignored, so you you get all printed output for the tests.

6.402 dependency_apply *switch*

If *switch* is set to **-yes**, dependencies like specified in **dependency_diagram** and **dependency_item** are included included in the calculation. If *switch* is set to **-no**, these dependencies are not included. This is done for all timestep records.

Default *switch* is set to **-yes**. See also **control_dependency_apply**.

6.403 dependency_diagram *index dof_value_0 ... data_item_value_0 ...*

See **dependency_item**.

6.404 dependency_method *index method*

See **dependency_item**.

6.405 dependency_geometry *index geometry_item_name geometry_item_index*

See **dependency_item**.

6.406 dependency_item *index data_item element_group dof n*

This record allows you to make an element data item **group_*** dependent on one of the dof's, see **dof_label** for dofnames, or on one of the post calculation results, see **post_calcul_label** for post calculation names. This is done for n values of the dof(n should be at least 2). The dependency should be specified in the **dependency_diagram** record (same index) with a multi linear diagram. In the diagram first a set of dof's values should be specified. Second the set of data item values for those dof values should be specified. Please realise that the record which you want to make dependent needs to be specified itself also.

Some examples are given below.

Temperature dependent Young's modulus of element_group 1 ($E = 1.e10$ at temperature 1, etc.):

dependency_item 1 -group_materi_elasti_young 1 -temp 4
dependency_diagram 1 1. 2. 3. 4. 1.e10 1.e9 1.e8 3.e5

Temperature dependent Young's moduli in two maxwell chains of element_group 1 (for the first chain the moduli $1.e10, 1.e9, \ldots$ for the second chain the moduli $1.e12, 1.e11, \ldots$ all relaxation times are $1.\ 10^{-2}$.):

dependency_item 1 -group_materi_maxwell_chain 1 -temp 4
dependency_diagram 1
1. 2. 3. 4.
1.e10 1.e9 1.e8 3.e5
1.e-2 1.e-2 1.e-2 1.e-2
1.e12 1.e11 1.e10 3.e7
1.e-2 1.e-2 1.e-2 1.e-2

As a special option, *dof* can be set to **-time_current**. This allows for time-dependent properties (aging). The example below shows time dependent Young's modulus of element_group 1 ($E = 1.e10$ at time 0, etc.):

dependency_item 1 -group_materi_elasti_young 1 -time_current 4
dependency_diagram 1 0. 1. 2. 3. 1.e10 1.e9 1.e8 3.e5

As a special option, *element_group* can be set to **-all**, so that the dependency diagram will be used for all groups.

As another special option, *dof* can be set to **-x**, **-y** or **-z**. This allows for dependency on one of the space coordinates. The example below shows a von-mises stress dependent on the z-coordinate for element_group 1:

dependency_item 1 -group_materi_plasti_vonmises 1 -z 4
dependency_diagram 1 -300. -200. -100. 0. 1.e5 1.e4 1.e3 1.e2

In 1D only **-x** can be used, in 2D only **-x** and **-y** can be used, and in 3D all of **-x**, **-y** and **-z** can be used.

The dependencies are available only for real precision data (and thus not for integer data). The **dependency_diagram** values should be specified from low to high values for the dof.

The **dependency_method** can be set to either **-use** or **-multiply**; with **-use** you specify that the values of **dependency_diagram** will overwrite specified values for the data item; with **-multiply** you specify that the values of **dependency_diagram** will multiply specified values for the data item; default, if **dependency_method** is not specified, **-use** will be used.

With the **dependency_type** record you can require that the cosinus, sinus or tangent of a data value is used in the dependency (in stead of the data value directly itself). The *type* can be set to either **-cosinus**, **-sinus** or **-tangent**. This is typically convenient for geotechnical safety factor calculations where you want that for a mohr coulomb law the cohesion and tangent of the friction angle are decreased at the same ratio in time. If you don't specify **dependency_type** the value itself will be changed. To be clear we give the following four examples. If **dependency_method** is set to **-use** and **dependency_type** is not specified, then the value specified in the dependency diagram will be used for the data. If **dependency_method** is set to **-use** and **dependency_type** is set to **-tangent**, then the arc-tangent of the value specified in the dependency diagram will be used for the data. If **dependency_method** is set to **-multiply** and **dependency_type** is not specified, then the value specified in the dependency diagram will be multiplied with the original value for the data, and the result will be used as new value for for the data. If **dependency_method** is set to **-multiply** and **dependency_type** is set to **-tangent**, then the value specified in the dependency diagram will be multiplied with the tangent of the original value for the data, the arc-tangent of the result will be taken, and the final result will be used as new value for for the data.

With the **dependency_number** record you can require that you only want to make one specific number of the data (0 for the first value, 1 for the second value, etc.) dependent. As a special option you can specify **-all** for the **dependency_number** record, so that tochnog understands that you want to make all values in a record dependent. If you don't specify **dependency_number** then all values of the record are made dependent.

The **dependency_geometry** can be set to select a geometry for which the dependency is valid; outside the geometry the dependency will not be used; default, if **dependency_geometry** is not specified, no geometry selection will be used.

The following gives as example lowering the tangent of the mohr coulomb friction angle with

a factor in time, for the elements of all groups within a radius distance from a point:

geometry_point 10 ...
...
dependency_item 1 -group_materi_plasti_mohr_coul -all -time_current 2
dependency_number 1 0 (only for the friction angle)
dependency_method 1 -multiply (use specified diagram as multiplication factor)
dependency_type 1 -tangent (for the tangent, so not for the value itself)
dependency_diagram 1 10. 11. 1. 0. (lower the tangent of friction angle between time 10 to time 11 from original value to 0)
dependency_geometry 1 -geometry_point 10 (do that only within a certain radius of a point)

You can use **print_group_data** to get the result for the calculated values using the dependency diagram. In fact, most **group_*** records can be used in the dependency diagram, but not all. Thus checking if things go like you want with the **print_group_data** is stringly adviced.

6.407 dependency_number *index number*

See **dependency_item**.

6.408 dependency_type *index type*

See **dependency_item**.

6.409 dof_element_dof *dof_per_element_0 dof_per_element_1 ...*

This record is for printing only. It is not meant as user input record. After the calculation the *dof_per_element_0* , *dof_per_element_1* etc. contain a **-yes** or **-no**. In case a dof is default calculated per element, so the field is non-continuous, a **-yes** is set. In case a dof is default calculated as continuous field a **-no** is set. This default calculation can be overruled by **global_element_dof_apply**.

6.410 dof_label *dof_0 dof_1 ...*

This record will be filled with labels of the dof's in the correct order. This information is required for understanding records like **node_dof** etc. The sequential order for the primary

dof's will match the order in which they are specified in the initialization part.

The total list of possible doflabels is:

-accx acceleration in x-direction, **-accy**, **-accz**,

-cchis0, **-cchis1** cam clay history variables,

-dam damage,

-dens density,

-dipriscohisv, **-dipriscohis1**, ..., di prisco plasticity history variables,

-disx displacement in x-direction, **-disy**, **-disz**,

-rdisx relative displacement in x-direction, **-rdisy**, **-rdisz**,

-ener material strain energy,

-epexx xx-strain elastic, **-epexy**, **-epexz**, **-epeyy**, **-epeyz**, **-epezz**,

-epixx xx-strain intergranular, **-epixy**, **-epixz**, **-epiyy**, **-epiyz**, **-epizz**,

-episa_cxx xx-strain isa intergranular, **-episa_cxy**, **-episa_cxz**, **-episa_cyy**, **-episa_cyz**, **-episa_czz**,

-episa_eacc isa intergranular accumulated strain,

-eppxx xx-strain plastic, **-eppxy**, **-eppxz**, **-eppyy**, **-eppyz**, **-eppzz**,

-eppcaxx xx-strain plastic cap model, **-eppcaxy**, **-eppcaxz**, **-eppcayy**, **-eppcayz**, **-eppcazz**,

-eppcoxx xx-strain plastic compression model, **-eppcoxy**, **-eppcoxz**, **-eppcoyy**, **-eppcoyz**, **-eppcozz**,

-eppdixx xx-strain plastic diprisco model, **-eppdixy**, **-eppdixz**, **-eppdiyy**, **-eppdiyz**, **-eppdizz**,

-eppdrxx xx-strain plastic druckprag model, **-eppdrxy**, **-eppdrxz**, **-eppdryy**, **-eppdryz**, **-eppdrzz**,

-eppgencamxx xx-strain plastic generalised non associate cam clay for bonded soils model, **-eppgencamxy**, **-eppgencamxz**, **-eppgencamyy**, **-eppgencamyz**, **-eppgencamzz**,

-epphaxx xx-strain plastic hardsoil model, **-epphaxy**, **-epphaxz**, **-epphayy**, **-epphayz**, **-epphazz**,

-eppmoxx xx-strain plastic mohr-coulomb model, **-eppmoxy**, **-eppmoxz**, **-eppmoyy**, **-eppmoyz**, **-eppmozz**,

-epptexx xx-strain plastic tension model, **-epptexy**, **-epptexz**, **-eppteyy**, **-eppteyz**, **-epptezz**,

-eppvoxx xx-strain plastic von-mises model, **-eppvoxy**, **-eppvoxz**, **-eppvoyy**, **-eppvoyz**, **-eppvozz**,

-eptxx xx-strain total, **-eptxy**, **-eptxz**, **-eptyy**, **-eptyz**, **-eptzz**,

-f plasticity yield rule,

-fn nonlocal plasticity yield rule,

-fscal time derivative of scalar,

-gvelx ground water velocity in x-direction, **-gvely**, **-gvelz**.

-hisv0, **-hisv1**, ..., material history variables,

-kap plastic hardening parameter kappa,

-kapsh shear plastic hardening parameter kappa,

-phimob mobilized friction angle plasticity in degrees,

-pres hydraulic pressure head,

-pres_gradx gradient hydraulic pressure head in x direction, **-pres_grady**, **-pres_gradz**

-rhoxx xx plastic kinematic hardening, **-rhoxy**, **-rhoxz**, **-rhoyy**, **-rhoyz**, **-rhozz**,

-rotx rotation around x-direction, **-roty**, **-rotz**,

-scal scalar,

-sigxx xx-stress, **-sigxy**, **-sigxz**, **-sigyy**, **-sigyz**, **-sigzz**,

-sigmkxx xx-stress in the k-th maxwell chain, **-sigmkxy**, **-sigmkxz**, **-sigmkyy**, **-sigmkyz**, **-sigmkzz**,

-strtokap total strain hardening parameter,

-strtocokap compression part of total strain hardening parameter,

-strtoshkap shear part of total strain hardening parameter,

-strtotekap tension part of total strain hardening parameter,

-temp temperature,

-velx velocity in x-direction, **-vely**, **-velz**,

-velix integrated velocity in x-direction, **-veliy**, **-veliz**,

-void material void fraction.

-work material second order work.

Furthermore, **-xvelx** denotes the spatial x-derivative of **-velx** in x-direction, etc.. Finally, **-tvelx** denotes the first time derivative of **-velx**, etc.. The time derivative and the space derivatives are only calculated if **derivatives** is included in the initialization part.

For example, the following might be seen after a print of the database

echo -yes
number_of_space_dimensions 2
derivatives
condif_temperature
end_initia
...
dof_label -temp -xtemp -ytemp -ttemp
...

Or, for example, the following might be seen after a print of the database

echo -yes
number_of_space_dimensions 2
condif_temperature
end_initia
...
dof_label -temp
...

6.411 dof_limit *lower_ dof_ 0 upper_ dof_ 0 lower_ dof_ 1 upper_ dof_ 1 ...*

With this record you can specify the lower and upper allowed values for all primary dof's. With *lower_ dof_ 0* you specify the lower allowed value for the first dof. With *upper_ dof_ 0*

you specify the upper allowed value for the first dof. Etc.

6.412 dtime *dt*

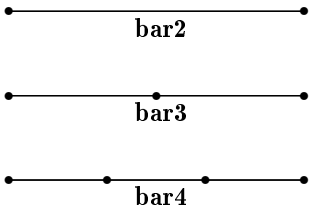
This record contains after the calculation the last timestep used in the calculation. This record is meant for printing only.

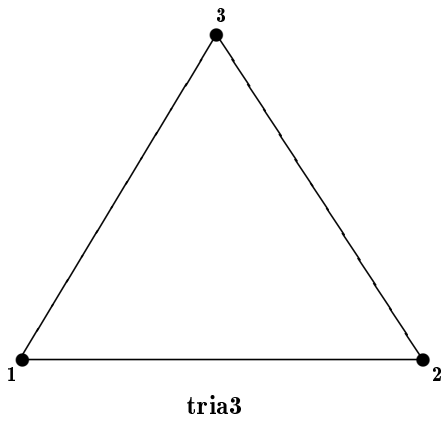
6.413 element *index element_name node_0 node_1 node_2 ...*

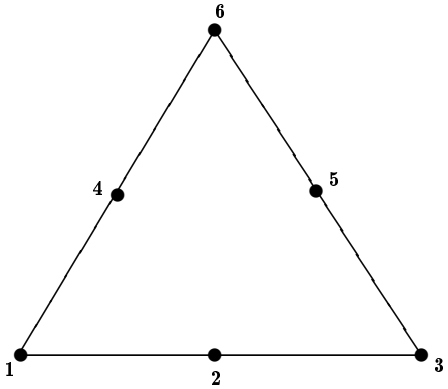
Nodal connective of element *index*. In 1D, *element_name* is **-bar2** (2 noded bar), **-bar3**, **-bar4**. In 2D, *element_name* is **-tria3** (3 noded triangle), **-tria6** (6 noded triangle), **-quad4** (4 noded quadrilateral), **-quad6** (6 noded quadrilateral, 2 sides of 3 nodes), **-quad8**, **-quad9**, **-quad16**. In 3D, *element_name* is **-tet4** (4 noded tetrahedral), **-prism6** (6 noded prismatic), **-prism12** (12 noded prismatic), **-prism15** (15 noded prismatic), **-prism18** (18 noded prismatic), **-tet10** (10 noded tetrahedral), **-hex8** (8 noded hexahedral), **-hex18** (18 noded hexahedral, 2 sides of 9 nodes), **-hex20** (20 noded hexahedral, not formally available yet, still being tested, use with care), **-hex27**.

Further possibilities for *element_name* are: **-spring2** (2 noded spring), **-contact_spring1** (1 noded contact element), **-contact_spring2** (2 noded contact element), the two nodes may have the same position in space. **-truss** (truss element), **-beam** (beam element), **-truss_beam** (combined truss-beam element).

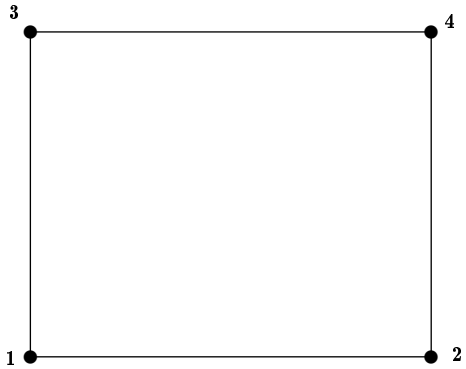
Some of the elements are drawn below.



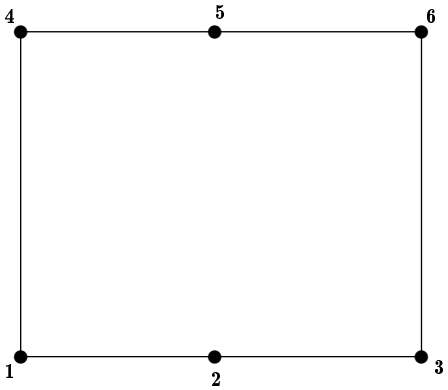




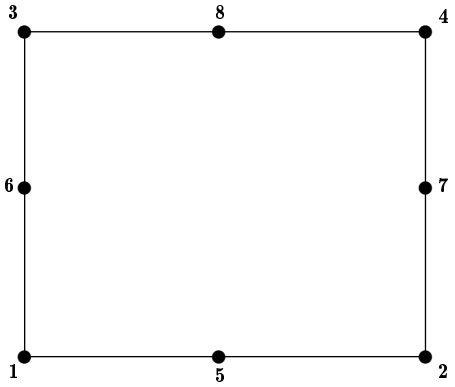
tria6



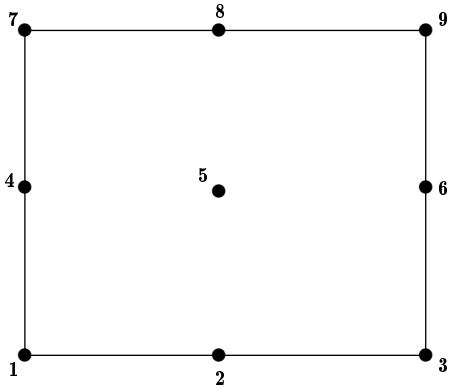
quad4



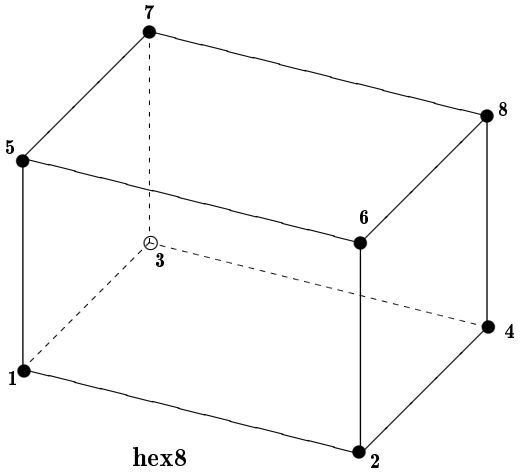
quad6



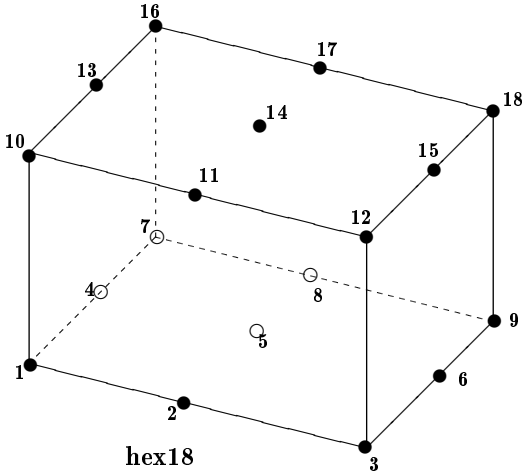
quad8



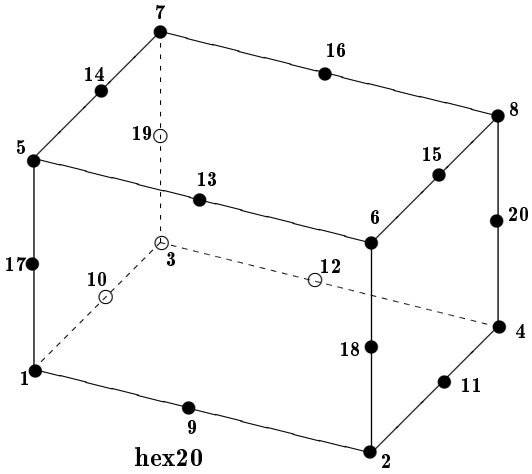
quad9



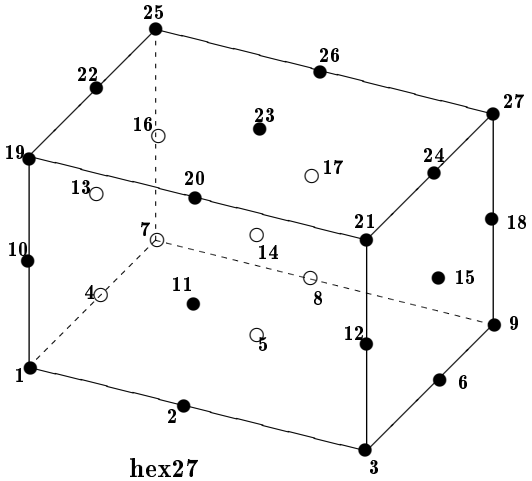
hex8



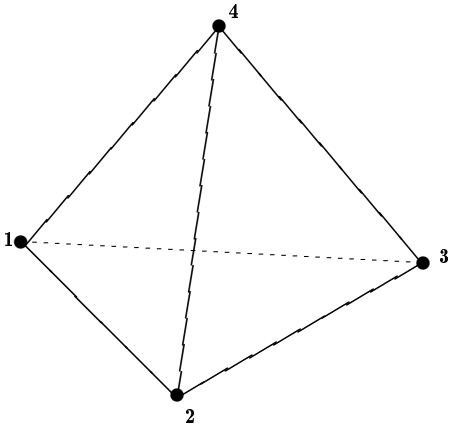
hex18



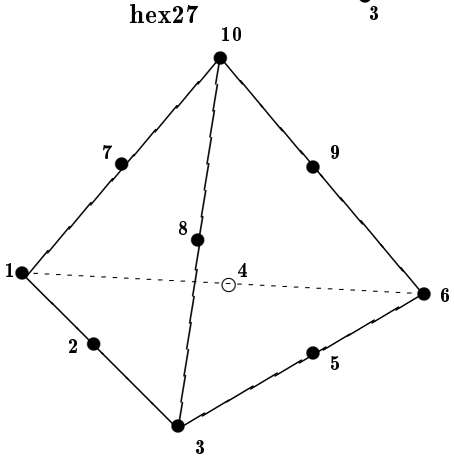
hex20



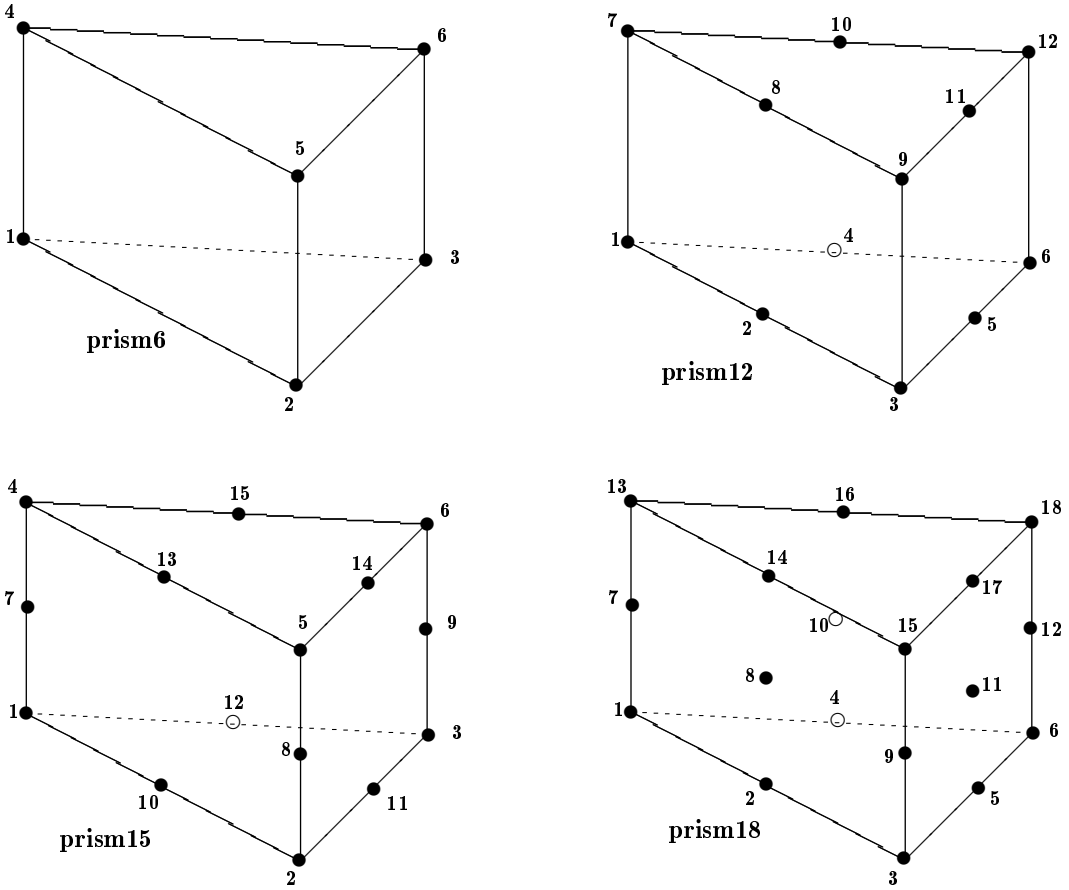
hex27



tet4



tet10



See also: **group_type** and **group_integration_points**.

6.414 element_beam_direction *index dir_x,x dir_x,y dir_x,z dir_y,x dir_y,y dir_y,z dir_z,x dir_z,y dir_z,z*

After the calculation, this record will be filled with the direction of a beam in space. The first three values give the direction of the local beam x direction, that is the beam torsion axis. The second three values give the direction of the local beam y direction, that is the beam y bending axis. The third three values give the direction of the local beam z direction, that is the beam z bending axis.

The *index* specifies the beam element number.

6.415 element_beam_direction_z *index dir_z,x dir_z,y dir_z,z*

The *index* specifies the beam element number.

Sate as **group_beam_direction_z**, but now per element however.

6.416 element_beam_force_moment *index force_x_first_node force_y_first_node force_z_first_node moment_x_first_node moment_y_first_node moment_z_first_node force_x_second_node force_y_second_node force_z_second_node moment_x_second_node moment_y_second_node moment_z_second_node* ...

After the calculation, this record will be filled with the forces and moments of a beam in the local beam axes x, y, z.

The *index* specifies the beam element number.

Attention: the values at the first node have a minus in their definition as compared with the values in the second node. For example in a beam number 20 with constant z moment of 10 you will find:

element_beam_force_moment 20 0. 0. 0. 0. 0. -10. 0. 0. 0. 0. 0. 10.

6.417 element_boundary *index switch*

The *switch* will be set to **-yes** if the element with index *index* is located on the boundary of the mesh.

This record will only become available if **mesh_boundary** is set to **-yes**. This record is meant for printing only, it should not be set by the user.

6.418 element_contact_spring_direction *index* $dirN_x$ $dirN_y$ $dirN_z$ $dirT1_x$ $dirT1_y$ $dirT1_z$ $dirT2_x$ $dirT2_y$ $dirT2_z$

In the input file, you can specify with this record the directions of a contact spring. If not specified, after the calculation this record will be filled with the used directions. The *index* specifies the spring element number.

6.419 element_contact_spring_strain *index strain_N strain_T1 strain_T2*

After the calculation, this record will be filled with the normal and tangential elongation in a contact_spring element. The *index* specifies the spring element number. The tangential strain *strain_T2* only is present in 3D.

6.420 element_contact_spring_force *index force_N force_T1 force_T2*

After the calculation, this record will be filled with the normal and tangential forces in a contact_spring element. The *index* specifies the spring element number. The tangential force *force_T2* only is present in 3D.

6.421 element_dof *index dof_0 dof_1 ...*

Unknowns as saved per element in the element nodes. First dof's in the first node. Then dof's in the second node. Etc.

This is done optionally by tochnog, only when needed for the calculation. The *index* specifies the element number.

6.422 element_dof_initial *index dof_0 dof_1 ...*

When an element comes the first time to live, it assumes that it had in the past the dof's specified in this **element_dof_initial** record. You can either specify one value for each dofor you can specify values for the dof's for all nodes (specify first all dof's for the first node, then specify the dof's for the second node, etc.). The *index* specifies the element number.

This record will influence inertia terms (like mass acceleration, temperature capacity, etc). As an example you can set so the initial temperature of a part that is connected to the mesh at some time.

6.423 element_dof_initial_specific_number *index number*

With this record you can an initial value for one specific dof. The *number* specifies the dof number, for example **-velx** or **-sigxx**, etc. The initial value for the dof needs to be specified with **element_dof_initial_specific_value**. The *index* specifies the element number.

6.424 element_dof_initial_specific_value *index value_0 value_grad_x value_grad_y value_grad_z*

This specifies for the **element_dof_initial_specific_number** record the initial value. Here *value_0* is the value at coordinate $x = y = z = 0$, *value_grad_x* is the x-gradient, *value_grad_y* is the y-gradient and *value_grad_z* is the z-gradient. In 1D you only need to specify for the gradients the *value_grad_x* and in 2D you only need to specify for the gradients the *value_grad_x* and *value_grad_y*. As special option you can specify no gradients at all, and then a constant value in space of size *value_0* will be used.

6.425 element_empty *index switch*

If Tochnog believes an element is empty, then it will set automatically *switch* to **-empty** for **element_empty**.

6.426 element_geometry *index geometry_set*

This data item specifies for element *index* a geometrical set number *geometry_set*. Elements with the same geometrical set number together form a geometry, which can be referenced by functionality selecting elements by a geometry. The syntax for referring is **-element_geometry** *geometry_set*.

A typical application would be changing material data (groups) in time for different sets of elements. In the example below element 1 belongs to geometrical set 10. The elements of geometrical set 10 get in time respectively groups 100, 101, 102 and 103.

```
element 1 -bar2 1 2
element 2 -bar2 2 3
element_geometry 1 10
element_geometry 2 20
...
area_element_group_sequence_time 11 0. 1. 2. 3.
area_element_group_sequence_geometry 11 -element_geometry 10
area_element_group_sequence_element_group 11 100 101 102 103
...
area_element_group_sequence_time 12 0. 1. 2. 3.
area_element_group_sequence_geometry 12 -element_geometry 20
area_element_group_sequence_element_group 12 200 201 202 203
...
```

The **element_geometry** cannot be used in a **geometry_set**.

6.427 element_geometry_present *index geometry_item_name_0 geometry_item_index_0 geometry_item_name_1 geometry_item_index_1 ...*

This record lists for element *index* the geometries in which it is present. So it is a print record only, for checking if the geometries include exactly the elements that you want. You can switch on or off filling of these records by setting **print_element_geometry_present** to **-yes** or **-no**.

6.428 element_group *index element_group*

This data item is specified which element data items should be taken for the element *index*. Example: elements 0 and 1 get density 1024 while element 2 gets density 1236

element 0 0 1 2
element 1 1 2 3
element 2 2 3 4
...
element_group 0 1
element_group 1 1
element_group 2 2
...
density 1 1024.
density 2 1236.

If no **element_group** records are specified, all element data should use *index* is 0.

See also **area_element_group** and **element_geometry**.

6.429 element_group_apply *index element_group_0 element_group_1 ...*

This is yet another option to change the group of elements. It works in combination with **control_element_group_apply**. We explain it by means of an example:

element 43 ...
element 44 ...
...
element_group_apply 43 1 7 4
element_group_apply 44 21 22 8
...

control_element_group_apply 10 0 (element 43 gets group 1, element 44 gets group 21)
...
control_element_group_apply 20 2 (element 43 gets group 4, element 44 gets group 8)
...
control_element_group_apply 30 1 (element 43 gets group 7, element 44 gets group 22)
...

6.430 element_interface_intpnt_direction *index normal_x_0 normal_y_0 normal_z_0 first_tangential_x_0 first_tangential_y_0 first_tangential_z_0 second_tangential_x_0 second_tangential_y_0 second_tangential_z_0 ...*

After the calculation this record will be filled with the direction vectors in interface element. Here *normal_x_0* is the x-component of the normal direction in the first integration point, etc.

6.431 element_interface_intpnt_gap_status *index status*

After the calculation, this record will be filled with the gap status in an interface element. The status is either **-opened** of **-closed**. The *index* specifies the interface element number.

6.432 element_interface_intpnt_materi_tension_status *index status*

After the calculation, this record will be filled with the materi tension status in an interface element. The status is either **-opened** of **-closed**. The *index* specifies the interface element number.

6.433 element_interface_intpnt_strain *index strain,normal,0 strain,shear,first,0 strain,shear,second,0 strain,normal,1 strain,shear,first,1 strain,shear,second,1 ...*

After the calculation, this record will be filled with the normal strain, the first shear strain and second shear strain in the integration points of an an interface element. The values with subscript 0 are for the first integration point; The values with subscript 1 are for the second integration point; etc. For a 2D interface element the second shear strain will not be set.

In fact, the normal strain is the normal displacement difference, and the shear strains are half of the shear displacement differences.

This **element_interface_intpnt_strain** record will only be filled if **materi_strain_total** is initialised. The *index* specifies the interface element number.

6.434 element_interface_intpnt_strain_average *index strain,normal,0 strain,shear,first,0 strain,shear,second,0*

Average of **element_interface_intpnt_strain**.

6.435 element_interface_intpnt_stress *index stress,normal,0 stress,shear,first,0 stress,shear,second,0 stress,normal,1 stress,shear,first,1 stress,shear,second,1 ...*

After the calculation, this record will be filled with the normal stress, the first shear stress and the second shear stress in the integration points of an an interface element. The values with subscript 0 are for the first integration point; The values with subscript 1 are for the second integration point; etc. For a 2D interface element the second shear stress will not be set.

The *index* specifies the interface element number.

See **control_reset_interface** on how to reset strains and stresses somewhere in a calculation.

6.436 element_interface_intpnt_stress_average *index stress,normal,0 stress,shear,first,0 stress,shear,second,0*

Average of **element_interface_intpnt_stress**.

6.437 element_intpnt_dof *index dof_0 dof_1 ...*

Unknowns as saved per element in the element integration points. The *index* specifies the element number.

6.438 element_intpnt_h *index ...*

This record is meant for printing only. It contains for each node of the element the value of the interpolation polynomial in the integration points.

6.439 element_intpnt_iso_coord *index ...*

This record is meant for printing only. It contains for each node of the element the value of the isoparametric coordinates in the integration points.

6.440 element_intpnt_materi_plasti_hardsoil_gammap_initial *index gammap_initial_integration_point_0 gammap_initial_integration_point_1 ...*

See theory section on hardsoil.

6.441 element_intpnt_materi_undrained_pressure *index undrained_total_pressure*

Total pressure from undrained analysis. See **group_materi_undrained_capacity**.

6.442 element_intpnt_method *index method*

This record is meant for printing only. It shows the space integration method that is actually used for element *index*. See also **group_integration_method**.

6.443 element_intpnt_npoint *index npoint*

This record is meant for printing only. It shows the number of space integration method points that are actually used for element *index*. See also **group_integration_points**.

6.444 element_middle *index middle_x middle_y middle_z*

After the calculation, this record will be filled with the middle coordinates of an element. The *index* specifies the element number.

6.445 element_normal *index normal_x normal_y normal_z*

This record will be generated in case it is needed during a calculation. It will contain the normal of an element in the inward normal direction of the mesh boundary. In 1d only *normal_x* will be filled. In 2d only *normal_x normal_y* will be filled. In 3d all of *normal_x normal_y normal_z* will be filled.

The side of an element is on the mesh boundary if no other element is connected to that side.

6.446 element_print_group_data_values *index ...*

Values as required by **print_group_data**. The first value as required by **print_group_data** is placed in the first value of **element_print_group_data_values**. The second value as required by **print_group_data** is placed in the second value of **element_print_group_data_values**. Etc. Please realise that some group data requires more than one value, so that more than one value is filled in the **element_print_group_data_values** record.

6.447 element_spring_force *index force*

After the calculation, this record will be filled with the force in a spring element. The *index* specifies the spring element number.

6.448 element_spring_strain *index strain*

After the calculation, this record will be filled with the strain in a spring element. In fact the strain in a spring element is the elongation of the spring. The *index* specifies the spring element number.

In case you perform a geotechnical analysis and want to set all strains in the model to 0 after gravity has been imposed, then do a **control_data_delete** on all **element_spring_strain** records. In such way the **element_spring_strain** records will contain in the remaining part of the calculation strains relative to the gravity status.

6.449 element_truss_direction *index dir_x dir_y dir_z*

After the calculation, this record will be filled with the direction of a truss in space. The *index* specifies the truss element number.

6.450 element_truss_force *index force*

After the calculation, this record will be filled with the normal force in a truss element. The *index* specifies the truss element number.

6.451 element_truss_strain *index strain*

After the calculation, this record will be filled with the strain in a truss element (length increase divided by length). The *index* specifies the truss element number.

6.452 element_truss_strain_temperature *index strain*

After the calculation, this record will be filled with the normal thermal strain in a truss element (thermal length increase divided by length). The *index* specifies the truss element number.

6.453 element_volume *index volume*

This record contains the volume of the isoparametric element number *index* after the calculation. In fact for 1D elements it contains the element length, for 2D elements it contains the element area, and for 3D elements it contains the element volume.

6.454 force_edge *index force_0 force_1 ...*

Distributed edge forces. These distributed forces are translated into equivalent nodal force terms on the edges of elements. You should specify a force term for each direction. Also the record **force_edge_geometry** should be specified, and optionally the records **force_edge_factor**, **force_edge_multi_linear_factor_x** and **force_edge_time** can be specified.

Attention: if this **force_edge** option is used INSIDE a FE mesh, then the elements on each side of the geometry will get the force. So you may need to specify only half of the physical force value.

Attention: this option is only available for linear and quadratic isoparametric elements.

6.455 force_edge_diagram *index vertical_displacement_0 factor_0 vertical_displacement_1 factor_1 ...*

This is a special purpose record, to make the specified forces dependent on vertical displacements. It actually contains multiplication factors for the force values as specified in the **force_edge** record with the same index. You need to specify sets of vertical displacements and corresponding multiplication values. Please realise the following:

- In many geotechnical calculations vertical displacements are negative (so eg vertical_displacement_0 is -3.e-2, vertical_displacement_1 is -2.e-2 , etc.)
- The vertical displacements should be specified from low to high in the diagram.
- You need to specify all possible displacement values in the diagram.

6.456 force_edge_element *index element_0 element_1 ...*

Selects the element for which the **force_edge** record with the same *index* should be applied.

6.457 force_edge_element_group *index element_group_0 element_group_1 ...*

Selects the element group for which the **force_edge** record with the same *index* should be applied.

6.458 force_edge_element_node *index element node_0 node_1 ...*

Selects the element and local node numbers for which the **force_edge** record with the same *index* should be applied.

6.459 force_edge_element_side *index element_0 element_1 ... side*

Selects the elements and local side number for which the **force_edge** record with the same *index* should be applied.

6.460 force_edge_factor *index* a_0 a_1 $\ldots a_n$

This data item defines a polynomial in space. This polynomial gives a factor which is used as a multiplication factor for **force_edge** records (with the same index). In this way, you can obtain coordinate dependent forces.

In 1D the polynomial is $a_0 + a_1 x$ (specify 2 values). In 2D the polynomial is $a_0 + a_1 x + a_2 y$ (specify 3 values). In 3D the polynomial is $a_0 + a_1 x + a_2 y + a_3 z$ (specify 4 values).

6.461 force_edge_geometry *index geometry_entity_name geometry_entity_index*

Selects the area for which the **force_edge** record with the same *index* should be applied. For example, **-geometry_line 1** can be used in 2D, indicating that the nodes on line 1 get the distributed force. The total edge of an element must be inside the geometry for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges.

6.462 force_edge_multi_linear_factor_x *index x_0 factor_0 x_1 factor_1 ...*

This factor is given as a multilinear diagram in x direction. This factor is used as a multiplication factor for **force_edge** records (with the same index). In this way, you can obtain x-coordinate dependent forces. Outside the specified x-range the factor will be taken as 0.

6.463 force_edge_node *index node_0 node_1 ...*

Selects the nodes for which the **force_edge** record with the same *index* should be applied. The *node_0* etc. specify global node numbers.

6.464 force_edge_node_factor *index* $factor_0$ $factor_1$ ...

Nodal multiplication factors with which the force of **force_edge** will be applied to the nodes of **force_edge_node**. You need to specify a factor for each node. Here $factor_0$ is the multiplication factor for the first node, etc.

6.465 force_edge_sine *index start_time end_time freq_0 amp_0 freq_1 amp_1 ...*

The **force_edge** record with the same *index* is imposed with the sum of the sine functions; the first sine function has frequency *freq_0* and amplitude *amp_0*, the second sine function has frequency *freq_1* and amplitude *amp_1*, etc.. The sine functions start at time 0. More general behavior in time can be imposed by using **force_edge_time** records. For a specific *index* only one of **force_edge_sine** and **force_edge_time** can be specified.

The sine loads will be only imposed after *start_time*, and only up to *end_time*.

More general time behavior can be specified with **force_edge_time**.

6.466 force_edge_time *index time load time load ...*

This record specifies a diagram which contains the factors with which the **force_edge** record with the same index is applied. Linear interpolation is used to extend the *time load* values to the intervals between these pairs. Outside the specified time range a factor 0 is used.

If this record is not specified, and the **force_edge_sine** record is not specified, the force is applied at all times with a factor 1.

If no external forces like **force_edge_time** are specified, the internal element forces become zero at free edges to satisfy equilibrium. This causes, for example, temperature gradients to become zero at free edges in heat problems.

6.467 force_edge_normal *index force*

Distributed normal force in the direction of the outward normal at the edge of a element. This distributed term is translated into equivalent nodal force terms on the edges of elements.

Also the record **force_edge_normal_geometry** should be specified, and optionally the record **force_edge_normal_time** can be specified.

Attention: this option is only available for linear and quadratic isoparametric elements.

Attention: if this **force_edge_normal** option is used INSIDE a FE mesh, then the elements on each side will get the force. So the total force will normally become zero since the normals of the elements at the side of the geometry are opposite.

6.468 force_edge_normal_element *index element_0 element_1 ...*

Restricts the element to which the **force_edge_normal** record with the same *index* should be applied.

6.469 force_edge_normal_element_node *index element node_0 node_1*

Selects the element and local node numbers for which the **force_edge_normal** record with the same *index* should be applied.

6.470 force_edge_normal_element_group *index element_group_0 element_group_1 ...*

Restricts the element group to which the **force_edge_normal** record with the same *index* should be applied.

6.471 force_edge_normal_element_side *index element_0 element_1 ... side*

Selects the elements and local side number for which the **force_edge_normal** record with the same *index* should be applied.

6.472 force_edge_normal_factor *index* a_0 a_1 $\ldots a_{n-1}$

This data item defines a polynomial in space. This polynomial gives a factor which is used as a multiplication factor for **force_edge_normal** records (with the same index). In this way, you can obtain coordinate dependent forces.

In 1D the polynomial is $a_0 + a_1 x$ (specify 2 values). In 2D the polynomial is $a_0 + a_1 x + a_2 y$ (specify 3 values). In 3D the polynomial is $a_0 + a_1 x + a_2 y + a_3 z$ (specify 4 values).

6.473 force_edge_normal_geometry *index geometry_ entity_ name geometry_ entity_ index*

Selects the area for which the **force_edge_normal** record with the same *index* should be applied. For example, **-geometry_line 1** can be used in 2D, indicating that the nodes on line 1 get the distributed force. The total edge of an element must be inside the geometry for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges.

6.474 force_edge_normal_node *index node_0 node_1 node_2 ...*

Selects the nodes for which the **force_edge_normal** record with the same *index* should be applied. The *node_0* etc. specify global node numbers.

6.475 force_edge_normal_node_factor *index* $factor_0$ $factor_1$ ...

Nodal multiplication factors with which the force of **force_edge_normal** will be applied to the nodes of **force_edge_normal_node**. You need to specify a factor for each node. Here $factor_0$ is the multiplication factor for the first node on the side, etc.

6.476 force_edge_normal_sine *index start_time end_time freq_0 amp_0 freq_1 amp_1 ...*

Same as **force_edge_sine**, now for normal edge loads however.

6.477 force_edge_normal_time *index time load time load ...*

This record specifies a diagram which contains the factors with which the **force_edge_normal** record with the same index is applied. Linear interpolation is used to extend the *time load* values to the intervals between these pairs. Outside the specified time range a factor 0 is used.

If this record is not specified, the force is applied at all times with a factor 1.

6.478 force_edge_projected *index force ph(0,0,0) ph_grad_x ph_grad_y ph_grad_z pv(0,0,0) pv_grad_x pv_grad_y pv_grad_z factor_normal factor_tangential vertical_dir_downward_x vertical_dir_downward_y vertical_dir_downward_z tunnel_dir_x tunnel_dir_y tunnel_z*

Distributed projected force on the edge of a element. This distributed term is translated into equivalent nodal force terms on the edges of elements.

This record typically can be used to model soil normal and tangential loading on tunnels. With ph(0,0,0) you specify the horizontal ground stress at x=0,y=0,z=0. With ph_grad_x, ph_grad_y and ph_grad_z you specify the gradients of the horizontal stress (such that a linear horizontal stress field can be modeled). With pv(0,0,0) you specify the vertical ground stress at x=0,y=0,z=0. With pv_grad_x, pv_grad_y and pv_grad_z you specify the gradients of the vertical stress (such that a linear vertical stress field can be modeled).

The vertical and horizontal stresses are projected on the edge of the element so that the radial stress sig_radial and the tangential stress sig_tangential of the edge of the element are obtained. You can decide to apply the radial stress sig_radial only with a factor factor_normal (between 0 and 1). Likewise, you can decide to apply the tangential shear stress sig_tangential only with a factor factor_tangential (between 0 and 1).

As extra information for Tochnog to determine the correct radial stress and tangential shear stress on the edge of an element you need to specify the downward vertical direction with vertical_dir_downward_x, vertical_dir_downward_y and vertical_dir_downward_z.

Only in 3D, you also need to specify the length direction of the tunnel axis with tunnel_dir_x, tunnel_dir_y and tunnel_z.

In 2D you should not specify the 3D information ph_grad_z, pv_grad_z, vertical_dir_downward_z , tunnel_dir_x, tunnel_dir_y and tunnel_z.

Also the record **force_edge_projected_geometry** should be used to specify where the force should be applied, and optionally the record **force_edge_projected_time** can be specified.

Attention: notice that horizontal soil stress in length direction of the tunnel is not included.

Attention: this option is only available for linear and quadratic isoparametric elements.

Attention: if this **force_edge_projected** option is used INSIDE a FE mesh, then the elements on each side will get the force. So the total force will protectedly become zero since the projected of the elements at the side of the geometry are opposite.

6.479 force_edge_projected_element *index element_0 element_1 ...*

Restricts the element to which the **force_edge_projected** record with the same *index* should be applied.

6.480 force_edge_projected_element_node *index element node_0 node_1 ...*

Selects the element and local nodes for which the **force_edge_projected** record with the same *index* should be applied.

6.481 force_edge_projected_element_group *index element_group_0 element_group_1 ...*

Restricts the element group to which the **force_edge_projected** record with the same *index* should be applied.

6.482 force_edge_projected_element_side *index element_0 element_1 ... side*

Selects the elements and local side number for which the **force_edge_projected** record with the same *index* should be applied.

6.483 force_edge_projected_factor *index* a_0 a_1 $\ldots a_n$

This data item defines a polynomial in space. This polynomial gives a factor which is used as a multiplication factor for **force_edge_projected** records (with the same index). In this way, you can obtain coordinate dependent forces.

In 1D the polynomial is $a_0 + a_1 x$ (specify 2 values). In 2D the polynomial is $a_0 + a_1 x + a_2 y$ (specify 3 values). In 3D the polynomial is $a_0 + a_1 x + a_2 y + a_3 z$ (specify 4 values).

6.484 force_edge_projected_geometry *index geometry_entity_name geometry_entity_index*

Selects the area for which the **force_edge_projected** record with the same *index* should be applied. For example, **-geometry_line 1** can be used in 2D, indicating that the nodes on line 1 get the distributed force. The total edge of an element must be inside the geometry for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges.

6.485 force_edge_projected_node *index node_0 node_1 node_2 ...*

Selects the nodes for which the **force_edge_projected** record with the same *index* should be applied. The *node_0* etc. specify global node numbers.

6.486 force_edge_projected_node_factor *index* $factor_0$ $factor_1$ ...

Nodal multiplication factors with which the force of **force_edge_projected** will be applied to the nodes of **force_edge_projected_node**. You need to specify a factor for each node. Here $factor_0$ is the multiplication factor for the first node, etc.

6.487 force_edge_projected_sine *index start_time end_time freq_0 amp_0 freq_1 amp_1 ...*

Similar to **force_edge_sine**, now for projected edge loads however.

6.488 force_edge_projected_time *index time load time load ...*

This record specifies a diagram which contains the factors with which the **force_edge_projected** record with the same index is applied. Linear interpolation is used to extend the *time load* values to the intervals between these pairs. Outside the specified time range a factor 0 is used.

If this record is not specified, the force is applied at all times with a factor 1.

6.489 force_edge_water *index switch*

If *switch* is set to **-yes**, distributed water pressure force is added to the model. This distributed term is translated into equivalent nodal force terms on the edges of elements. The distributed force is automatically calculated as density_water g Δz where g is the gravitational acceleration, and Δz is the distance to the phreatic level. The water pressure force acts normal to the element edge, in inward direction. You need to specify also **force_edge_water_geometry**.

The water density is given by **groundflow_density**. The gravity acceleration is given by the vertical component of **force_gravity**. The water height is relative to the water height is given by **groundflow_phreatic_level**.

Attention: if this **force_edge_water** option should be used with care INSIDE a FE mesh.

The total edge of an element must be inside the geometry for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges.

6.490 force_edge_water_element *index element_0 ...*

Selects the element for which the **force_edge_water** record with the same *index* should be applied.

6.491 force_edge_water_element_group *index element_group_0 ...*

Selects the element groups for which the **force_edge_water** record with the same *index* should be applied.

6.492 force_edge_water_element_node *index element node_0 node_1 ...*

Selects the element and local nodes for which the **force_edge_water** record with the same *index* should be applied.

6.493 force_edge_water_element_side *index element_0 element_1 ... side*

Selects the elements and local side number for which the **force_edge_water** record with the same *index* should be applied.

6.494 force_edge_water_factor *index* a_0 a_1 $\ldots a_n$

This data item defines a polynomial in space. This polynomial gives a factor which is used as a multiplication factor for **force_edge_water** records (with the same index). In this way, you can obtain coordinate dependent forces.

In 1D the polynomial is $a_0 + a_1 x$ (specify 2 values). In 2D the polynomial is $a_0 + a_1 x + a_2 y$ (specify 3 values). In 3D the polynomial is $a_0 + a_1 x + a_2 y + a_3 z$ (specify 4 values).

6.495 force_edge_water_geometry *index geometry_item_name geometry_item_index*

Selects the area for which the **force_edge_water** record with the same *index* should be applied. For example, **-geometry_line 1** can be used in 2D, indicating that the nodes on line 1 get the distributed water pressure force.

6.496 force_edge_water_node *index node_0 node_1 ...*

Selects the nodes for which the **force_edge_water** record with the same *index* should be applied. The *node_0* etc. specify global node numbers.

6.497 force_edge_water_time *index time load time load ...*

This record specifies a diagram which contains the factors with which the **force_edge_water** record with the same index is applied. Linear interpolation is used to extend the *time load* values to the intervals between these pairs. Outside the specified time range a factor 0 is used.

If this record is not specified, the force is applied at all times with a factor 1.

6.498 force_gravity *g_x g_y g_z*

Gravitational acceleration.

In 1D, only the gravity in x-direction needs to be specified. In 2D, the gravity in x-direction and y-direction needs to be specified. In 3D, the gravity in x-direction, y-direction and z-direction needs to be specified.

See also **force_gravity_time**.

6.499 force_gravity_geometry *geometry_item_name geometry_item_index*

With this record you can specify a geometrical entity on which the gravity force should be used. Only elements inside the geometry get the gravity force.

If this record is not specified all elements can get the gravity force.

See also **force_gravity_time**.

6.500 force_gravity_time *time load time load ...*

This record specifies a multi-linear diagram which contains the factors with which the **force_gravity** record is applied. This allows you to impose the gravity on a structure slowly, which might be needed for path dependent problems. Outside the specified time range a factor 0 is used.

If this record is not specified, the gravity is applied at all times with a factor 1.

6.501 force_point *index coord_ 0 coord_ 1 coord_ 2 force_ 0 force_ 1 force_ 2*

Point force in space; it needs not to be exactly in a node. The force will be distributed over the element nodes in which the point force is located. This will be done consistent with the element interpolation functions (linear or quadratic).

The *coord_ 0* specifies the x-coordinate in space. The *coord_ 1* specifies the y-coordinate in space (only in two or 3 dimensions). The *coord_ 2* specifies the z-coordinate in space (only in 3 dimensions). The *force_ 0* specifies the x-force in space. The *force_ 1* specifies the y-force in space (only in two or 3 dimensions). The *force_ 2* specifies the z-force in space (only in 3 dimensions).

You can use the usual **change_dataitem_time** to change the position (or value) of the point force in time.

6.502 force_volume *index force_ 0 force_ 1 ...*

Distributed volume forces for each direction. Here *force_ 0* is the distributed force in the x-direction, etc. Consider the example with distributed volume force in x-direction for a 2D material:

force_volume 0 1.0.

The **force_volume** record can be used in **dependency_diagram** records (just like element group data)/

See also **force_volume_factor**, **force_volume_geometry**, and **force_volume_time**.

6.503 force_volume_element *index element_ 0 element_ 1 ...*

Specifies the elements for which the **force_volume** record with the same *index* should be applied.

6.504 force_volume_element_group_0 element_group_1 ... *index element_ group*

Specifies the element group for which the **force_volume** record with the same *index* should be applied.

6.505 force_volume_factor *index* a_0 a_1 ... a_n

This polynomial gives a factor which is used as a multiplication factor for **force_volume** records (with the same index). In this way, you can obtain coordinate dependent forces.

In 1D the polynomial is $a_0 + a_1 x$ (specify 2 values). In 2D the polynomial is $a_0 + a_1 x + a_2 y$ (specify 3 values). In 3D the polynomial is $a_0 + a_1 x + a_2 y + a_3 z$ (specify 4 values).

6.506 force_volume_geometry *index geometry_ item_ name geometry_ item_ index*

Specifies the area for which the **force_volume** record with the same *index* should be applied. For example, **-geometry_quadrilateral 1** can be used in 2D, indicating that the elements on quadrilateral 1 get the distributed force.

If both the **force_volume_element** and **force_volume_geometry** are not specified, then a geometry which encloses the whole model will be applied.

6.507 force_volume_sine *index start_ time freq_ 0 amp_ 0 freq_ 1 amp_ 1 ...*

Same as **force_volume_sine**, now for volume loads however.

6.508 force_volume_time *index time load time load ...*

This record specifies a multi-linear diagram which contains the factors with which the **force_volume** record with the same index is applied.

If this record is not specified, the force is applied at all times with a factor 1.

6.509 geometry_boundary *index switch*

With this record you can restrict a geometry to the boundary of the mesh, or to the inside of the mesh. If *switch* is set to **-yes** only nodes which are at the boundary of the mesh are actually used for the geometry with the same index. If *switch* is set to **-no** only nodes which are not at the boundary of the mesh are actually used for the geometry with the same index.

Attention: for this option to work correctly, the mesh should not contain badly shaped elements. See the section at the end of this manual for more information on bad element shapes.

6.510 geometry_bounda_sine_x *index a b*

This sets, for the geometrical entity with the same index an extra factor which is used for the **bounda_dof** and the **bounda_force** records. The factor gives a sinus variation in x-direction. The size of the factor is $sin(a + b * x)$.

6.511 geometry_bounda_sine_y *index a b*

This sets, for the geometrical entity with the same index an extra factor which is used for the **bounda_dof** and the **bounda_force** records. The factor gives a sinus variation in y-direction. The size of the factor is $sin(a + b * y)$.

6.512 geometry_bounda_sine_z *index a b*

This sets, for the geometrical entity with the same index an extra factor which is used for the **bounda_dof** and the **bounda_force** records. The factor gives a sinus variation in z-direction. The size of the factor is $sin(a + b * z)$.

6.513 geometry_brick *index x_c y_c z_c l_x l_y l_z tolerance*

This data item defines a brick in space. Other data items can check if nodes are located on this geometry. The coordinate of the center is *x_c y_c z_c*. The length in respectively x, y and z direction are *l_x l_y l_z*. All **node** within a distance *tolerance* are considered to be part of the brick.

6.514 geometry_circle *index x_c y_c ... radius tolerance*

This data item defines a circle in space. Other data items can check if nodes are located on this geometry. The coordinate of the center is *x_c y_c*. In 2D you need to specify *x_c y_c radius tolerance*. In 2D all **node** within a distance *tolerance* of the radius are considered to be part of the circle. In 3D you need to specify *x_c y_c z_c normal_x normal_y normal_z radius tolerance*, where *normal_x normal_y normal_z* specifies the direction normal to the surface. In 3D all **node** within a distance *tolerance* of the circle surface are considered to be part of the circle.

6.515 geometry_circle_part *index x_c y_c angle_start angle_end radius tolerance*

This data item defines a circle in 2D space. Other data items can check if nodes are located on this geometry. The coordinate of the center is *x_c y_c*. All **node** within a distance

tolerance of the radius are considered to be part of the circle. The circle part starts at angle *angle_start*, measured in radians from the positive x-axis. The circle part ends at angle *angle_end*, measured in radians from the positive x-axis.

6.516 geometry_circle_segment *index x_c y_c radius side_x side_y tolerance*

This data item defines a circle segment in space. Other data items can check if nodes are located on this geometry. The coordinate of the center is *x_c y_c*. If *side_x* is set to a positive value, say +1., then only x-values larger then *x_c* are considered to be part of the geometry. If *side_x* is set to a negative value, say -1., then only x-values smaller then *x_c* are considered to be part of the geometry. If *side_x* is set to 0 , then all x-values are considered to be part of the geometry. Likewise remarks hold for y-values. All **node** within a distance *tolerance* of the radius are considered to be part of the circle segment.

6.517 geometry_cylinder *index x_0 y_0 z_0 x_1 y_1 z_1 radius tolerance*

This data item defines a cylinder segment in space. Other data items can check if nodes are located on this geometry. The coordinate of the center point at the bottom is *x_0 y_0 z_0*. The coordinate of the center point at the top is *x_1 y_1 z_1*. The cylinder can only be used in 3D. All **node** within a distance *tolerance* of the radius are considered to be part of the cylinder.

6.518 geometry_cylinder_part *index x_0 y_0 z_0 x_1 y_1 z_1 radius angle_start_0 angle_end_0 angle_start_1 angle_end_1 ... tolerance*

This data item defines parts of a cylinder in space. Other data items can check if nodes are located on this geometry.

The *index x_0 y_0 z_0 x_1 y_1 z_1 radius* are the same as in **geometry_cylinder**.

The *angle_start_0 angle_end_0* defines the first valid part of the cylinder, where *angle_start_0* is the start angle of the part and *angle_end_0* is the end angle. The angles are measured in the x-y plane, starting from the positive x-axis towards the positive y-axis. Likewise, the *angle_start_1 angle_end_1* defines a second valid part of the cylinder. You should define at least one valid part, and optionally you can specify several valid parts.

Start angles and end angles should be non-negative. End angles should be larger than start angles.

Angles will be measured relative to the vector as specified in **geometry_cylinder_part_start_vector**, if that vector is specified. This **geometry_cylinder_part_start_vector** should be specified perpendicular to the cylinder axes. This **geometry_cylinder_part_start_vector**

should be exactly in the middle of the angle range that you want to select. With **geometry_cylinder_part_start_vector** only one angle range is allowed, and the start angle should be 0. All nodes with an angle smaller or equal to the end angle are accepted as valid (thus, you get a total angle range of twice the end angle size as valid range).

If **geometry_cylinder_part_start_vector** is not specified, the **geometry_cylinder_part** should be either along the x-direction, y-direction or z-direction; then the angle is measured relative to the axes (for example for a cylinder along the z-direction the angle starts at the x-axes).

All **node** within a distance *tolerance* of the radius and inside a valid part are considered to be part of the cylinder part.

6.519 geometry_cylinder_part_start_vector *index v_x v_y v_z*

See **geometry_cylinder_part**.

6.520 geometry_cylinder_segment *index x_0 y_0 z_0 x_1 y_1 z_1 radius side_x side_y side_z tolerance*

This data item defines a cylindrical segment in space. Other data items can check if nodes are located on this geometry. The coordinate of the center point at the bottom is *x_0 y_0 z_0*. The coordinate of the center point at the top is *x_1 y_1 z_1*. If *side_x* is set to a positive value, say +1., then only x-values larger then *x_c* are considered to be part of the geometry. If *side_y* is set to a negative value, say -1., then only x-values smaller then *x_c* are considered to be part of the geometry. If *side_x* is set to 0 , then all x-values are considered to be part of the geometry. Likewise remarks hold for y- and z-values. The cylinder segment can only be used in 3D. All **node** within a distance *tolerance* of the radius are considered to be part of the cylinder.

6.521 geometry_exclude *index geometry_item_name_0 geometry_item_index_0 geometry_item_name_1 geometry_item_index_1 ...*

With this record you can exclude geometries from the geometry with the same index. The next 2D example excludes a circular area with radius 0.3 inside a quadrilateral:

```
...
geometry_quadrilateral 10 0. 0. 1. 0. 0. 1. 1. 1.
geometry_exclude 10 -geometry_point 20

geometry_point 20 0.5 0.5 0.3
...
```

You are not allowed to let a **geometry_*** use a **geometry_exclude** which contains itself.

6.522 geometry_element_geometry *index element_geometry_0 element_geometry_1 ...*

Similar to **geometry_element_group** , but now using **element_geometry** i.s.o. **element_group** however.

6.523 geometry_element_geometry_method *index method*

Similar to **geometry_element_group_method**.

6.524 geometry_element_group *index element_group_0 element_group_1 ...*

With this record you can restrict the geometry as specified in the geometry record with the same *index*. For example for the geometry as specified by

```
...
geometry_quadrilateral 10 ...
geometry_element_group 10 ...
...
```

nodes which are located on the **geometry_quadrilateral 10**, but at the same time are also a node of elements of one of the specified element groups *element_group_0 element_group_1* etc., belong to the geometry. Nodes which are not a node of elements of one of the groups do not belong to the geometry, even if such nodes are located on the **geometry_quadrilateral 10**.

See also **geometry_element_group_method**.

6.525 geometry_element_group_method *index method*

With this record you can set the *method* that the **geometry_element_group** record uses. If *method* is set to **-all** then a node should be attached to all the specified element groups, to be part of the geometry. If *method* is set to **-any** then a node should be attached to any of the specified element groups, to be part of the geometry. If *method* is set to **-only** then a node should be attached to only the specified element groups, to be part of the geometry. Default, if *method* is not specified then **-any** is assumed.

6.526 geometry_ellipse *index x_ c y_ c a b tolerance*

The coordinate of the center is *x_ c y_ c*. The equation for the ellipse is:

$$\left(\frac{x - x\_c}{a}\right)^2 + \left(\frac{y - y\_c}{b}\right)^2 = 1$$

Other data items can check if nodes are located on this geometry. The ellipse can only be used in 2D. All **node** within a distance *tolerance* of the ellipse are considered to be part of the ellipse.

6.527 geometry_factor *index factor_ 0 ...*

This sets for some geometries extra factors which are used for the **bounda_dof**, **bounda_force** and **force_edge_*** records. For a **geometry_line** either 2 or 3 factors should be specified; 2 factors define a linear variation where the factors hold at the start and end of the line respectively; 3 factors define a parabolic variation where the factors hold at the start, at the middle and at the end of the line respectively. For a **geometry_triangle** 3 factors should be specified (a linear variation with factors for the first, second and third corner point respectively). For a **geometry_quadrilateral** 4 factors should be specified (a linear variation with factors for the first, second, third and fourth corner point respectively). For a **geometry_point** 1 factor should be specified; a multiplication with a half sine wave will be used, with the specified factor in the middle (exactly at the point) creasing to factor 0 at a distance *tolerance* from the point,

In the example below, node 2 will get temperature $20 * 1.6$ and node 3 will get temperature $20 * 2.2$.

```
...
number_of_space_dimensions 2
condif_temperature
...
end_initia
node 2 0.2 0
node 3 0.4 0.
...
geometry_line 1 0. 0. 1. 0. 0.01
geometry_factor 1 1. 4.
bounda_dof 0 -geometry_line 1 -temp
bounda_time 0 0. 20. 1.e6 20.
...
end_data
```

6.528 geometry_hexahedral *index x_0 y_0 z_0 x_1 y_1 z_1 x_2 y_2 z_2 x_3 y_3 z_3 x_4 y_4 z_4 x_5 y_5 z_5 x_6 y_6 z_6 x_7 y_7 z_7*

This data item defines a hexahedral in space. Other data items can check if nodes are located on this geometry (everything inside the hexahedral belongs to the geometry). The coordinates of the corner points are *x_0 y_0 z_0* etc.. The points of the hexahedral should be specified in the correct order; the order is clarified in the example below.

Example

```
...
number_of_space_dimensions 3
...
geometry_hexahedral 0 0. 0. 0. 1. 0. 0. 0. 1. 0. 1. 1. 0. 0. 0. 1. 1.
0. 1. 0. 1. 1. 1. 1. 1.
...
```

Notice the order in which the points are to be specified.

6.529 geometry_line *index x_0 y_0 z_0 x_1 y_1 z_1 radius*

This data item defines a line in space. Other data items can check if nodes are located on this geometry. Coordinates of the end points are denoted by *x_0*, etc.. In 1D, only the x-coordinates should be specified, etc.. All **node** within a distance *radius* are considered to be part of the line.

In the example, a line in 2D space is defined and is used by a **convection_geometry** record (nodes located on the line will convect heat)

```
...
geometry_line 2 1. 0. 1. 1. 0.01
...
group_condif_convection_edge_normal_geometry 0 -geometry_line
2
...
```

6.530 geometry_line_eps_iso *index iso_tolerance*

With this parameter you can ask Tochnog to accept points just outside the line in direction of the line. Typically try $1.e-3$ for *iso_tolerance* .

6.531 geometry_list *index number_0 number_1 ...*

This is a list of numbers which can be used in geometry selection options.

For example

...
geometry_list 10 1 45 43 26 27
...
bounda_dof 200 -geometry_list 10 ... (set the boundary condition on the nodes of the list)
...

6.532 geometry_method *index method*

For selecting elements with a geometry enity you can set the *method* either to **-all**, **-any** or **-average**. With **-all** all nodes of an element should be inside the geometry entity for the element to be selected (completely inside). With **-any** any node of an element should be inside the geometry entity for the element to be selected (at least partially inside). With **-average** the middle coordinate of an element should be inside the geometry entity for the element to be selected. Default if this record is not specified the *method* is set to **-all**.

6.533 geometry_moving *index geometry_entity*

This option comes handy when you want to model moving excavations in complex FE meshes. For complex geological regions it is not possible to make the FE mesh a priori in such way that the excavation zones can be easily defined in terms of element groups or otherwise. In such case this option allows geometrical entities to move through the complex FE mesh. The geometrical entity will determine automatically which elements become part of the entity at which times, and then will automatically excavate those elements. Elements which are at a moment in time only partly inside the geometrical entity, will be only partly excavated to the same amount as which they are inside the geometrical entity. Elements which are at a moment in time completely inside the geometrical entity, will be fully excavated.

We first explain the usage of this option by means of an example:

...
geometry_moving 10 -geometry_point (geometical point that will move in space and excavate the mesh)
geometry_moving_parameter 10 -1. -1. 2.e-1 (start x-coordinate of

point, start y-coordinate of point, radius of point)
geometry_moving_operat 10 -translate (translate the point in space)
geometry_moving_operat_parameter 10 1. 1. (velocity of point in x-direction, velocity of point in y-direction)
geometry_moving_operat_time 10 0. 3. (start time of point moving, end time of point moving)
geometry_moving_n 10 200 200 (number of time discretision, number of space distretisation)
...
mesh_delete_geometry_moving 10 10 (tell Tochnog to use the geometry_moving records with index 10 to excavate the mesh)
...
control_geometry_moving 25 -initialise (prepare the point for moving through the mesh)
...
control_timestep 30 ...
...

The geometrical entity can be one of **-geometry_point**, **-geometry_triangle**, **-geometry_quadrilateral**, **-geometry_hexahedral** and **-geometry_tethrahedral**.

6.534 geometry_moving_parameter *index parameters of entity*

For each vertex of the geometry you need to specify the initial x-coordinate, y-coordinate (only for 2D and 3D) and z-coordinate. A point has one vertex, a triangle three, a quadrilateral four, a hexahedral eight and a tethrahedral six. The sequence of the vertices is the same as the sequence of nodes for the similar finite elements (see **element**). For a **-geometry_point** you need to specify additionally the radius.

See also **geometry_moving**.

6.535 geometry_moving_operat *index operator*

This *operator* specifies how the geometry changes between *time_start* and *time_end*. If *operator* is set to **-translate** the geometry moves in space with a constant velocity vector.

See also **geometry_moving**.

6.536 geometry_moving_operat_parameter *index parameters of operator*

For a **-translate** you need to specify the x-velocity, y-velocity (only for 2D and 3D) and z-cvelocity.

See also **geometry_moving**.

6.537 geometry_moving_operat_time *index start_time end_time*

The *start_time* specifies when the geometry comes into existance and starts to move. The *end_time* specifies when the geometry stops moving but remains in existance.

See also **geometry_moving**.

6.538 geometry_moving_n *index ntime nspace*

The **geometry_moving** command needs to find out for each element at each time point which part of the element is part of the geometrical entity. In order to found this out, it is checked for many points inside each element if the point is inside the geometrical entity. In fact, for a 1D element *nspace* points will be used, for a 2D element *nspace* * *nspace* points will be used and for *nspace* * *nspace* * *nspace* points will be used.

This checking which part of each element is inside the geometrical entity will be done at *ntime* time moments between *time_start* and *time_end*.

Default, if **geometry_moving** is not specified, we use *ntime* is 100 and *nspace* is 5.

See also **geometry_moving**.

6.539 geometry_mpc *index switch*

With this record you can restrict the geometry as specified in the geometry record with the same *index*. Only nodes which have mpc's are considered to be part of the geometry.

6.540 geometry_node_type *node_type*

If *node_type* is set to **-node_start_refined** the values of **-node_start_refined** are used for evaluating the geometry. If *node_type* is set to **-node** the values of **-node** are used for evaluating the geometry. If *node_type* is set to **-plus_displacement** the values of **-node** plus nodal displacements are used for evaluating the geometry. Default *node_type* is set to **-node_start_refined**.

6.541 geometry_point *index x y z radius*

This data item defines a point in space. Other data items can check if nodes are located on this geometry. The coordinate of the point is *x y z*. In 1D, only *x* should be specified, etc.. All **node** within a distance *radius* are considered to be part of the point.

6.542 geometry_polynomial *index* a_0 a_1 $\ldots a_n$ *x_0 x_1 y_0 y_1 tolerance*

This data item defines a polynomial in space in 2D or 3D. Other data items can check if nodes are located on this geometry.

In 2D the polynomial is $a_0 + a_1 x + a_2 y$ (specify 3 values). In 3D the polynomial is $a_0 + a_1 x + a_2 y + a_3 z$ (specify 4 values).

In 2D $x_0 - x_1$ defines the domain of x. In 3D $x_0 - x_1$ defines the domain of x and $y_0 - y_1$ defines the domain of y. All **node** with a distance (that is the y-distance in 2D or the z-distance in 3D) not more than *tolerance* are considered to be part of the polynomial.

6.543 geometry_projection_type *index type*

This record allows you to control what geometry will actually be used. Set *type* to **-project_inside** or **-project_exact**. For example if the geometry is a **geometry_circle** then **-project_inside** means that everything inside the circle will be used, whereas **-project_exact** means that everything within a tolerance from the circle edge will be used. Default *type* is **-project_exact**.

6.544 geometry_quadrilateral *index x_0 y_0 z_0 x_1 y_1 z_1 x_2 y_2 z_2 x_3 y_3 z_3 tolerance*

This data item defines a quadrilateral in space. Other data items can check if nodes are located on this geometry. The coordinates of the corner points are *x_0 y_0 z_0* etc.. In 2D, only *x_0*, *y_0* etc. should be specified etc.. The points of the quadrilateral should be specified in the correct order; the order is clarified in the example below.

In 2D all **node** inside the quadrilateral (the tolerance is neglected). In 3D all **node** within a distance *tolerance* are considered to be part of the quadrilateral (this is a brick with thickness *tolerance*). All **node** within a distance *tolerance* are considered to be part of the quadrilateral (in 2D this gives a quadrilateral with corners nodes specified by the corners points, in 3D this gives a brick corners nodes specified by the corners points and with thickness *tolerance*). Internally in TOCHNOG, the quadrilateral is divided into two **geometry_triangle**s, which is only approximately true if the quadrilateral is twisted. Example

```
...
number_of_space_dimensions 2
...
geometry_quadrilateral 0 0. 0. 1. 0. 0. 1. 1. 1. 1.e-3
...
```

Notice the order in which the points are to be specified.

6.545 geometry_quadrilateral_eps_iso *index iso_tolerance*

With this parameter you can ask Tochnog to accept points just outside the quadrilateral in direction of the quadrilateral plane. Typically try $1.e-3$ for *iso_tolerance* .

6.546 geometry_set *index geometry_entity_0 geometry_entity_index_0 geometry_entity_1 geometry_entity_index_1 ...*

This set combines a number of geometrical entities (e.g. **geometry_circle**, **geometry_line**, etc.) into a new entity. You cannot use another geometry set for the geometrical entities (that is, geometry sets cannot be nested).

Other data items can check if nodes are located on this geometry.

6.547 geometry_sphere *index x_c y_c z_c radius tolerance*

This data item defines a sphere in space. Other data items can check if nodes are located on this geometry. The coordinate of the center is *x_c y_c z_c*. All **node** within a distance *tolerance* of *radius* are considered to be part of the sphere.

6.548 geometry_sphere_segment *index x_c y_c z_c radius side_x side_y side_z tolerance*

This data item defines a spherical segment in space. Other data items can check if nodes are located on this geometry. The coordinate of the center is *x_c y_c z_c*. If *side_x* is set to a positive value, say +1., then only x-values larger then *x_c* are considered to be part of the geometry. If *side_x* is set to a negative value, say -1., then only x-values smaller then *x_c* are considered to be part of the geometry. If *side_x* is set to 0 , then all x-values are considered to be part of the geometry. Likewise remarks hold for y- and z-values.

All **node** within a distance *tolerance* of *radius* are considered to be part of the spherical segment.

6.549 geometry_tetrahedral *index x_0 y_0 z_0 x_1 y_1 z_1 x_2 y_2 z_2 x_3 y_3 z_3*

This data item defines a tetrahedral in space. Other data items can check if nodes are located on this geometry. The coordinates of the corner points are *x_0 y_0 z_0* etc..

6.550 geometry_triangle *index x_0 y_0 z_0 x_1 y_1 z_1 x_2 y_2 z_2 tolerance*

This data item defines a triangle in space. Other data items can check if nodes are located on this geometry. The coordinates of the corner points are *x_0 y_0 z_0* etc.. In 2D the z coordinates should not be specified. All **node** within a distance *tolerance* are considered to be part of the triangle (this gives a wedge with thickness 2*tolerance*).

6.551 geometry_triangle_eps_iso *index iso_tolerance*

With this parameter you can ask Tochnog to accept points just outside the triangle in direction of the triangle plane. Typically try $1.e-3$ for *iso_tolerance* .

6.552 global_node_dof_empty *switch*

If *switch* is set to **-yes**, the dof's in a node are set to zero when the node is only connected to empty elements. If *switch* is set to **-no**, the dof's in a node are not set to zero when the node is only connected to empty elements. Default *switch* is set to **-yes**.

6.553 global_element_dof_apply *switch*

If you set **switch** to **-yes**, then dof's like strains, stresses, etc. will be saved in the element integration points in the records **element_intpnt_dof**. So, not the dof's from the global nodes will be used, but each element uses its own values for these dof's in the integration points. This will only be done for dof's like strains, stresses, history variables, etc. Other principal dof's like velocities, temperature, etc. are used from the global nodes.

If you set **switch** to **-no**, then elements will actually use the averaged nodal results, and will not remember its own values.

Default, if **global_element_dof_apply** is not specified, **global_element_dof_apply** is set to **-yes**. See also **global_element_dof_from_node_dof** .

Realise that even when the dofs like strains, stresses etc are remembered and stored in integration points, they still be be added to the global node dofs to facilitate, for example, plot programs using thse nodal results for plotting. As a special option you can suppressing

this adding to tha global nodal dofs by using **-only** for the *switch*; then again the dofs like strains, stresses etc. are remembered in integration points, but now also these dofs are not added to the global node dofs.

6.554 global_element_dof_from_node_dof *switch*

If **global_element_dof_apply** is set to **-yes**, and the **element_intpnt_dof** record does not exist, but **node_dof** records exist in the input file, you can either require that the **element_intpnt_dof** records will be initialised from the **node_dof** records, or will not be initialised from the **node_dof** records. If you set *switch* to **-yes** the **element_intpnt_dof** records will be initialised from the **node_dof** records. If you set *switch* to **-no** the **element_intpnt_dof** records will not be initialised from the **node_dof** records. Default, if **global_element_dof_from_node_dof** is not specified, *switch* is set to **-no**.

6.555 global_post_point_node_type *node_type*

With this record you can determine how records like **post_point**, **control_print_dof_point** and **control_print_dof_line** are evaluated. If *node_type* is set to **-node** the current nodal coordinates for elements are used to determine for which material point inside elements the dof's should be determined; if you do an updated lagrange calculation in which the coordinates of nodes change, so the **node** records change, you get dof results for the material at the current moment presented on the point or line. If *node_type* is set to **-node_start_refined** the initial start nodal coordinates for elements are used to determine for which material point inside elements the dof's should be determined; thus you get dof results for the material at the initial start moment presented on the point or line.

Default, if this record is not set, *node_type* is set to **-node_start_refined**.

6.556 groundflow_apply *switch*

If *switch* is set to **-no**, then the groundflow equation is skipped, and all groundflow data is ignored. This is done for all timesteps.

6.557 groundflow_consolidation_apply *switch*

If *switch* is set to **-no**, then the material divergence part in the groundflow equation is skipped. This is done for all timesteps.

Default *switch* is **-no**.

6.558 groundflow_density ρ

Density of ground water.

6.559 groundflow_flux_edge_normal *index flux*

Distributed prescribed water flux normal to the edge of an element. This distributed flux is translated into equivalent nodal flux on the edges of elements. Also the record **groundflow_flux_edge_normal_geometry** should be specified, and optionally the record **groundflow_flux_edge_normal_time** can be specified.

Attention: this option is only available for linear and quadratic isoparametric elements.

Attention: if this option is used INSIDE a FE mesh, then the elements on each side will get the distributed flux. So the total water flux will normally become zero since the normals of the elements at the side of the geometry are opposite.

6.560 groundflow_flux_edge_normal_element *index element_0 element_1 ...*

Restricts the elements to which the **groundflow_flux_edge_normal** record with the same *index* should be applied.

6.561 groundflow_flux_edge_normal_element_group *index element_group_0 element_group_1 ...*

Restricts the element groups to which the **groundflow_flux_edge_normal** record with the same *index* should be applied.

6.562 groundflow_flux_edge_normal_element_node *index element node_0 node_1 ...*

Selects the element and local node numbers for which the **groundflow_flux_edge_normal** record with the same *index* should be applied.

6.563 groundflow_flux_edge_normal_element_node_factor *index* $factor_0$ $factor_1$ ...

Nodal multiplication factors with which the **groundflow_flux_edge_normal** will be applied to the element of **groundflow_flux_edge_normal_element_node**. You need

to specify a factor for each node on the side. Here $factor_0$ is the multiplication factor for the first node on the side, etc.

6.564 groundflow_flux_edge_normal_element_side *index element_0 element_1 ... side*

Selects the elements and local side number for which the **groundflow_flux_edge_normal** record with the same *index* should be applied.

6.565 groundflow_flux_edge_normal_factor *index* a_0 a_1 ... a_n

This data item defines a polynomial in space. This polynomial gives a factor which is used as a multiplication factor for **groundflow_flux_edge_normal** records (with the same index). In this way, you can obtain coordinate dependent water fluxes.

In 1D the polynomial is $a_0 + a_1 x$ (specify 2 values). In 2D the polynomial is $a_0 + a_1 x + a_2 y$ (specify 3 values). In 3D the polynomial is $a_0 + a_1 x + a_2 y + a_3 z$ (specify 4 values).

6.566 groundflow_flux_edge_normal_geometry *index geometry_entity_name geometry_entity_index*

Selects the area for which the **groundflow_flux_edge_normal** record with the same *index* should be applied. For example, **-geometry_line 1** can be used in 2D, indicating that the nodes on line 1 get the distributed flux. The total edge of an element must be inside the geometry for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges.

6.567 groundflow_flux_edge_normal_node *index node_0 node_1 node_2 ...*

Selects the nodes for which the **groundflow_flux_edge_normal** record with the same *index* should be applied. The *node_0* etc. specify global node numbers.

6.568 groundflow_flux_edge_normal_sine *index start_time end_time freq_0 amp_0 freq_1 amp_1 ...*

Similar to **force_edge_sine**, now for water flux however.

6.569 groundflow_flux_edge_normal_time *index time load time load ...*

This record specifies a diagram which contains the factors with which the **groundflow_flux_edge_normal** record with the same index is applied. Linear interpolation is used to extend the *time load* values to the intervals between these pairs. Outside the specified time range a factor 0 is used.

If this record is not specified, the flux is applied at all times with a factor 1.

6.570 groundflow_nonsaturated_apply *index switch*

If *switch* is set to **-no**, then nonsaturated groundflow data (eg van Genuchten) will not be applied; only saturated data will be used. This is done for all timesteps.

Default *switch* is **-yes**.

6.571 groundflow_phreatic_bounda *switch*

If *method* is set to **-yes**, the phreatic level is used to automatically prescribe the hydraulic pressure head of nodes which are located on or above the phreatic level.

Default, if **groundflow_phreatic_bounda** is not specified, *method* is set to **-yes**,

6.572 groundflow_phreatic_level ...

Groundwater level.

In a 1D calculation this record should be given x value of the groundwater level. The groundwater is below that x-value.

In a 2D calculation this record should be given sets of $x - y$ which specify the y level of the groundwater at several x locations; In 2D you need to give the $x - y$ sets as follows:

- specify $x - y$ sets for increasing x

In 3D the phreatic line is specified as follows. Denote the lowest x with x_0, the next higher x with x_1 etc. Denote the lowest y with y_0, the next higher y with y_1 etc. Denote the phreatic level z value for x_i y_j with z_ij. Then give the following:

- x_0 y_0 z_00 x_1 y_0 z_10 etc.
- x_0 y_1 z_01 x_1 y_1 z_11 etc.

- etc.

In 3d, the number of points in x and y direction respectively should be set with *nx* and *ny* of the **groundflow_phreatic_level_n** record.

In nodes above the phreatic level the total pressure will be set to zero during the calculation.

As a special option in 2D and 3D, you can specify one value only, which sets a constant phreatic level of that value everywhere. In this special case, you do not need to specify **groundflow_phreatic_level_n**.

6.573 groundflow_phreatic_level_n nx ny

See **groundflow_phreatic_level**.

6.574 groundflow_phreatic_level_static switch

If *switch* is set to **-yes**, total pressures (pore pressures) in nodes for which the **groundflow_phreatic_level** holds, will be set equal to the static pressure.

This is convenient if the phreatic line is located above the mesh part to which it belongs; then nodes of the mesh will not get a boundary condition, so that the correct hydraulic pressure head can not be determined. And thus, it is necessary to determine the total pressure (pore pressure) from the difference of nodal coordinates and phreatic line height.

It is also convenient if you do not want to initialise and solve the hydraulic pressure heads with the groundflow storage equation. This saves computer memory and CPU time.

In the **group_type** for elements which should get the static groundflow pressure you need to add **-groundflow**.

6.575 groundflow_phreatic_level_multiple *index* ...

The same as **groundflow_phreatic_level**, but now however several groundwater levels can be specified. For each **groundflow_phreatic_level_multiple** you should specify a separate value for *index*.

This option typically can be used if you have in vertical direction non-permeable layers separating the total domain in independent parts with each its own groundwater level.

You can specify with one of **groundflow_phreatic_level_multiple_element** or **groundflow_phreatic_level_multiple_element_geometry** or **groundflow_phreatic_level_multiple_elemer**
or **groundflow_phreatic_level_multiple_node** the parts of the domain that belong

to the groundwater level of **groundflow_phreatic_level_multiple** with the same index. Only one of these record can be used, you cannot combine them.

With **groundflow_phreatic_level_multiple_n** you specify *nx ny* in 3D again.

In the **group_type** for elements which should get the static groundflow pressure you need to add **-groundflow**.

6.576 groundflow_phreatic_level_multiple_element *index* element_0 element_1 ...

Element numbers for **groundflow_phreatic_level_multiple** with the same index.

6.577 groundflow_phreatic_level_multiple_element_group *index* element_group_0 element_group_1 ...

Element group numbers for **groundflow_phreatic_level_multiple** with the same index.

6.578 groundflow_phreatic_level_multiple_element_geometry *index* element_geometry_0 element_geometry_1 ...

Element geometry numbers for **groundflow_phreatic_level_multiple** with the same index.

6.579 groundflow_phreatic_level_multiple_n nx ny

See **groundflow_phreatic_level_multiple**.

6.580 groundflow_phreatic_level_multiple_node *index* node_0 node_1 ...

Node numbers for **groundflow_phreatic_level_multiple** with the same index.

6.581 groundflow_phreatic_level_multiple_static *index* switch

If *switch* is set to **-yes**, total pressures (pore pressures) in nodes for which the **groundflow_phreatic_level_multiple** holds, will be set equal to the static pressure.

This is convenient if the phreatic line is located above the mesh part to which it belongs; then nodes of the mesh will not get a boundary condition, so that the correct hydraulic pressure head can not be determined. And thus, it is necessary to determine the total pressure (pore pressure) from the difference of nodal coordinates and phreatic line height.

It is also convenient if you do not want to initialise and solve the hydraulic pressure heads with the groundflow storage equation. This saves computer memory and CPU time.

6.582 groundflow_phreatic_only *switch*

If *switch* is set to **-yes** groundflow data is removed for groups which are not part of **groundflow_phreatic_level_multiple_element_group** records. Thus only groundflow data is retained for groups for which a multiple phreatic level is defined.

6.583 groundflow_phreatic_project *switch*

If *switch* is set to **-yes**, the hydraulic pressure head which is imposed on nodes above the phreatic level uses the project coordinate on the phreatic level (smallest distance); thus not simply the distance in vertical direction. For some calculations that gives better groundwater velocities.

Default, it **groundflow_phreatic_project** is not specified, *switch* is set to **-no**.

6.584 groundflow_pressure_factor *factor*

With this record you can specify a factor which is used to add the pore pressure to the effective stress to get the total stress: total stress = effective stress + factor * pore pressure.

If you calculate with the van genuchten law, automatically the factor will be set to *Se* of that law.

6.585 groundflow_seepage_eps *eps*

The *eps* specifies the tolerance if the groundflow seepage condition should be applied or not. If the inner product of the groundflow water flow direction with the normal outside the material is smaller then *eps*, the seepage status will be set to closed, and the total pressure condition will not be applied (so that the boundary is really closed for water flow). If not specified, *eps* is set to 0.1.

6.586 groundflow_seepage_geometry *index geometry_item_name geometry_item_index*

This record specifies an edge of the groundflow domain for which the groundwater is only allowed to flow outwards of the domain; flow into the domain is not allowed on that edge. The geometrical entity should be specified such that the normal of the geometry points outwards the material (so outwards the groundflow domain). This option comes handy when the point of groundwater flow exit is not known in advance of the calculation; it will be a result of the calculation instead.

Example:

```
...
groundflow_seepage_geometry 10 -geometry_line 100
...
bounda_dof 20 -geometry_line 100 -total_pressure
bounda_time 20 0.0
```

In this example the total pressure (pore pressure) is set to 0 on the geometry line number 100, to account for free air at that edge. Since at that edge water cannot enter the domain the seepage option is applied to that edge. The result of these combined options is that on nodes with outward flow a total pressure 0 boundary condition is imposed, whereas on other nodes no boundary conditions is imposed (so that the flow is 0 at those nodes). The transition point between these outflow nodes and nodes with zero flow will be found automatically as a result of the calculation.

6.587 groundflow_seepage_node *index node_0 node_1 ...*

This record does the same as the **groundflow_seepage_geometry** record, but now however you specify node numbers at which the seepage condition holds. The *node_0* is the first node number, the *node_1* is the second node number, etc.

6.588 groundflow_total_pressure_limit *limit*

With this record you can specify the maximum allowed total pressure value. Any higher value resulting from the groundflow equations will be cutoff to this value. Default the *limit* is set to 0.

6.589 group_axisymmetric *index switch*

If *switch* is set to **-yes**, the calculation becomes axi-symmetrical for the group *index*. Each specified x coordinate becomes a radius and y becomes the length (=vertical) direction. The z-direction is the axi-symmetric direction. Specify only non-negative x coordinates, i.e. define the computational domain in the right half-plane.

This option is onloy available for groups with isoparametric 1D elements (bar2, ...), or isoparametric 2D elements (tria3, quad4, ...), or for 2D interface elements (quad4 interface, ...).

6.590 group_beam_force_moment_plasti *index force_x_plasti_first_node force_y_plasti_first_node force_z_plasti_first_node moment_x_plasti_first_node moment_y_plasti_first_node moment_z_plasti_first_node force_x_plasti_second_no force_y_plasti_second_node force_z_plasti_second_node moment_x_plasti_second_n moment_y_plasti_second_node moment_z_plasti_second_node*

With this record you can set ideally plastic limits on forces and moments in beam elements. You can specify different values for each of the local x, y and z-directions, so that a different plastic behavior can be specified for beams having different properties in the different directions. You can also different values for each of the two nodes.

6.591 group_beam_inertia *index Iyy Izz J*

Bending and torsion properties for beam elements. Here Iyy is the area moment of inertia for bending along the local beam y axis, and Izz is the area moment of inertia for bending along the local beam z axis, and J is the polar moment of inertia for torsion along the local beam x axis.

See also **beam_rotation** in the initialisation part.

The *index* specifies the element_group, see **element_group**.

6.592 group_beam_memory *index memory_type*

Memory model for beam; either **-updated_linear**, **-updated** or **-total_linear**. The **-updated** model is a geometrically nonlinear model which takes large beam rotations into account. The *index* specifies the element_group, see **element_group**.

6.593 group_beam_direction_z *index dir_z,x dir_z,y dir_z,z*

This record specifies the local beam z direction in global space. If **group_beam_direction_z** is not specified in 2D then *0 0 1* will be used. If **group_beam_direction_z** is not specified in 3D then a arbitrary direction perpendicular to the beam length axes will be used.

The local beam axes will be placed in the **element_beam_direction** record after the calculation.

The *index* specifies the element_group, see **element_group**.

See also **group_beam_direction_z_reference_point** for automatic beam z-axis towards a reference point.

6.594 group_beam_direction_z_reference_point *index point_x point_y point_z*

This data record defines a reference point that allows you to influence the local beam z-direction. The local beam z-direction will be setup as follows:

- The length direction of the beam is determined, that is the local beam x-axis.
- A vector is taken from the beam middle point to the reference point.
- The part of this vector perpendicular to the length direction defines the local beam z-axis.

The above procedure ensures that the beam z-axis is perpendicular to the length direction, and that the z-axis points as much as possible to the reference point. As a typical example, you can use this option to take care that the local beam z-axis points to the middle of a tunnel, which is convenient if a tunnel lining with the local z-axis towards the tunnel middle; to do so specify the middle point of the tunnel axis as reference point *point_x point_y point_z*.

6.595 group_beam_young *index E*

Young's modulus for a beam (for bending moment calculation). The *index* specifies the element_group, see **element_group**.

6.596 group_beam_shear *index G*

Shear modulus for a beam (for torsion moment calculation). The *index* specifies the element_group, see **element_group**.

6.597 group_condif_absorption *index a*

Absorption coefficient. The *index* specifies the element_group, see **element_group**.

6.598 group_condif_capacity *index C*

Heat capacity. The *index* specifies the element_group, see **element_group**.

6.599 group_condif_conductivity *index* k_x k_y k_z

Heat conductivity in x, y and z direction respectively. As a special option you can also specify one value only, which then will be used in each direction. The *index* specifies the element_group, see **element_group**.

6.600 group_condif_density *index density*

Density for convection-diffusion equation. The *index* specifies the element_group, see **element_group**.

6.601 group_condif_flow *index* $beta_1$ $beta_2$ $beta_3$

Known flow field. In 1D only $beta_1$ should be specified, etc. The *index* specifies the element_group, see **element_group**.

6.602 group_contact_spring_direction *index* $dirN_x$ $dirN_y$ $dirN_z$

Normal direction of a contact_spring. The *index* specifies the element_group, see **element_group**.

As an alternative, you can specify **element_contact_spring_direction** which allows for specification of the direction for each element separately.

As yet another alternative you can set *switch* in **group_contact_spring_direction_automatic** to **-yes**. Then the contact spring will automatically determine the directions.

6.603 group_contact_spring_direction_automatic *index switch*

See **group_contact_spring_direction**.

6.604 group_contact_spring_plasti_cohesion *index c*

The normal contact force F_N is not allowed to become larger then cohesion c in tension (positive values of F_N). If it would become larger, then the contact is broken, a gap is assumed and the contact force F_N is put to 0. To have really a positive F_N for extension of the contact spring, the order of the two nodes as specified in the **element** record for the contact spring should be correct.

Notice that when you use **control_mesh_generate_contact_spring** to obtain the contact spring elements, you are not sure what the first and what the second node of an element will be, and thus you should not use this **group_contact_spring_cohesion** record. Otherwise, it is not important what you use as first and second node, so that **control_mesh_generate_contact_spring** can be used safely.

If this **group_contact_spring_plasti_cohesion** is not specified, infinite cohesion is assumed.

The *index* specifies the element_group, see **element_group**.

6.605 group_contact_spring_plasti_friction *index f*

With this record you can specify a fixed friction coefficient for contact springs. If this record is not specified, a very large value for f will be applied.

The *index* specifies the element_group, see **element_group**.

See also **group_contact_spring_stiffness** and **group_contact_spring_friction_automatic**.

6.606 group_contact_spring_plasti_friction_automatic *index switch*

If *switch* is set to **-yes**, the friction coefficient for contact springs will be determined from the plasticity law angle of neighboring elements. For a neighboring **group_materi_plasti_mohr_coul** the friction coefficient f will be set to $f = (2./3.)\tan\phi$ with ϕ the friction angle in the mohr-coulomb law of the neighboring elements. For a neighboring **group_materi_plasti_diprisco** the friction coefficient f will be set to a value depending on the parameter γ of that law.

If no neighbor elements with appropriate material law are found, then f will be set to 0.2.

The *index* specifies the element_group, see **element_group**. See also **group_contact_spring_direction_aut**

6.607 group_contact_spring_direction_automatic_planes *index switch_x switch_y switch_z*

With this option you can help the **group_contact_spring_friction_automatic** by telling in which planes the automatically determined spring direction is allowed to be. If a switch is set to **-yes**, then the direction may have a component in that plane. If a switch is set to **-no**, then the direction may not have a component in that plane. Default all switches are **-yes**.

The *index* specifies the element_group, see **element_group**.

6.608 group_contact_spring_memory *index memory_type*

Memory model for contact_spring; either **-updated_linear**, **-total_linear**. The *index* specifies the element_group, see **element_group**.

6.609 group_contact_spring_stiffness *index* k_N k_T

Stiffnesses for contact springs. The force F_N in normal direction of the contact spring is determined from $F_N = k_N\ u_N$ where u_N is the normal displacement difference of the two nodes (that is, the displacement of the second node in normal direction minus the displacement of the first node in normal direction). The first tangential force F_{T1} of the contact spring is determined from $F_{T1} = k_T\ u_{T1}$ where u_{T1} is the tangential displacement difference of the two nodes in the first tangential direction; the same is done for the second tangential force. The total tangential force $\sqrt{F_{T1}^2 + F_{T2}^2}$ cannot exceed $f\ F_N$ with f friction coefficient; then frictional slip occurs and the total tangential force is set to $f\ F_N$ To model continuing stick between two bodies just put the friction coefficient f very high.

In 1D the parameters k_T and f will not be used (but should be specified as dummies nevertheless).

The *index* specifies the element_group, see **element_group**.

See also **group_contact_spring_friction** and **group_contact_spring_friction_automatic**.

6.610 group_dof_initial *index dof_0 dof_1 ...*

Same as **element_dof_initial**, now specified for a group of elements however.

6.611 group_dof_initial_specific_number *index dof*

Same as **element_dof_initial_specific_number**, now specified for a group of elements however.

6.612 group_dof_initial_specific_value *index value_0 value_grad_x value_grad_y value_grad_z*

Same as **element_dof_initial_specific_value**, now specified for a group of elements however.

6.613 group_groundflow_capacity *index C*

Capacity in ground water flow equation. The *index* specifies the element_group, see **element_group**.

6.614 group_groundflow_consolidation_apply *index switch*

If *switch* is set to **-no** consolidation will not be applied for the elements of the group.

6.615 group_groundflow_expansion *index* α

Thermal expansion coefficient for ground water, for a combined groundwater with temperature analysis. The *index* specifies the element_group, see **element_group**.

6.616 group_groundflow_nonsaturated_eps_permeability *index eps*

The nonsaturated law lowers the permability relative to the specified linear permeability as specified in **group_groundflow_permeability**. With this **group_groundflow_nonsaturated_eps_perme** you can specify the lowest allowed factor for reducing the permeability.

6.617 group_groundflow_nonsaturated_vangenuchten *index* S_{residu} S_{sat} g_a g_l g_n

Parameters for non-saturated van Genuchten ground water flow, see the theory section. The *index* specifies the element_group, see **element_group**.

Since the van-Genuchten law is highly nonlinear, convergence of the calculation can be difficult. Always check if the calculation converges by printing **post_node_rhside_ratio**. You can try including inertia to improve convergence.

6.618 group_groundflow_permeability *index* pe_x pe_y pe_z

Permeability coefficient in ground water flow, in each space direction. In 1D you only should specify pe_x, etc. If you specify only value, then that will be used in each direction. The *index* specifies the element_group, see **element_group**.

6.619 group_groundflow_permeability_vertical_stress *index a b* σ_0 *minimum maximum*

This is a special purpose equation for the permeability coefficient in ground water flow:

$$k^p = \frac{a}{(\sigma_v/\sigma_0)^b}$$

where a and b and σ_0 are user specified parameters, and σ_v is the vertical effective stress. The permeability calculated this way is not allowed to become smaller than *minimum* and larger then *maximum*.

This option should only be used in 2D or 3D. This option should be used in combination with **group_groundflow_permeability**; the permeability as specified in **group_groundflow_permeability** will then be used in regions where the vertical stress is extremely small, to prevent division by zero; in all other regions the permability as specified by this **group_groundflow_permeability_vertical_stres** law will be used.

The *index* specifies the element_group, see **element_group**.

6.620 group_groundflow_total_pressure_tension *index plastic_tension_minimum water_height*

Using this option you can control that the water pressure in an element is at least the value as determined from the specified *water_height*. More precise, if the static water pore pressure as determined from the water density, the gravity and the *water_height* exceeds the pore water pressure from the groundflow equation (in absolute terms) , this static water pressure actually is used. This is only done if the largest eigenvalue of **materi_strain_plastic_tension** exceeds *plastic_tension_minimum*. To calculate the eigenvalues of **materi_strain_plastic_tension** you need to include **post_calcul-materi_strain_plasti_tension-prival** in the input file.

This option comes handy to take care that in cracks in concrete actually the largest water pressure from an environment is used. It so ensures that a critical safety analysis for concrete cracking is obtained.

6.621 group_integration_method *index method*

Here *method* sets the integration method for bars, quad en hex elements. You can either set *method* to **-gauss**, **-lobatto** or **-reduced**.

The gauss and lobatto integration method are explained in text books on finite element methods. The reduced method is a weighted combination of lobatto and 1-point cell centered integration. The weighting is set by the **group_integration_method_reduced_factor** record.

If this record is not set, the default method as described in **group_integration_points** is chosen.

It is advised to keep the default method, so not specify this **group_integration_method** record, unless you know what you are doing.

6.622 group_integration_method_reduced_factor *index factor*

When *factor=1* the reduced method is in fact lobatto integration. When *factor=infinite* the reduced method is in fact 1-point cell centered integration. When the *factor* is in between 1 and infinity the intergation is done with a weighted combination of the lobatto and 1-point cell centered integration.

Default the *factor* is set to 10.

6.623 group_integration_points *index type*

Here *type* sets the number of integration points in an element. It should be set to **-normal**, **-minimal** or to **-maximal**.

For **-tria3** elements the integration point will be located in the middle with **-minimal** integration, or a four-point integration scheme will be used with **-maximal** integration.

For **-tria6** elements a seven-point scheme will be used for **-maximal** and a four-point scheme will be used with **-minimal** integration.

For **-tet4** elements the integration point will be located in the middle with **-minimal** integration, or a five-point integration scheme will be used with **-maximal** integration.

For **-tet10** elements a five-point scheme will be used for **-minimal** and a ten-point scheme will be used with **-maximal** integration.

For other elements, if **-minimal** is used then the number of integration points in a direction is set equal to the number of nodes in the direction minus 1, and gauss integration is used. If for the other elements **-maximal** is used then the number of integration points in a direction is set equal to the number of nodes in the direction; gauss integration is used, but in case

inertia is applied then lobatto integration will be used.

Default **-minimal** is used for **-bar2**, **-tria3**, and **-tet4** elements; it is default **-maximal** otherwise.

If *type* is set to **-normal**, the default integration will be used.

The above is valid for normal isoparametric elements. For interface elements default lobatto integration is used (integration points in nodes).

It is advised to keep the default method, so not specify this **group_integration_points** record.

The *index* specifies the element_group, see **element_group**.

6.624 group_interface *index switch*

With this record, you set that the element with element group *index* will act as an interface element by setting *switch* to **-yes**. This is available for **-quad4**, **-quad6**, **-hex8**, **-hex18**, **-prism6** and **-prism12**.

See **group_interface_*** which data can be set for interfaces.

In interfaces strains are displacement differences between the opposite interface sides.

6.625 group_interface_condif_conductivity *index k*

The 'index' specifies the group number. The conductivity k specifies the heat flow in interface thickness direction per unit temperature difference. Thus the conductivity is not the material conductivity but the conductivity of the layer simulated by the interface incorporating the thermal thickness of the interface, The 'conductivity' has units [power]/[temperature*length] in 2D, and [power]/[temperature*length*length] in 3D.

6.626 group_interface_gap *index gap*

By specifying this record you can account for initial empty space between the sides of an interface element. Only when the sides displacements are such that the normal strain becomes lower then the specified *gap* value the interface will be closed and start to generate stresses.

So typically you set *gap* to a negative number if there is a physical gap.

If you want to allow always tension stresses in an interface set *gap* to, by example, 1.e20.

6.627 group_interface_groundflow_capacity *index C*

This record specifies the capacity for interface elements.

6.628 group_interface_groundflow_permeability *index pe*

This record specifies the permeability per unit length in 2D or unit area in 3D for interface elements.

6.629 group_interface_materi_elasti_stiffness *index kn kt,first kt,second*

This record allows you to specify a normal stiffness and tangential shear stiffnesses for discrete interface elements with **-materi** in **group_type**. Normal stresses in the interface element follow from normal strains multiplied with *kn* (stress,normal = kn * strain,normal). Shear stresses in the interface element in the first tangential direction follow from shear strains in the first tangential direction multiplied with *kt,first* (stress,shear,first = kt,first * shear,gamma,first = 2 * kt,first * strain,shear,first). Shear stresses in the interface element in the second tangential direction follow from shear strains in the second tangential direction multiplied with *kt,second* (stress,shear,second = kt,second * shear,gamma,second = 2 * kt,second * strain,shear,second). The *kt,second* should be specified for 3D interfaces only.

Too high values for interface stiffness will cause convergence problems in calculations. Thus, if you are running a calculation with interface elements and you are experiencing convergence problems please try lower values for the interface stiffnesses. Typically the normal interface stiffness can be chosen as 10 times the Young's modulus of the neigbouring isoparametric element divided by the length of that element in normal direction. Typically the tangential interface stiffness can be chosen as half of the normal interface stiffness.

Attention: an interface will only build up stresses if the interface normal strain is not larger then the gap specified in **group_interface_gap**. If the interface normal strain is larger then the gap , then the interface status is considered to be opened, and the interface does not have stresses.

A 3d example:

```
...
number_of_space_dimensions 3
...
group_interface_materi_elasti_stiffness 0 0.10000e+11 0.50000e+10
0.50000e+10
...
```

6.630 group_interface_materi_expansion_normal *index expansion_coefficient_normal*

The 'index' specifies the group number. The *expansion_coefficient_normal* specifies the thermal strain expansion in interface thickness direction per unit temperature in the interface. The temperature is the average of the temperature of the both sides at the location of the integration point. This option is only available if group_interface_materi_memory is set to **-total_linear** or **-updated_linear**. Furthermore, **materi_strain_elasti** should be initialised.

6.631 group_interface_materi_memory *index memory_type*

Either *memory_type* should be set to **-updated_linear** or **-total_linear**.

6.632 group_interface_materi_plasti_mohr_coul_direct *index phi c phiflow*

Mohr-coulomb plasticity model for interfaces. The angles are in radians. The cohesion c has stress unit (so just the same as for **group_materi_plasti_mohr_coul** in normal isoparameteric elements). The maximum friction force in the interface is $c + F_n * tan(phi)$ where c is the cohesion, *phi* is the friction angle in radians and F_n is the normal force (which is a negative value under compression).

6.633 group_interface_materi_plasti_tension_direct *index tension_limit*

With this record you can specify the tension limit in interface elements. You may want to set **group_interface_gap** to a large value if you want a tensile stress for opening interfaces.

6.634 group_interface_materi_residual_stiffness *index factor*

With *factor* you can set the part of the original stiffness to be used as stiffness in opened interfaces. Default, if this record is not specified, the *factor* is set to some small value.

6.635 group_interface_groundflow_total_pressure_tension *index strain_normal_minimum water_height*

Using this option you can control that the water pressure in an interface element is at least the value as determined from the specified *water_height*. More precise, if the static water pore pressure as determined from the water density, the gravity and the *water_height* exceeds the pore water pressure from the groundflow equation (in absolute terms) , this

static water pressure actually is used. This in only done if the interface normal strain (displacement different between interface sides) exceeds *strain_normal_minimum*.

This option comes handy to take care that in cracks in concrete actually the largest water pressure from an environment is used. It so ensures that a critical safety analysis for concrete cracking is obtained.

6.636 group_interface_tangential_reference_point *index point_x point_y point_z*

This data record defines a reference point that allows you to influence the tangential directions in a 3D interface element. The tangential directions will be setup as follows:

- The normal direction to the interface plane is determined.
- A vector is taken from the integration point in the interface element to the reference point.
- The part of this vector perpendicular to the normal direction defines the first tangential direction.
- The outer product of the normal direction and the first tangential direction gives the second tangential direction.

The above procedure ensures that the tangential directions are perpendicular to the normal direction, and that the first tangential directions points as much as possible to the reference point. As a typical example, you can use this option to take care that the first tangential direction points to the middle of a tunnel, so the first tangential interface direction equals in fact the tunnel radial direction; to do so specify the middle point on the tunnel axis as reference point *point_x point_y point_z*.

If this **group_interface_tangential_reference_point** is not specified, it is only certain that the tangential directions are in plane of the interface (perpendicular to the normal direction), but are not defined otherwise.

See also **element_interface_intpnt_direction**.

6.637 group_materi_damage_mazars *index* $epsilon_0 a_t\ b_t\ a_c\ b_c\ \beta$

Parameters for the Mazars damage law. The *index* specifies the element_group, see **element_group**.

6.638 group_materi_damping *index d*

Material damping coefficient *d*. See also the dynamics section near the end of this manual.

The *index* specifies the element_group, see **element_group**.

6.639 group_materi_damping_method *index method*

See **group_materi_damping**.

6.640 group_materi_density *index density*

Density for material flow equation. The *index* specifies the element_group, see **element_group**.

6.641 group_materi_density_groundflow *index density_wet density_dry*

Density for material flow equation when a calculation is performed in combination with groundflow. If the element is filled with groundwater the *density_wet* will be used and otherwise the *density_dry* will be used. To determine if an element is filled with water, tochnog does not the following: If **post_calcul -groundflow_pressure -total_pressure** is put in the input file then total pressures (pore pressures) are calculated. Then if the pore pressure in an element is negative the wet density is taken. Otherwise the dry density. If **post_calcul -groundflow_pressure -total_pressure** is NOT put in the input file the total pressures are not calculated. Then tochnog looks if a phreatic level is given; if so, then if an element is below the phreatic level the wet density is used, otherwise if an element is above the phreatic level the dry density is used.

Here *density_wet* is the amount of kg of soil + water in a unit volume. And *density_dry* is the amount of kg of soil in a unit volume.

The *index* specifies the element_group, see **element_group**.

In case total pressures are calculated

In case total pressures are calculated from the **post_calcul groundflow_pressure -total_pressure** command, the *density_wet* will be used if the total pressure is smaller then 0, whereas *density_dry* will be used if the total pressure is larger or equal to 0.

In case total pressures are not calculated but a phreatic level is specified

In case an element is above a specified phreatic level the *density_dry* will be used. In case an element is below a specified phreatic level, the *density_wet* will be used.

In other cases

In other cases *density_dry* will be used.

6.642 group_materi_elasti_borja_tamagnini *index* G_0 α $\hat{k}$ p_r

Elastic data for the modified Borja Tamagnini model, see [1]. The *index* specifies the element_group, see **element_group**.

6.643 group_materi_elasti_c *index 81 values*

With this record you can directly specify the 81 values of the linear material stiffness C_{ijkl} which will be used to calculate stresses from strains with $\sigma_{ij} = C_{ijkl}\epsilon_{kl}$. Here σ_{ij} is the stress matrix and ϵ_{kl} is the strain matrix.

The sequence of strains and stresses is xx, xy, xz, yx, yy, yz, zx, zy and zz.

The 81 values should be specified row by row, where each row contains 9 values. See also **group_materi_elasti_c_direction**.

6.644 group_materi_elasti_c_direction *index dir_0 dir_1 dir_2*

This record specifies local axes for which the **group_materi_elasti_c** is specified. In total 9 values need to be specified, first the 3 values for dir_0 , then the 3 values for dir_1 and then the 3 values for dir_2. Default, if this record is not specified, the global axes will be used.

6.645 group_materi_elasti_camclay_g *index G*

Elastic data G for the modified CamClay model. The *index* specifies the element_group, see **element_group**.

6.646 group_materi_elasti_camclay_poisson *index* ν

Elastic data ν for the modified CamClay model. This option is alternative to the **group_materi_elasti_camclay** option (so, only one of both can be defined). With this option the poisson ratio ν is assumed constant, and is used as follows:

$$G = \frac{3}{2}K(1-2\nu)/(1+\nu)$$

The *index* specifies the element_group, see **element_group**.

6.647 group_materi_elasti_camclay_pressure_min *index pressure_min*

This specifies a minimal allowed value for the pressure in the calculation of the bulk modulus for the camclay model. In the calculation pressures below *pressure_min* will be set to *pressure_min*. This prevents numerical problems for very low bulk modulus K values.

The *index* specifies the element_group, see **element_group**.

6.648 group_materi_elasti_compressibility *index co*

Compressibility for materials. A positive value should be used. The *index* specifies the element_group, see **element_group**.

6.649 group_materi_elasti_hardsoil *index* E_{50}^{ref} $sigma_{50}^{ref}$ ν_{50} m E_{ur}^{ref} $sigma_{ur}^{ref}$ ν_{ur}

Elasticity data for Hardening Soil model. The *index* specifies the element_group, see **element_group**.

6.650 group_materi_elasti_k0 *index K0*

Elastic data $K0$. When this data is specified, and also **control_materi_elasti_k0** is set to **-yes**, then the *K0* parameter will be used in the elastic stress law with **group_materi_elasti_young** or **group_materi_elasti_young_power** and **group_materi_elasti_poisson**, or with **group_materi_elasti_hardsoil**. In fact it will be used to determine the poisson coefficient consistent with the *K0*; this poisson coefficient is used in the elastic stress law.

This **group_materi_elasti_k0** in combination with **control_materi_elasti_k0** is a convenient method to get 'K0 stresses' when imposing gravity in a geotechnics calculation. After gravity is imposed simply do not set the **control_materi_elasti_k0** anymore, so that the normal **group_materi_elasti_poisson** will be used in the remaining steps.

For K0>0.95 Tochnog will take 0.95. K0 exceeding 1 (or 0.95) may lead to ill-conditioned calculations.

6.651 group_materi_elasti_lade *index* B R λ

Elastic data $B - 0$, R, λ for the Lade model. The *index* specifies the element_group, see **element_group**.

6.652 group_materi_elasti_poisson *index poisson*

Poisson ratio for solid. The *index* specifies the element_group, see **element_group**.

6.653 group_materi_elasti_poisson_power *index* $\nu_0\nu_1\nu_2p\_1\alpha$

Power law poisson ratio for solid material. See the theory part. The *index* specifies the element_group, see **element_group**.

6.654 group_materi_elasti_shear_factor *index factor*

Specifying this record causes the shear stiffness following from a specified young and poisson to be multiplied with *factor*. This provides a convenient way to test in a calculation what the effect of low shear stresses is. The *index* specifies the element_group, see **element_group**.

6.655 group_materi_elasti_stress_pressure_history_factor *index factor*

This record allows you to model a different soil stiffness when first loading or unloading/reloading instead. The **materi_stress_pressure_history** should be initialised, which records the maximum soil pressure that occurred in history. If the current pressure is smaller then the largest pressure in history, the material is unloading or reloading, and the stiffness will be multiplied with *factor*. If the current pressure is the larger then the largest pressure from history, then this current pressure becomes the maximum history pressure, and the stiffness will not be multiplied with *factor*.

This **group_materi_elasti_stress_pressure_history_factor** can be combined with the young as specified by **group_materi_elasti_young** or the young calculated from **group_materi_elasti_young_power**.

Typically the factor has a value of about 3.

6.656 group_materi_elasti_transverse_isotropy *index* E_1 E_2 ν_1 ν_2 G_2 *dir_x dir_y dir_z*

Specifies the unique direction (*dir_x dir_y dir_z*) and elastic moduli in the transverse isotropic model. Here E_2 is the young modulus in the unique direction, E_1 is the young modulus in both directions perpendicular to the unique direction, etc. The *index* specifies the element_group, see **element_group**.

6.657 group_materi_elasti_volumetric_poisson *index* ν

See **group_materi_elasti_volumetric_young_values**

6.658 group_materi_elasti_volumetric_young_order *index* n

See **group_materi_elasti_volumetric_young_values**

6.659 group_materi_elasti_volumetric_young_values *index epsilon_0 sigma_0 epsil*

This is a special record to model the volumetric stress part of a nonlinear material, given the experimental results of a volumetric compression test (compression in one direction, fixed size in other two directions).

The table *epsilon_0 sigma_0 epsilon_1* $sigma_1$ ... specifies the strain-stress results for the volumetric compression test. Together with the poisson ratio as specified in **group_materi_elasti_volumetric_** an isotropic law in a nonlinear Young's modulus and a constant poisson ratio is fitted to this experiment. The Young modulus in fact is taken as the polynomial expansion $E_0 + E_1 epsilon + E_2 epsilon^2 + \ldots + E_{n-1} epsilon^{n-1}$ where n denotes the order of the polynomial expansion (as given in **group_materi_elasti_volumetric_young_order**).

The poisson ratio should be taken very high, say 0.4999999 or so, to ensure that the resulting law only models volumetric stresses. Then afterwards a normal young-poisson isotropic law (**group_materi_elasti_young** and **group_materi_elasti_poisson**) can be added to get an extra deviatoric part.

6.660 group_materi_elasti_young *index* E

Young's modulus for solid material. The *index* specifies the element_group, see **element_group**.

6.661 group_materi_elasti_young_polynomial *index* E_0 $E_1 \ldots$

Polynomial parameters for strain dependent Young's modulus for solid material. See the theory part. The *index* specifies the element_group, see **element_group**.

6.662 group_materi_elasti_young_power *index* $E_0 E_1 E_2 E_3 p\_ 1 \alpha$

Power law Young's modulus for solid material. See the theory part. The *index* specifies the element_group, see **element_group**.

If you want to get the calculated young as output, initialise with **materi_history_variable 1**; the history variable will be filled with the calculated young, and can be plotted for example in GID.

6.663 group_materi_elasti_young_user *index switch*

If *switch* is set to **-yes** the user supplied routine **user_young** will be called. There the youngs modulus should be calculated from the solution fields and the stress history. Typically degradation of material stiffness for cyclic loading can be programmed with this user specified routine.

You can plot in gid the values for the young as follows:

```
...
print_group_data -group_materi_elasti_young
...
```

6.664 group_materi_expansion_linear *index* α

Linear expansion coefficient. The *index* specifies the element_group, see **element_group**.

6.665 group_materi_expansion_volume *index* β

Volume expansion coefficient. The *index* specifies the element_group, see **element_group**.

6.666 group_materi_factor *index factor*

This factor comes convenient if your material stress law is specified in other units then you actually want in your calculation. Then you can specify *factor* to take care that your material stresses become consistent with the remaining part of the input file. For example, if you want your input file to work with kPa but your material stress law works with MPa then simply set *factor* to 1000.

6.667 group_materi_failure_crunching *index threshold delete_time*

If the compression strain in an element exceeds *threshold*, the element is considered to be fail. The element will be slowly deleted. It is totally deleted if the *delete_time* has passed.

The *index* specifies the element_group, see **element_group**.

6.668 group_materi_failure_damage *index threshold delete_time*

If the damage in an element exceeds *threshold*, the element is considered to be fail. The element will be slowly deleted. It is totally deleted if the *delete_time* has passed.

The *index* specifies the element_group, see **element_group**.

6.669 group_materi_failure_plasti_kappa *index threshold delete_time*

If the plastic parameter kappa in an element exceeds *threshold*, the element is considered to be fail. The element will be slowly deleted. It is totally deleted if the *delete_time* has passed.

The *index* specifies the element_group, see **element_group**.

6.670 group_materi_failure_rupture *index threshold delete_time*

If the tensile strain in an element exceeds *threshold*, the element is considered to be fail. The element will be slowly deleted. It is totally deleted if the *delete_time* has passed.

The *index* specifies the element_group, see **element_group**.

6.671 group_materi_failure_void_fraction *index threshold delete_time*

If the void fraction in an element exceeds *threshold*, the element is considered to be fail. The element will be slowly deleted. It is totally deleted if the *delete_time* has passed.

The *index* specifies the element_group, see **element_group**.

6.672 group_materi_history_variable_user *index switch*

Set *switch* to **-yes** if you want to activate the user supplied routine for material history variables. The *index* specifies the element_group, see **element_group**.

6.673 group_materi_history_variable_user_parameters *index ...*

Specify parameters for the user supplied routine for material history variables. The *index* specifies the element_group, see **element_group**.

6.674 group_materi_hyper_besseling *index* $K_1 K_2 \alpha$

Parameters for Besseling Hyper elastic rubber model. The *index* specifies the element_group, see **element_group**.

6.675 group_materi_hyper_blatz_ko *index* $G\beta$

Parameters for Blatz-Ko model. The *index* specifies the element_group, see **element_group**.

6.676 group_materi_hyper_mooney_rivlin *index* $K_1 K_2$

Parameters for Mooney-rivlin hyper elastic rubber model. The *index* specifies the element_group, see **element_group**.

6.677 group_materi_hyper_neohookean *index* K_1

Parameter for Neo-Hookean hyper elastic rubber model. The *index* specifies the element_group, see **element_group**.

6.678 group_materi_hyper_reduced_polynomial *index* K_1 K_2 ...

Parameters for reduced polynomial hyper elastic rubber model. The *index* specifies the element_group, see **element_group**.

6.679 group_materi_hyper_volumetric_linear *index* K

Parameter for the linear volumetric hyperelasticity model. The *index* specifies the element_group, see **element_group**.

6.680 group_materi_hyper_volumetric_murnaghan *index* $K\beta$

Parameter for the murnaghan volumetric hyperelasticity model. The *index* specifies the element_group, see **element_group**.

6.681 group_materi_hyper_volumetric_ogden *index* $K\beta$

Parameter for the ogden volumetric hyperelasticity model. The *index* specifies the element_group, see **element_group**.

6.682 group_materi_hyper_volumetric_polynomial *index* K_0 K_1 ...

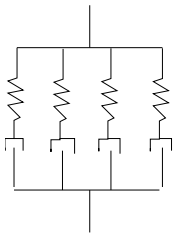
Parameters for the polynomial volumetric hyperelasticity model. The *index* specifies the element_group, see **element_group**.

6.683 group_materi_hyper_volumetric_simo_taylor *index* K

Parameter for the simo-taylor volumetric hyperelasticity model. The *index* specifies the element_group, see **element_group**.

6.684 group_materi_maxwell_chain *index E_ 0 t_ 0 ... E_ n-1 t_ n-1*

In total n parallel maxwell chains are defined with stiffness *E_ 0*, relaxation time *t_ 0*, etc..



The number n should equal **materi_maxwell_stress** in the input initialization part. The *index* specifies the element_group, see **element_group**.

6.685 group_materi_membrane *index switch*

If **switch** is set to **-yes** the zz stress becomes zero in 2D and the yy and zz stress become zero in 1D (in combination with axi-symmetry in 1D, only the yy stress becomes zero since zz is the axi-symmetric direction). So this option models plane stress conditions.

If **group_materi_membrane** is not used the plane strain conditions are used. Always the z-thickness is 1. in 3D, and the y, and z-thickness are 1. in 2D; see however also **volume_factor**.

The **group_materi_membrane** option cannot be used in combination with **group_materi_elasti_compress** **group_materi_hyperelasticity** and **group_materi_viscosity**.

The *index* specifies the element_group, see **element_group**.

6.686 group_materi_memory *index memory_type*

Either *memory_type* should be set to **-updated**, **-updated_jaumann**, **-updated_linear**, **-total** or **-total_linear**. See the theoretical part for some explanation.

For an linear total Lagrange solid the input file may look like, and is recommended for most solid calculations:

```
...
materi_velocity
materi_displacement
materi_strain_total
materi_stress
end_initia
...
node 1 ...
node 2 ...
...
group_materi_memory 0 -total_linear
group_materi_elasti_young 0 ...
...
end_data
```

For a large deformation total Lagrange solid with a straightforward decomposition of the deformation tensor into a rotation tensor and a stretch tensor the input file may look like

```
...
materi_velocity
materi_displacement
materi_strain_total
materi_stress
end_initia
...
group_materi_memory 0 -total
group_materi_elasti_young 0 ...
...
end_data
```

For an updated Lagrange solid the input file may look like

```
...
```

materi_velocity
materi_velocity_integrated
materi_stress
end_initia
...
mesh -follow_material ...
...
node 1 ...
node 2 ...
...
group_materi_memory 0 -updated
group_materi_elasti_young 0 ...
...
end_data

Notice that for an updated Lagrange formulation you should always set that the mesh follows the material.

For a fluid the input file may look like

...
materi_velocity
materi_stress
end_initia
...
(use Eulerian mesh)
mesh -fixed_in_space ...
timestep_predict_velocity -yes
...
node 1 ...
node 2 ...
...
group_materi_memory 0 -updated_linear
group_materi_viscosity 0 ...
group_materi_elasti_compressibility 0 ...
...
end_data

The *index* specifies the element_group, see **element_group**.

6.687 group_materi_plasti_bounda *index index_0 index_1 ...*

With this option, you can model reduction of friction of soil material and alike granular materials on walls. Set *index_0*, *index_1* etc. to the index of the **bounda_dof** records

for which you want to use this reduction. We define an element to be on a wall when at least one of the velocities (displacements) of the elements is prescribed (via **bounda_dof**). As a special option, you can use **-all** which indicates that the **bounda_dof** records for all indeces will be used.

The reduction of friction is done for
group_materi_plasti_mohr_coul,
group_materi_plasti_mohr_coul_direct,
group_materi_plasti_druck_prag,
group_materi_plasti_hardsoil, if specified,
by reducing the friction angle *phi* and dilatancy angle *phiflow*
and cohesion c of the granular material with a factor (2./3.).

This is done for **group_materi_plasti_camclay**, if specified, by reducing M with a factor (2./3.).

This is done for **group_materi_plasti_hypo_***, if specified, by reducing deviatoric stress increments with a factor (2./3.).

The *index* specifies the element_group of the granular material, see **element_group**.

See also **group_materi_plasti_bounda_factor** and **group_materi_plasti_mohr_coul_direct_wall**.

6.688 group_materi_plasti_bounda_factor *index factor*

With this record you can specify a factor other then the default 2./3. used by the **group_materi_plasti_bounda** record. You need to specify a factor for each of *index_0*, *index_1* etc. If you specify one factor only it will be used for all boundaries.

The *index* specifies the element_group of the granular material, see **element_group**.

6.689 group_materi_plasti_coord_limit *index coord_limit*

To prevent plasticity problems near free surfaces, you can require that Tochnog neglects plasticity laws if the vertical coordinate exceeds *coord_limit*. This option is not available for hypoplasticity laws, since for these laws nonlinear elasticity and plasticity are defined by one law, so the plasticity part cannot be suppressed by itself.

6.690 group_materi_plasti_camclay *index* M κ λ

Plastic data M, κ and λ for the modified CamClay model. The *index* specifies the element_group, see **element_group**.

6.691 group_materi_plasti_cap1 *index* ϕ c M λ^* κ^* K^{ref} $p^{ref}m$

Plastic data for the cap1 plasticity model.

The *index* specifies the element_group, see **element_group**.

6.692 group_materi_plasti_cap2 *index* c ϕ α R $epsilon_v^p$ p_b ...

Plastic data for the cap2 plasticity model. The $epsilon_v^p$ p_b ... represents a table with $epsilon_v^p$ versus p_b values; at least two sets of values need to be specified.

The *index* specifies the element_group, see **element_group**.

6.693 group_materi_plasti_compression *index sigy*

Yield data for compression plasticity. The *index* specifies the element_group, see **element_group**. Condition: **materi_strain_plasti** should be initialized.

6.694 group_materi_plasti_compression_direct *index sigy*

Compression limit. Principal stresses lower than *sigy* are not allowed and will be cut of by Tochnog. This model uses directly a cut-off of stresses, and does not use plastic strains. The *index* specifies the element_group, see **element_group**.

You can apply softening with a **dependency_diagram** on **materi_strain_total_compression_kappa**.

6.695 group_materi_plasti_compression_direct_visco *index tm*

Characteristic relaxation time for visco plasticity with **group_materi_plasti_compression_direct**. Choose *tm* small if you want to have fast relaxation of the plasticity to the plastic state.

Thus the **group_materi_plasti_compression_direct** can only use this **group_materi_plasti_compressi** for visco-plasticity, and no other visco-plasticity model.

See also **group_materi_plasti_mohr_coul_direct_visco**.

6.696 group_materi_plasti_diprisco *index* γ $\hat{\beta}_f$ b_p c_p t_p $\hat{\theta}_c$ $\hat{\theta}_e$ ξ_c ξ_e β_f^0

Yield data for di Prisco plasticity. The *index* specifies the element_group, see **element_group**. Condition: **materi_strain_plasti** and **materi_plasti_diprisco_history 11** should be initialized.

6.697 group_materi_plasti_diprisco_density *index* γ_l $\hat{\beta}_{lf}$ b_{lp} c_{lp} t_{lp} $\hat{\theta}_{lc}$ $\hat{\theta}_{le}$ ξ_{lc} ξ_{le} β_{lf^0} γ_d $\hat{\beta}_{df}$ b_{dp} c_{dp} t_{dp} $\hat{\theta}_{dc}$ $\hat{\theta}_{de}$ ξ_{dc} ξ_{de} β_{df^0} e_l e_d

Yield data for di Prisco plasticity with varying density. All data with an l in the subscript holds for loose soil, whereas all data with an d in the subscript holds for dense soil. The actually used data will be interpolated between the loose and dense data using the current density.

The *index* specifies the element_group, see **element_group**. Condition: **materi_strain_plasti** and **materi_plasti_diprisco_history 12** should be initialized.

6.698 group_materi_plasti_druck_prag *index phi c phiflow*

Both yield data and flow data (indicated by the word flow) for Drucker-Prager plasticity. Choose *phi* and *phiflow* in between 0 and $\frac{\pi}{2}$. The *index* specifies the element_group, see **element_group**. Condition: **materi_strain_plasti** should be initialized.

6.699 group_materi_plasti_element_group *index group_0 group_1 ...*

With this record you can model frictional slip of soil material and alike granular materials on other materials like concrete, steel, etc.

This is done for **group_materi_plasti_mohr_coul**, **group_materi_plasti_druck_prag**, **group_materi_plasti_hardsoil**, if specified,
by reducing the friction angle *phi* and dilatancy angle *phiflow*
and cohesion c of the granular material with a factor (2./3.).

This is done for **group_materi_plasti_camclay**, if specified, by reducing M with a factor (2./3.).

This is done for **group_materi_plasti_tension**, if specified, by reducing *sigy* with a factor (2./3.).

This is done for **group_materi_plasti_hypo_***, if specified, by reducing the deviatoric stress increments with a factor (2./3.).

With *group_0* , *group_1* etc. you can specify the groups of the concrete material, steel material etc. The reduction of the friction angle and dilatancy angle will only be applied to the granular elements (of *element_group*) which are a direct neighbor of an element which has one of the groups *group_0* , *group_1* etc.

Please realise that this method only works well if the finite elements are not too large.

The *index* specifies the element_group of the granular material, see **element_group**.

See also **group_materi_plasti_element_group_factor**.

6.700 group_materi_plasti_element_group_factor *index factor_0 factor_1 ...*

With this record you can specify a factor other then the default 2./3. used by the **group_materi_plasti_element** record. You need to specify a factor for each group.

As a special option you can specify one value only, which will then be used for all factors.

The *index* specifies the element_group of the granular material, see **element_group**.

6.701 group_materi_plasti_generalised_non_associate_cam_clay_for_bonded_ *index ...*

Yield data for the Generalised Non Associate Cam Clay for Bonded Soils plasticity model. The *index* specifies the element_group, see **element_group**.

6.702 group_materi_plasti_gurson *index sigy q1 q2 q3*

Yield data (also used as flow data) for Gurson plasticity. The *index* specifies the element_group, see **element_group**.

6.703 group_materi_plasti_hardsoil *index* ϕ c ψ R_f

Plasticity data for Hardening Soil model. The *index* specifies the element_group, see **element_group**.

This model requires sufficient small timesteps; in case of trouble try smaller timesteps.

6.704 group_materi_plasti_heat_generation *factor*

This *factor* specifies how much of the plastic energy loss is transformed into heat (this only makes sense if **condif_temperature** is initialized). The *factor* should be between 0 and 1. The *index* specifies the element_group, see **element_group**.

6.705 group_materi_plasti_hypo_cohesion *index c*

Cohesion parameter in hypoplastic law. First, the cohesion in this record is subtracted from the normal stresses in the hypo law evaluation, so that the hypo law is evaluated at a lower pressure level. Second, if the pressure level then still exceeds the $-3. * c$, the hypo law only will use its linear contribution. These actions increase numerical stability of the calculation in zones of small stresses (free surfaces).

The *index* specifies the element_group, see **element_group**.

6.706 group_materi_plasti_hypo_masin *index* φ_c λ^* κ^* N r

Masin hypoplasticity parameters; see the theory section. The angle φ_c should be specified in degrees. The λ^* should be bigger than the κ^*.

6.707 group_materi_plasti_hypo_masin_clay *index* φ_c λ^* κ^* N ν_{pp}

Masin clay hypoplasticity parameters. The angle φ_c should be specified in degrees. The λ^* should be bigger than the κ^*. Typical values are $\varphi_c = 25$, $\lambda^* = 0.1$, $\kappa^* = 0.01$, $N = 1$ and $\nu_{pp} = 0.2$.

6.708 group_materi_plasti_hypo_masin_clay_advanced_parameters *index* α_G α_f a_y o_c

Optional advanced parameters α_G α_f a_y o_c for masin lay law. If not specified the defaults are: $\alpha_G = 1$, α_f from governing equation in [13], $a_y = 0.3$ and $o_c = 2$.

6.709 group_materi_plasti_hypo_masin_clay_avanced_direction *index* dir_i

Optional advanced integer parameter for Masin clay law. If not specified the default for the vertical direction dir_i is: 0 in 1D calculation, 1 in 2D calculation and 2 in 3D calculation.

6.710 group_materi_plasti_hypo_masin_clay_ocr *index OCR*

OCR in masin hypoplastic law; the initial void ratio will be calculated from this. A typical value is $OCR = 1.5$. You need to set **control_materi_plasti_hypo_masin_clay_ocr_apply** to **-yes**.

6.711 group_materi_plasti_hypo_masin_clay_structure *index k A s_f*

Masin clay hypoplasticity structure parameters; see the theory section. The k should be at least 0. The A should be greater or equal to 0, and lower than 1. The s_f should be greater or equal to 1. Typical values are $k = 0.4$, $A = 0.1$ and $s_f = 1.5$.

6.712 group_materi_plasti_hypo_masin_clay_visco *index D_r I_v*

Masin clay hypoplasticity visco hypoplasticity parameters; see the theory section. Typical values are $D_r = 1.e-6$ and $I_v = 0.1$.

Remark: this law should not be combined with intergranular strains.

6.713 group_materi_plasti_hypo_masin_ocr *index OCR*

OCR in masin hypoplastic law; the initial void ratio will be calculated from this. You need to set **control_materi_plasti_hypo_masin_ocr_apply** to **-yes**.

6.714 group_materi_plasti_hypo_masin_structure *index k A s_f*

Masin hypoplasticity structure parameters; see the theory section. The k should be at least 0. The A should be greater or equal to 0, and lower than 1. The s_f should be greater or equal to 1.

6.715 group_materi_plasti_hypo_minimum_void_ratio *index minimum_void_ratio*

This option sets a minimum for the void ratio as calculated by hypoplasticity laws. If the void ratio would become lower than this *minimum_void_ratio* value it will be reset to this *minimum_void_ratio* value.

This option becomes handy when in difficult nonlinear calculations the void ratio may become negative in local zones, preventing the remainder of the calculation to continue. You should check the final results of the calculation if they are what you want.

The *index* specifies the element_group, see **element_group**.

6.716 group_materi_plasti_hypo_strain_intergranular *index* R m_R m_T β_r χ θ

Intergranular strain parameters in hypoplastic law. The *index* specifies the element_group, see **element_group**.

6.717 group_materi_plasti_hypo_strain_intergranular_masin_clay *index* R A_g n_g m_{rat} β_r χ θ

Intergranular strain parameters for masin clay hypoplastic law. Typical values are $R = 5.e-5$, $A_g = 270$, $n_g = 1$, $m_rat = 0.5$, $\beta_r = 0.08$, $\chi = 7$ and $\theta = 7$. The *index* specifies the element_group, see **element_group**.

6.718 group_materi_plasti_hypo_strain_isa *index* $\chi_{\max}$ C_a

ISA-Intergranular strain parameters in hypoplastic law; see the theory section. The *index* specifies the element_group, see **element_group**.

6.719 group_materi_plasti_hypo_wolffersdorff *index* φ h_s n e_{c0} e_{d0} e_{i0} *alpha beta*

Von-Wolffersdorff parameters in hypoplastic law; see the theory section. Here φ is in degrees. The *index* specifies the element_group, see **element_group**.

6.720 group_materi_plasti_hypo_wolffersdorff_niemunis *index* ν z

Von-Wolffersdorff-Niemunis extended parameters in hypoplastic law; see the theory section. The *index* specifies the element_group, see **element_group**.

6.721 group_materi_plasti_hypo_niemunis_visco *index* φ *nu* D_r I_v e_{e0} p_{e0} *lambda* β_R *kappa*

Parameters φ ν D_r I_v e_{e0} p_{e0} λ β_R κ for the visco part of hypoplasticity; see the theory section.

The history variables are the same as for **group_materi_plasti_hypo_wolffersdorff**. You also need to specify **control_materi_plasti_hypo_niemunis_visco_ocr_apply**.

The *index* specifies the element_group, see **element_group**.

6.722 group_materi_plasti_hypo_niemunis_visco_ocr *index OCR*

OCR in visco hypoplastic law. The initial void ratio will be calculated from this; see the theory section.

In case you would like to have an OCR dependent on space coordinate you can use **dependency_diagram** and **dependency_item**.

The *index* specifies the element_group, see **element_group**.

6.723 group_materi_plasti_hypo_void_ratio_linear *index switch*

Normally the void ratio change in hypoplasticity is calculated by using the trace of the deformation tensor. That in fact uses a linear approximation of the volume change. This linear approximation is convenient to compare results with analytical theories which are based on such linear approximation, and also to use parameters in hypoplastic laws which are calibrated with such approximation.

Optionally, using **-no** in this **group_materi_plasti_hypo_void_ratio_linear** record, the exact volume change of the material is calculated using the determinant of the deformation tensor, and used to calculate the exact new void ratio. However, hypoplasticity laws are usually fitted on the linear approximation of the volume change. So you should not use **-no** unless you are perfectly certain what you are doing.

6.724 group_materi_plasti_kinematic_hardening *index a*

This record specifies the size of the rate of the kinematic hardening matrix ρ_{ij}. The *index* specifies the element_group, see **element_group**.

6.725 group_materi_plasti_mohr_coul *index phi c phiflow*

Both yield data and flow data (indicated by the word flow) for Mohr-Coulomb plasticity. Choose *phi* and *phiflow* in between 0 and $\frac{\pi}{2}$. The *index* specifies the element_group, see **element_group**.

It is advised to use **group_materi_plasti_tension** or preferably with **group_materi_plasti_tension_direc** for tension cutoff of large tension stresses.

6.726 group_materi_plasti_mohr_coul_direct *index phi c phiflow*

Both yield data and flow data (indicated by the word flow) for Mohr-Coulomb plasticity. Choose *phi* and *phiflow* in between 0 and $\frac{\pi}{2}$. The *index* specifies the element_group, see

element_group.

Principal stress differences higher than allowed by the mohr-coulomb criterium are not allowed and will be cut of by Tochnog. This model uses an alternative programming of the mohr-coulomb law, which tends to be very stable.

You must specify also **group_materi_plasti_tension_direct**.

You can apply softening with a **dependency_diagram** on **materi_strain_total_shear_kappa**.

6.727 group_materi_plasti_mohr_coul_direct_normal *index normal_x normal_y normal_z*

This option i.c.w. **group_interface_materi_plasti_mohr_coul_direct** ensures that the friction stress does not exceed the mohr coulomb shear stress limit on specifically the plane with normal vector *normal_x normal_y normal_z*. In 1d only specify *normal_x*, etc.

If this option is used i.c.w. **group_materi_plasti_element_group** or **group_materi_plasti_bounda** it will only be actually used in elements with satisfy the condition listed in **group_materi_plasti_element_gro** or **group_materi_plasti_bounda**.

To limit tension stress on specifically the plane with a normal vector use **group_materi_plasti_tension_direct_normal**.

6.728 group_materi_plasti_mohr_coul_direct_normal_automatic *index switch*

This option is similar to **group_materi_plasti_mohr_coul_direct_normal**, however now the normal direction is automatically taken from the element normal **element_normal**. You need to set *switch* to **-yes**.

6.729 group_materi_plasti_mohr_coul_direct_visco *index tm*

Characteristic relaxation time for visco plasticity with **group_materi_plasti_mohr_coul_direct**. Choose *tm* small if you want to have fast relaxation of the plasticity to the plastic state.

Thus the **group_materi_plasti_mohr_coul_direct** can only use this **group_materi_plasti_mohr_coul** for visco-plasticity, and no other visco-plasticity model.

For **group_materi_plasti_..._direct_visco** laws visco plasticity works as follows. Suppose the stress at time t is σ_t. Calculate the elastic response (non-plastic) at time $t+dt$ as $\sigma_{e,t+dt}$. Calculate the plastic non-viscous response at time $t+dt$ as $\sigma_{p,t+dt}$. Calculate the plastic viscous response at time $t+dt$ as

$$\sigma_{vp,t+dt} = \sigma_{e,t+dt} + factor * (\sigma_{p,t+dt} - \sigma_{e,t+dt})$$

where

$$factor = 1 - exp(-dt/tm)$$

Notice that for dt is very small $factor = 0$ so $\sigma_{vp,t+dt} = \sigma_{e,t+dt}$, thus purely elastic response (which is the stress at the previous time plus the elastic stress increment). Notice that for dt is very large $factor = 1$ so $\sigma_{vp,t+dt} = \sigma_{p,t+dt}$, thus purely plastic response (which is the stress completely mapped to the plastic surface). And for dt in between the response is in between the elastic response and purely plastic response.

6.730 group_materi_plasti_mohr_coul_direct_wall *index phi c phiflow*

As a special option for **group_materi_plasti_mohr_coul_direct** you can use a record **group_materi_plasti_mohr_coul_direct_wall** *index phi c phiflow*. These values will be used when an element is attached to a wall. The input file needs to contain **group_materi_plasti_element_group**, **group_materi_plasti_bounda** or **group_materi_plasti_mp** to specify when an element is at the wall. Thus a typical input file looks like:

...
group_materi_plasti_mohr_coul_direct 0 ... (values for elements not attached to wall)
group_materi_plasti_mohr_coul_direct_wall 0 ... (values for elements attached to wall)
group_materi_plasti_mpc 0 -yes (elements with mpc's are attached to wall)
...
end_data

See also **group_materi_plasti_element_group**, **group_materi_plasti_bounda** and **group_materi_plasti_mpc**.

6.731 group_materi_plasti_mohr_coul_hardening_softening *index phi_0 c_0 phiflow_0 phi_1 c_1 phiflow_1 kappashear_crit*

Both yield data and flow data (indicated by the word flow) for Mohr-Coulomb hardening-softening plasticity. See the theoretical part. Choose each of the angles *phi_0 phiflow_0 phi_1 phiflow_1* in between 0 and $\frac{\pi}{2}$. It is advised to use **group_materi_plasti_tension** or preferably with **group_materi_plasti_tension_direct** for tension cutoff of large tension stresses. The *index* specifies the element_group, see **element_group**.

6.732 group_materi_plasti_mohr_coul_direct_wall *index phi c phiflow*

As a special option for **group_materi_plasti_mohr_coul_direct** you can use a record **group_materi_plasti_mohr_coul_direct_wall** *index phi c phiflow*. These values will be used when an element is attached to a wall. The input file needs to contain **group_materi_plasti_bounda** or **group_materi_plasti_mpc** to specify when an element is at the wall. Thus a typical input file looks like:

...
group_materi_plasti_mohr_coul_direct 0 ... (values for elements not attached to wall)
group_materi_plasti_mohr_coul_direct_wall 0 ... (values for elements attached to wall)
group_materi_plasti_mpc 0 -yes (elements with mpc's are attached to wall)
...
end_data

See also **group_materi_plasti_bounda** and **group_materi_plasti_mpc**.

6.733 group_materi_plasti_mpc *index switch*

Same as **group_materi_plasti_bounda**, but now for **mpc_...** records however. If you set *switch* to **-yes**, the reduction factor will be applied if there is any mpc at the node of an element.

See also **group_materi_plasti_mpc_factor**.

6.734 group_materi_plasti_mpc_factor *index factor*

Same as **group_materi_plasti_bounda_factor**, but now for **group_materi_plasti_mpc** however.

6.735 group_materi_plasti_pressure_limit *index pressure_limit*

To prevent plasticity problems near free surfaces, you can require that Tochnog neglects plasticity laws if the pressure exceeds *pressure_limit*. This option is not available for hypoplasticity laws, since for these laws nonlinear elasticity and plasticity are defined by one law, so the plasticity part cannot be suppressed by itself.

See also **group_materi_plasti_pressure_limit_method**.

6.736 group_materi_plasti_residual_stiffness *index factor*

With *factor* you can set the part of the original shear stiffness stiffness to be used as stiffness in plastic elementss. Default, if this record is not specified, the *factor* is set to 1.

6.737 group_materi_plasti_tension *index sigy*

Yield data for tension plasticity. The *index* specifies the element_group, see **element_group**. Condition: **materi_strain_plasti** should be initialized.

It is encouraged to use **group_materi_plasti_tension_direct** instead, which tends to give more stable calculations.

6.738 group_materi_plasti_tension_direct *index sigy*

Tension limit. Principal stresses higher than *sigy* are not allowed and will be cut of by Tochnog. This model uses directly a cut-off of stresses, and does not use plastic strains. The *index* specifies the element_group, see **element_group**.

If this option is not specified *sigy* is set to 0 if also the **group_materi_plasti_mohr_coul_direct** is available for the group.

You can apply softening with a **dependency_diagram** on **materi_strain_total_tension_kappa**.

6.739 group_materi_plasti_tension_direct_normal *index normal_x normal_y normal_z*

This option i.c.w. **group_materi_plasti_tension_direct** limits the tension stress specifically on specifically the plane specified by the normal *index normal_x normal_y normal_z*. In 1D only *normal_x* should be specified etc.

If this option is used i.c.w. **group_materi_plasti_element_group** or **group_materi_plasti_bounda** it will only be actually used in elements with satisfy the condition listed in **group_materi_plasti_element_gro** or **group_materi_plasti_bounda**.

6.740 group_materi_plasti_tension_direct_normal_automatic *index switch*

This option is similar to **group_materi_plasti_tension_direct_normal**, however now the normal direction is automatically taken from the element normal **element_normal**. You need to set *switch* to **-yes**.

6.741 group_materi_plasti_tension_direct_visco *index tm*

Characteristic relaxation time for visco plasticity with **group_materi_plasti_tension_direct**. Choose *tm* small if you want to have fast relaxation of the plasticity to the plastic state.

Thus the **group_materi_plasti_tension_direct** can only use this **group_materi_plasti_tension_direct** for visco-plasticity, and no other visco-plasticity model.

See also **group_materi_plasti_mohr_coul_direct_visco**.

6.742 group_materi_plasti_tension_direct_wall *index sigy*

As a special option for **group_materi_plasti_tension_direct** you can use a record **group_materi_plasti_tension_direct_wall** *index sigy*. This value will be used when an element is attached to a wall. The input file needs to contain **group_materi_plasti_element_group**, **group_materi_plasti_bounda** or **group_materi_plasti_mpc** to specify when an element is at the wall.

6.743 group_materi_plasti_user *index switch*

If *switch* is set to **-yes** the user supplied routine for plasticity is called.

See also the file **user.cpp** in the distribution.

The *index* specifies the element_group, see **element_group**.

6.744 group_materi_plasti_visco_exponential *index* γ α

This record specifies visco-plasticity data for the exponential model. It should be used in combination with a plasticity model.

6.745 group_materi_plasti_visco_exponential_limit *index limit*

This record defines the limit for the exponential viscoplasticity argument *alphaf* . If the argument *alphaf* becomes larger than *limit* then actually *limit* will be used instead as argument for the exponent.

Default, if **group_materi_plasti_visco_exponential_limit** is not specified, then 3 will be used as limit.

This record specifies visco-plasticity data for the exponential model. It should be used in combination with a plasticity model.

6.746 group_materi_plasti_visco_exponential_name *index name_0 name_1 ...*

Same as **group_materi_plasti_visco_power_names**, now for the exponential law however.

6.747 group_materi_plasti_visco_exponential_values *index* γ_0 α_0 γ_1 α_1 ...

See **group_materi_plasti_visco_exponential_name**.

6.748 group_materi_plasti_visco_power *index* η p

This record specifies visco-plasticity data for the power model. It should be used in combination with a plasticity model.

The *index* specifies the element_group, see **element_group**.

6.749 group_materi_plasti_visco_power_name *index name_0 name_1 ...*

This **group_materi_plasti_visco_power_name** together with **group_materi_plasti_visco_power_value** allows you to specify different viscoelastic parameters for each of the plasticity models.

Set each of the names *name_0* , *name_1* , etc. to the plasticity models that you use (eg **-group_materi_plasti_mohr_coul** etc.) Set the visco parameters for *name_0* in η_0 and p_0 , set the visco parameters for *name_1* in η_1 and p_1 , etc.

In case a plasticity model is used, but is not present in the names *name_0* , *name_1*, etc. then that model will be evaluated elasto-plastic (and thus not elasto-viscoplastic).

The *index* specifies the element_group, see **element_group**.

6.750 group_materi_plasti_visco_power_value *index* η_0 p_0 η_1 p_1 ...

See **group_materi_plasti_visco_power_name**.

6.751 group_materi_plasti_vonmises *index* $sigma_{y0}$

Yield data for Von-Mises plasticity.

The *index* specifies the element_group, see **element_group**. Condition: **materi_strain_plasti** should be initialized.

6.752 group_materi_plasti_vonmises_nadai *index* C κ_0 n

Data for Von-Mises Nadai hardening. The $sigma_{y0}$ of the **group_materi_plasti_vonmises** record is taken as $sigma_{y0}$ in the nadai law.

The *index* specifies the element_group, see **element_group**. Condition: **materi_plasti_kappa** should be initialized.

6.753 group_materi_stokes *index switch*

If *switch* is set to **-yes**, then stokes flow is used. If *switch* is set to **-no**, then stokes flow is not used. Default it is set to **-yes**. The *index* specifies the element_group, see **element_group**.

6.754 group_materi_stress_null *index dir ...*

With this option you can set the stress in the material in direction *dir* to zero. For *dir* you can use each of the local directions **-x**, **-y**, **-z** or the local shear directions **-xy**, **-xz**, **-yz**. You can specify multiple directions, for example **group_materi_stress_null index -y -z**.

With **group_materi_stress_null_direction** you can specify local frame directions (nine values) **-x**, **-y**, **-z**. Take care that these directions are perpendicular and of unit length.

If **group_materi_stress_null_direction_automatic** is specified, the local frame **-x**, **-y**, **-z** is made out of the element normal direction **element_normal** and two directions perpendicular to it.

If **group_materi_stress_null_direction** and **group_materi_stress_null_direction_automatic** are not specified, the global frame is used as local frame.

6.755 group_materi_stress_null_direction *index dir0_x dir0_y dir0_z dir1_x dir1_y dir1_z dir2_x dir2_y dir2_z*

See **group_materi_stress_null**.

6.756 group_materi_stress_null_direction_automatic *switch*

See **group_materi_stress_null**.

6.757 group_materi_umat *index switch*

If *switch* is set to **-yes** then the user supplied umat routine is called for the element group *index*.

See also the section about user supplied routines at the end of this manual.

6.758 group_materi_umat_parameters *index parameter_0 parameter_1 ...*

User supplied parameters for **group_materi_umat**.

6.759 group_materi_umat_pardiso_decompose *index switch*

If *switch* is set to **-yes** and an umat routine is present, Tochnog will ask the pardiso solver to decompose the system matrix each and every iteration of each and every timestep. If *switch* is set to **-no** and an umat routine is present, Tochnog will ask the pardiso solver to decompose the system matrix only once (please realise, however, that because of other input file options the decomposition possibly can be done more than once). Default, if *switch* is not defined, it is set to **-yes**.

6.760 group_materi_undrained_capacity *index C*

Capacity for undrained analysis. See the theory section for details on undrained analyses.

6.761 group_materi_viscosity *index* ν

Dynamic viscosity for nearly incompressible Newtonian flow. The *index* specifies the element_group, see **element_group**.

6.762 group_materi_viscosity_heatgeneration *index switch*

If *switch* is set to **-yes**, then viscous dissipation will be used as a heat generation source. See also the theoretical part at the start of this manual. The *index* specifies the element_group, see **element_group**.

6.763 group_plasti_apply *index switch*

If *switch* is set to **-no** any plasticity data in the group *index* will be neglected. Default, if **group_plasti_apply** is not specified, *switch* is set to **-yes**.

6.764 group_porosity *index n*

Porosity in material. For example needed for **group_groundflow_nonsaturated_vangenuchten**. The *index* specifies the element_group, see **element_group**.

6.765 group_spring_direction *index dir_x dir_y dir_z*

Direction of a spring. If for a **-spring2** this record is not specified, the direction is taken to be from the first node of the spring to the second node. The *index* specifies the element_group, see **element_group**.

6.766 group_spring_memory *index memory_type*

Memory model for spring; either **-updated_linear**, **-total_linear** or **-updated**. The **-updated** model is a geometrically nonlinear model which takes large spring rotations into account fro two-noded springs. The *index* specifies the element_group, see **element_group**.

6.767 group_spring_plasti *index* F_y

Maximum force in a spring. The *index* specifies the element_group, see **element_group**.

6.768 group_spring_stiffness *index k*

Stiffness of a spring. It is multiplied with the elongation of the spring to calculate the spring force. The *index* specifies the element_group, see **element_group**.

6.769 group_spring_stiffness_nonlinear *index epsilon*$_0$ k_0 *epsilon*$_1$ k_1 ...

Diagram with spring stiffness dependent on total spring strain (= total spring elongation). Here *epsilon*$_0$ k_0 is the first point in the diagram, with *epsilon*$_0$ the total spring strain and k_0 the spring stiffness. Likewise for the next points in the diagram. Take care that you

specify diagram values with a strain range that includes all spring strain that actually occur in the calculation.

The *index* specifies the element_group, see **element_group**.

6.770 group_time *index birth death*

With this option you can set the time of birth of the elements (in group *index*) and the time of death of the elements.

Out of the range *birth* - *death* the elements of the group will not be used in the calculation (the starting *birth* limit itself is not included in the range, whereas the ending *death* limit itself is included).

6.771 group_time_fill *index birth_empty birth_filled death*

With this option you can set the time of birth of the elements (in group *index*) and the time of death of the elements.

Out of the range *birth_empty* - *death* the elements of the group will not be used in the calculation (the starting *birth_empty* limit itself is not included in the range, whereas the ending *death* limit itself is included).

Between *birth_empty* and *birth_filled* the elements will be 'slowly filled with material'. This means that the density of the element and the total pressure (pore pressure), in case groundflow is present, will be scaled with a factor 0 at time *birth_empty* up to a factor 1 at time *birth_filled*. To prevent numerical problems at low gravity, any plasticity data will be ignored when an element is being filled; after the element is completely filled plasticity will become active (plasticity data will be applied).

6.772 group_truss_area *index A*

Cross-sectional area for a truss. The *index* specifies the element_group, see **element_group**.

6.773 group_truss_density *index* ρ

Density for a truss. The *index* specifies the element_group, see **element_group**.

6.774 group_truss_elasti_elongation_force_diagram *index l_0 F_0 l_1 F_1 ...*

With this record you can specify a force versus elongation diagram for a truss. Here each l_i is the ratio of the truss elongation divided by the initial truss length. And each F_i is the corresponding force. This **group_truss_elasti_elongation_force_diagram** cannot be combined with **group_truss_elasti_young**.

6.775 group_truss_elasti_young *index E*

Young's modulus for a truss. The truss force F is $F = EA\Delta u$, where Δu is the elongation of the truss. The *index* specifies the element_group, see **element_group**.

See also **group_truss_area**.

6.776 group_truss_expansion *index alpha*

Thermal expansion coefficient for trusses. A temperature increment dT leads to a thermal incremental length of the size alpha * dT * initial length;

6.777 group_truss_initial_force *index initial_force*

Initial truss force in truss elements.

6.778 group_truss_memory *index memory_type*

Memory model for truss; either **-updated_linear**, **-updated** or **total_linear**. The **-updated** model is a geometrically nonlinear model which takes large truss rotations into account. The *index* specifies the element_group, see **element_group**.

6.779 group_truss_rope *index switch*

The truss will act as a rope if *switch* is set to **-yes**. This means that negative forces will not be allowed (the force remains zero in compression). The *index* specifies the element_group, see **element_group**.

6.780 group_truss_plasti *index* $sigma_c$ $sigma_t$

Compressive and tension yield stress for truss. The actual stress cannot become lower than the $sigma_c$ in compression, and the actual stress cannot become higher than the $sigma_t$ in tension. The *index* specifies the element_group, see **element_group**.

6.781 group_type *index type_name_0 type_name_1 ...*

With this record a differential equation is specified for the element group *index*. Allowed type names are **-condif**, **-groundflow**, **-materi**, **-wave**, **-spring**, **-contact_spring**, **-truss**, **-beam**, **-truss_beam**. Also **-empty** is allowed; it indicates that the element is empty.

For the **-truss_beam** type you need to set parameters with **group_truss_*** and **group_beam_*** records. For the **-truss** type you need to set parameters with **group_truss_*** records. For the **-beam** type you need to set parameters with **group_beam_*** records. For the **-condif** type you need to set parameters with **group_condif_*** records. For the **-materi** type you need to set parameters with **group_materi_*** records. Etc etc.

See also **element_group**.

6.782 group_volume_factor *index factor*

In 1D or 2D you can specify the cross-section and thickness respectively, for elements of the element group *index* (see **element_group**).

See also **volume_factor**.

6.783 group_wave_speed_of_sound *index c*

Speed of sound in wave equation. The *index* specifies the element_group, see **element_group**.

6.784 icontrol *icontrol*

With this record you can set the control index which already have been performed. Thus if you set it to 10, all **control_*** records up to and including those with index 10 will be skipped, and the control indices starting from 11 will be performed.

6.785 incremental_driver ...

All incremental driver options are given in the example input file below:

```
echo -no
number_of_space_dimensions 2
materi_velocity
materi_velocity_integrated
materi_strain_total
materi_strain_plasti
materi_strain_intergranular
materi_strain_isa_c
materi_strain_isa_eacc
materi_plasti_hypo_history 4
materi_stress
groundflow_pressure
end_initia

( RUNNING:
  Run this file with the normal tochnog executable.
  Results are written in incremental_driver_result.txt.

  EQUILIBRIUM:
  At the start equilibrium is assumed (an external force is assumed which
  makes equilibrium with the internal stress and internal pore water
  pressure if specified).

  UNITS:
  The word force below means a force unit (eg kN).
  The word stress below means a stress unit (eg kPa).
  The incremental driver does not use specific units; all units can be
  used which are consistent. As an exception the hypoplastic masin law
  uses specific units (see the tochnog users manual).

  EXPERIMENTS:

  -INCREMENTAL_DRIVER_OEDOMETRIC
   'group_axisymmetric index -yes' is allowed; then x=r and y=theta.
   'incremental_driver_volume_constant index -yes' is not allowed
   x: zero displacement in x-direction
   y: zero displacement and strain in y-direction
   z: compression in z-direction
   user specified: displacement or force on top plane in z-direction,
                   the specified values should be negative for compression

  -INCREMENTAL_DRIVER_TRIAX
   'group_axisymmetric index -yes' is allowed; then x=r and y=theta.
   'incremental_driver_volume_constant index -yes' is allowed;
     then the volume is kept constant (undrained water pressure is not needed)
   x: fixed stress in x-direction
   y: if axisymmetric then y-strain comes from calculation,
      if not axisymmetric then constant stress in y direction
```

```
 z: compression in z-direction
 user specified: displacement or force on top plane in z-direction,
                 the specified values should be negative for compression

-INCREMENTAL_DRIVER_DIRECT_SHEAR
 'group_axisymmetric index -yes' is not allowed.
 'incremental_driver_volume_constant index -yes' is allowed;
   then the volume is kept constant (undrained water pressure is not needed)
 x: zero strain in x-direction
 y: zero displacement and strain in y-direction
 z: shear of top z-plane in x-direction, fixed stress in z-direction
 user specified: shear displacement or shear force on top plane in x-direction

-INCREMENTAL_DRIVER_HYDROSTATIC
 'group_axisymmetric index -yes' is allowed.
 'incremental_driver_volume_constant index -yes' is not allowed
 equal compression in x- and y- and z-direction
 user specified: volumetric displacement
   ( (x- plus y- plus z-displacement ) / 3. ) or volumetric stress
 notice: not a force but instead a stress is specified.

COMBINED EXPERIMENTS:
Only combined experiments will be analysed, and only output will be printed for
these combined experiments; the experiments by themselves will not be analysed.
The start time of each experiment in a combined experiment should be equal to
the end time of a previous experiment in that combined experiment.
Only for the first experiment the variables incremental_driver_void_ratio,
incremental_driver_stress ,incremental_driver_pressure and
incremental_driver_intergranular_strain can be specified;
for all subsequent experiments these values will be taken from the end values
of the previous experiment.
If no combined experiments are specified, automatically a combined experiment will
be generated for each experiment, containing that experiment only.
Notice that prescribed displacements and forces in an experiment are additional
to the last values of the previous experiment.
In an experiment all forces that are not prescribed and don't belong to a
prescribed displacement remain equal to those of the previous experiment.

UNDRAINED:
You can obtain undrained behavior in two different ways:
1. Use groundwater in the test specimen. The groundwater capacity physically
   causes the test specimen to behave undrained.
2. Apply 'incremental_driver_volume_constant index -yes' . This causes the
   deformations of the test specimen to be such that the volume remains constant.
You should choose one of both methods. You should not combine both methods.

GROUNDFLOW:
In case of 'group_type index -groundflow' groundwater is present in the test specimen.
```

```
  Then all groundflow initialisation and data needs to be specified (search for
  groundflow in this file to see what is needed).

  MATERIAL LAWS:
  group_materi_plasti_mohr_coul_direct*
  group_materi_plasti_hypo*
  group_materi_umat*
  See the tochnog users manual.

  MATERIAL MEMORY:
  If you use -updated_linear then small deformation theory is used, and the area
  change of the surface where forces are applied is not taken into account.
  If you use -updated_area then small deformation theory is used, but the area
  change of the surface where forces are applied is taken into account.
  If you use -updated then large deformation theory is used, and the area change
  of the surface where forces are applied is taken into account.

  AXISYMMETRIC:
  Either all experiments are axisymmetric or all experiments are not axisymmetric.
  Do not mix axisymmetric and non-axisymmetric experiments in a combined experiment.

)

post_calcul -groundflow_pressure -total_pressure

group_type                              0  -materi

group_axisymmetric                      0  -no

group_materi_memory                     0  -updated_area

group_materi_plasti_hypo_cohesion       0  1.

group_materi_plasti_hypo_wolffersdorff 0  30. 5800.e3 0.28 0.84 0.53 1.00 0.13 1.05

group_materi_plasti_hypo_strain_intergranular 0  1.e-4 5.0 2.0 0.50 6.0 6.0

group_materi_plasti_hypo_strain_isa     0 20.0 0.017


group_type                            1  -materi -groundflow

group_axisymmetric                    1  -no

group_materi_memory                   1  -updated_area

group_materi_elasti_young             1   6000.
```

```
group_materi_elasti_poisson          1   0.4

group_materi_plasti_mohr_coul_direct 1   0.4 1.e1 0.1

(gamma_0  c_0  gamma_1 c_1 ..., optional)
group_materi_plasti_mohr_coul_direct_incremental_driver_c   1
0. 10. 0.01 9. 100. 0.

(gamma_0 phi_0 gamma_1 phi_1 ..., optional)
group_materi_plasti_mohr_coul_direct_incremental_driver_phi 1
0. 0.4 0.01 0.3 100. 0.1

(gamma_0 psi_0 gamma_1 psi_1 ..., optional)
group_materi_plasti_mohr_coul_direct_incremental_driver_psi 1
0. 0.1 0.01 0.05 100. 0.02

group_groundflow_capacity            1   1.e-4

( etc )

(number of timesteps to be used for each experiment, default 1000.
 In these steps the total time table as specified by
 incremental_driver_experiment_time is performed)
incremental_ntime 1000

(set to experiment name)
incremental_driver               0 -incremental_driver_direct_shear

(set to element group used)
incremental_driver_element_group 0 0

(set to -yes for force controlled experiment,
set to -no for displacement controlled)
incremental_driver_experiment_force_controlled    0 -no

(time table for additional displacement or additional force at top y-plane
 in x-direction relative to start time experiment)
incremental_driver_experiment_time    0 0.0 0.0 1.0 0.02

(initial stress: sigxx sigxy sigxz sigyy sigyz sigzz)
incremental_driver_stress        0 -100 0 0 -100 0 -100

(initial pore pressure for undrained analysis for groundflow)
incremental_driver_pressure      0 -10.

(initial void_ratio for hypo laws)
incremental_driver_void_ratio    0 0.75
```

```
(initial intergranular strain for hypo: epixx epixy epixz epiyy epiyz epizz)
incremental_driver_intergranular_strain  0 -0.0000577 0. 0. -0.0000577 0. -0.0000577

(initial isa intergranular back-strain for hypo: episa_cxx episa_cxy episa_cxz episa_cyy episa_
incremental_driver_isa_strain  0 -0.0000404145 0. 0. -0.0000404145 0. -0.0000404145

(initial length in x-direction)
incremental_driver_length_x      0  0.1

(initial length in y-direction, not needed in axisymmetric)
incremental_driver_length_y      0  0.1

(initial length in z-direction)
incremental_driver_length_z      0  0.2

(set to experiment name)
incremental_driver               1 -incremental_driver_direct_shear

(set to element group used)
incremental_driver_element_group 1 0

(set to -yes for force controlled experiment,
 set to -no for displacement controlled)
incremental_driver_experiment_force_controlled    1 -no

(time table for additional displacement or additional force at top y-plane
 in x-direction relative to start time experiment)
incremental_driver_experiment_time    1 1.0 0.0 2.0 0.02

(initial length in x-direction)
incremental_driver_length_x      1  0.1

(initial length in y-direction, not needed in axisymmetric)
incremental_driver_length_y      1  0.1

(initial length in z-direction)
incremental_driver_length_z      1  0.2

( etc )

(a combined experiment which only contains experiment 0)
incremental_driver_combined  0  0

(a combined experiment which contains both experiment 0 and 1)
incremental_driver_combined  1  0 1

( etc )
```

```
end_data
```

6.786 inertia_apply *switch_0 switch_1 ...*

If *switch_0* is set to **-yes**, the corresponding inertia term is included (material mass, heat capacity, ..). The same for the other switches. A switch should be specified for each of the principal dof's. See the 'input file - data part - introduction - types of dof's' section for an explanation about principal dof's. The sequence of the principal dof's is in the order as initialised in the **initia** ... **end_initia** part.

As a special option you can specify only one switch, and then the specified value will automatically be used for all principal dof's.

This **inertia_apply** is applied for all timestep records.

Default, if **inertia_apply** is not specified, then each of *switch_0*, *switch_1* etc. is set to **-no**.

See also **control_inertia_apply**.

6.787 input_abaqus *switch*

Set *switch* to **-yes** for reading the abaqus input file **abaqus.inp**. Tochnog will use it to generate a tochnog input file **tochnog_abaqus.dat**. This can typically be done by making an input file like:

```
...
echo -yes
number_of_space_dimensions 3
materi_velocity
materi_stress
end_initia
input_abaqus -yes
input_abaqus_mesh -no
input_abaqus_continue -yes
...
include tochnog_abaqus.dat
...
( other data , you can use the abaqus sets of tochnog_abaqus.dat )
...
end_data
```

You need to initialise the fields like **materi_velocity**, **materi_stress**, etc that you will

actually use later in the calculation. Only a limited set of data is transferred from the abaqus input file to the tochnog input file; you need to check if the Tochnog input file is like you want. Abaqus element sets and node sets are evaluated and can be used in the tochnog calculation.

ABAQUS is a registered trademark or trademark of Dassault Systemes. Abaqus input files can be generated by many programs, among which **mecway** is relatively affordable, see https://mecway.com/ .

6.788 input_abaqus_continue *switch*

If *switch* is set to **-yes** then after **tochnog_abaqus.dat** is generated the remainder of the input file read and the calculation continues. If *switch* is set to **-no** then after **tochnog_abaqus.dat** is generated the remainder of the input file will not be read and the calculation aborts. The **input_abaqus_continue** record should always be present as last record of the **input_abaqus_*** records.

6.789 input_abaqus_group *switch*

If *switch* is set to **-yes** then also **group_*** is written to **tochnog_abaqus.dat**. If *switch* is set to **-no** then no **group_*** is written to **tochnog_abaqus.dat**. So you can set *switch* to **-no** in case you want to provide the **group_*** yourself, and don't want it to be taken from the **abaqus.inp**.

Default, if **input_abaqus_group** is not specified, the *switch* is set to **-yes**.

6.790 input_abaqus_mesh *switch*

If *switch* is set to **-no** then only mesh data is written to **tochnog_abaqus.dat**; so timestep information and post processing prints are not written. This record should be placed before the **input_abaqus_continue** record.

Default the *switch* is set to **-no**.

6.791 input_abaqus_set *set_0 set_1 ...*

With this option you can specify for which set numbers the elements should be written. See the generated **tochnog_abaqus.dat** for the set numbers.

6.792 input_abaqus_name *name_0 name_1 ...*

With this option you can specify which abaqus element types should be converted into tochnog elements. For example specify **-tria3** if you want to include **tria3** elements in the Tochnog input file. In case you do not specify **input_abaqus_name** all elements will be converted into tochnog elements. However, not all abaqus elements are available as tochnog element; if a non-available element is encountered it will be skipped.

6.793 input_feflow_mesh *switch*

If *switch* is set to **-yes** the mesh is read from a FEFLOW file. FEFLOW is a dedicated groundwater analysis program, see **https://www.mikepoweredbydhi.com/products/feflow**. The Tochnog input file itself should not contain a mesh (elements and nodes). Presently, in a 3D analysis the thickness of each layer should be uniform over the nodes (no varying layer thickness in x- and y-direction). Default elements of the FEFLOW file get the **element_group** 0 in the Tochnog calculation; however, for each set of elements specified inside the feflow file with **K_xx** inside **MAT_I_FLOW** an increasing element group number is generated (1 for the elements specified in the first **K_xx**, 2 for the elements specified in the second **K_xx**, etc.).

6.794 input_feflow_fem *switch*

If the *switch* in **input_feflow_fem** is set to **-yes** the mesh is read from the file **feflow.fem**. If the *switch* in **input_feflow_fem** is set to **-no** the mesh is read from the file **feflow.dac**. Both files should be in ASCII text format. Default, if **input_feflow_fem** is not specified, the *switch* is set to **-no**.

See also **input_feflow_mesh**.

6.795 input_feflow_mesh_hydraulic_head *switch*

If the *switch* in **input_feflow_hydraulic_head** is set to **-yes** then also the hydraulic head is read from the **feflow.dac** file. The **feflow.dac** should contain hydraulic pressure head results for all time points in the Tochnog calculation. The hydraulic pressure head as calculated by FEFLOW is then used as prescribed value in the Tochnog calculation, so that Tochnog only calculates stress (influenced however by the presence of the hydraulic pressure head). This option allows you to calculate hydraulic safety factors using FEFLOW hydraulic pressure heads and Tochnog stresses (see **safety_piping** and **safety_lifting** in **post_calcul**).

See also **input_feflow_mesh**.

6.796 input_gmsh *switch*

Set *switch* to **-yes** for reading the **gmsh** mesh file **tochnog_in.msh**. Only linear and quadratic elements are read.

The **gmsh** program is a free external pre- and postprocessor. See http://www.geuz.org/gmsh .

Only the data **element**, **element_group** and **node** is read.

6.797 interface_gap_apply *switch*

If *switch* is set to **-yes** then any **group_interface_gap** will be applied. If *switch* is set to **-no** then any **group_interface_gap** will be ignored.

Default, if **interface_gap_apply** is not specified, *switch* is set to **-yes**.

This **interface_gap_apply** record will be overruled by the **control_interface_gap_apply** record if specified.

6.798 linear_calculation_apply *switch*

If you set the *switch* to **-yes**, Tochnog will skip nonlinearities from the input file. This option is convenient for testing and problem search. Simple set **linear_calculation -yes** so that the calculation should run without any trouble, and use a **control_print** for **-post_node_rhside_ratio**. The printed **-post_node_rhside_ratio** should be very small, typically 1.e-10 or lower, since the calculation is linear now. If that is not the case, there may be a problem with the boundary conditions or some other problem.

A typical sequence for testing very large calculations may be following: first run with **solver -none** and check the mesh at all times; second run with **linear_calculation_apply -yes** to check if good linear solutions fields are obtained (check the linear results carefully); finally run your actual calculation without any special options.

The following specific actions are taken:

- Any **control_plasti_apply** is deleted, and **plasti_apply** is set to **-no**.
- **mesh** is set to **-fixed_in_space**.
- For all **group_*_memory** the memory type is set to **-total_linear** if **materi_displacement** is initialised, and it is set to **-updated_linear** otherwise.
- Any **dependency_item** , **dependency_diagram** containing **group_*** data dependening on one of the dof's of **dof_label** is deleted.

- Any **group_materi_elasti_hardsoil** is deleted and substituted by a **group_materi_elasti_young** with *E50ref* as Young's modulus.
- Any **group_materi_elasti_polynomial** is deleted and substituted by a **group_materi_elasti_young** with *E0* as Young's modulus.
- Any **group_materi_elasti_young_power** is substituted by a linear **group_materi_elasti_young**.
- Any **group_materi_plasti_hypo_wolffersdorff** is deleted and substituted by a **group_materi_elasti_young** with *hs* as Young's modulus, and a **group_materi_elasti_poisson** with value 0.2.
- Any **group_spring_stiffness_nonlinear** is deleted and substituted by a **group_spring_stiffness** with the stiffness value at strain 0.
- Any **group_groundflow_nonsaturated** is deleted.
- Any **group_interface_gap** is deleted.
- Any **group_interface_materi_hardening** is deleted.
- Any **group_interface_materi_elasti_stiffness_tangential_diagram** is deleted.
- Any **group_materi_damage** is deleted.
- Any **group_materi_failure** is deleted.
- Any **group_truss_rope** is deleted.
- Any **contact_*** is deleted.
- Any **groundflow_seepage_*** is deleted.

6.799 materi_damage_apply *switch*

If *switch* is set to **-no**, any damage data in the input file will be ignored. This is done for all timesteps.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with damage data. See also **control_materi_damage_apply**.

6.800 materi_dynamic *factor*

This option is specifically meant for dynamic calculations. When the solution is known at time t and is being solved in the new timestep for time $d + dt$ the stresses at time t are used with $1 - factor$ and the stress at time $t + dt$ are used with $factor$. Thus using a factor less than 1 makes the scheme less implicit, and thus less numerical damping will occur. Default, if this option is not specified, $factor$ is set to 1 (so fully implicit).

For quasi static calculations this option should not be used since it results in a loss of stability for strong nonlinearities. Also in case of dynamic calculations with heavy nonlinearity it is better to use the default timestepping method with sufficient small steps. You can try if by using this option the calculation converges; if the calculation converges it is better to use this option; if the calculation diverges by using this option it should be removed.

Using this **materi_dynamic** option the value of **post_node_rhside_ratio** is not usable anymore. So this option is typically used in combination with fixed timestepping. In fact, you should perform the dynamic calculation with typical timestep, and afterwards perform the calculation again with a smaller timestep to see if results change significantly.

In solid mechanics dynamics we always use for velocities and accelerations $velocity^{t+dt} = (displacement^{t+dt} - displacement^{t})/dt$ and $acceleration^{t+dt} = (velocity^{t+dt} - velocity^{t})/dt$. In fluid calculations where velocities are calculated and displacements of particles are not relevant, we only have $acceleration^{t+dt} = (velocity^{t+dt} - velocity^{t})/dt$.

6.801 materi_elasti_young_power_apply *switch*

If *switch* is set to **-no**, any nonlinearity in young dependent on a power law will be ignored; simply the constant young as encountered in the **group_materi_elasti_young_power** records will be applied at all times.

6.802 materi_failure_apply *switch*

If *switch* is set to **-no**, any failure data in the input file will be ignored. This is done for all timesteps.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with failure data. See also **control_materi_failure_apply**.

6.803 materi_plasti_hypo_substepping *index switch*

If *switch* is set to **-yes** substepping will be applied in hypoplasticity routines. If *switch* is set to **-no** substepping will not be applied in hypoplasticity routines.

If the record **control_materi_plasti_hypo_substepping** is specified that record will be used. If none record is not specified *switch* is set to **-yes**.

6.804 materi_plasti_maximum_iterations *maximum_iterations*

Plasticity needs iterations on integration point level. Default at maximum 20000 iterations are allowed. With this **materi_plasti_maximum_iterations** options you can increase

the number of allowed iterations, if it looks like results are inaccurate and more iterations are needed. This might be the case in calculations with very heavy plasticity.

6.805 materi_plasti_tension_apply *switch*

If *switch* is set to **-no**, any tension-plasticity data in the input file will be ignored. This is done for all timesteps.

See also **control_materi_plasti_tension_apply**.

6.806 materi_plasti_visco_apply *switch*

If *switch* is set to **-no**, any visco-plasticity data in the input file will be ignored. This is done for all timesteps.

See also **control_materi_plasti_visco_apply**.

6.807 mesh *specifier_x specifier_y specifier_z*

If *specifier_x* is set to **-fixed_in_space**, the nodal points of the mesh remain fixed in space in x-direction. If a *specifier_x* is set to **-follow_material**, the nodal points of the mesh will follow material displacements in x-direction. The same holds for the other directions. In 1D, you only need to give *specifier_x*, etc.

Default each specifier is set to **-fixed_in_space**.

This record **mesh** only is used if **materi_velocity** is initialised. If **materi_displacement** is initialized each specifier is automatically set to **-fixed_in_space**.

6.808 mesh_activate_gravity_element *index element_range*

See **mesh_activate_gravity_time**.

6.809 mesh_activate_gravity_element_group *index element_group_0 element_group_1 ...*

See **mesh_activate_gravity_time**.

6.810 mesh_activate_gravity_geometry *index geometry_item_name geometry_item_index*

See **mesh_activate_gravity_time**.

6.811 mesh_activate_gravity_method *index method*

Set to **-method1** or **-method2**. Default Tochnog will use **-method2**.

See **mesh_activate_gravity_time**.

6.812 mesh_activate_gravity_stiffness_factor *index factor*

See **mesh_activate_gravity_time**.

6.813 mesh_activate_gravity_time *index time_start time_end*

With this record you can slowly activate gravity for elements between *time_start* and *time_end*.

You can specify an element range with **mesh_activate_gravity_element**. The elements you need to specify as elements range. Possible formats for the elements are a number (eg. 5), a number range (eg. **-ra** 5 4 8 **-ra**), or all elements (**-all**).

Or otherwise, you can specify element group numbers with **mesh_activate_gravity_element_group**.

Or otherwise, you can specify a geometry with **mesh_activate_gravity_geometry** so that elements completely in the geometry will be used.

Tochnog will activate the elements from the bottom to the top. For each specific element the start time of activation is interpolated from the global *time_start* and *time_end* and the lowest coordinate of the element. Likewise, for the element end time of activation the highest coordinate is used. Typically take care that the timestep is so small that each timestep only about 10 percent of an element gets filled.

This option comes handy to slowly build dams or so, starting at the bottom and building upwards to the top.

If **mesh_activate_gravity_method** is set to **-method1**, before the element start time of activation, the element is not active in the calculation. After the element end time of activation, the element is fully active in the calculation. Between these times the element is active, but the gravity is 0 at the element start time of activation, the gravity gets its full value at the element end time of activation, and the gravity is interpolated in between. With this **-method1** the displacements for activated nodes are 0 at the moment of activation,

and grow later in time. Thus the displacements in the activation area are relative to the moment of material activation, and not relative to the moment of start of the calculation.

If **mesh_activate_gravity_method** is set to **-method2**, before the element start time of activation, the element is active in the calculation, but has no gravity force yet. After the element end time of activation, the element is fully active in the calculation with full gravity force. Between these times the element is active, but the gravity is 0 at the element start time of activation, the gravity gets its full value at the element end time of activation, and the gravity is interpolated in between. With this **-method2** the displacements for activated nodes are not 0 at the moment of activation, but already have values resulting from activation of material below. For elements which are not activated yet, Tochnog will reduce the stiffness so that it will not really influence displacements inside the elements which are already being activated; the stiffness reduction factor can be specified by **mesh_activate_gravity_stiffness_factor** , and is 1.e-6 by default. For elements which are not activated yet, Tochnog will not print the elements to the gid postprocessing files; however you can demand that these elements will also be printed by specifying **-yes** in **print_gid_mesh_activate_gravity** or **control_print_gid_mesh_activate_gravity** (default **-no**).

You can set with **mesh_activate_gravity_time_initial** when elements become active in a calculation; before the specified *time_of_birth* an element will not take part of the calculation.

You can only use this option not in combination with *materi_displacement*. See also **control_mesh_activate_gravity_apply**.

6.814 mesh_activate_gravity_time_initial *index time_of_birth*

See **mesh_activate_gravity_time**.

6.815 mesh_activate_gravity_time_strain_settlement *index switch*

If *switch* is set to **-yes** then strain settlement should be used for the **mesh_activate_gravity_time** record with the same index.

6.816 mesh_boundary *switch*

If *switch* is set to **-yes**, Tochnog determines the boundary of the mesh and sets **element_boundary** and **node_boundary** records. If *switch* is set to **-no**, Tochnog does not determine the boundary of the mesh. Default, if **mesh_boundary** is not specified, the *switch* is **-no**.

6.817 mesh_correct *switch*

If *switch* is set to **-yes**, Tochnog checks that the connectivity list for quadrilateral and hexahedral interfaces is correct. If the connectivity list would not be correct (that is, according to the required sequence in Tochnog for such elements), the connectivity list will be corrected.

Default *switch* is set to **-no**.

6.818 mesh_delete_geometry_moving *index geometry_moving_index*

With *geometry_moving_index* you tell Tochnog to excavate the mesh with the geometrical entity as specified by the **geometry_moving*** records with index *geometry_moving_index*.

6.819 mesh_element_group_apply *index group_0 group_1 ...*

If you specify this record, only the element groups specified will be evaluated in all timesteps. Default, if **mesh_element_group_apply** is not specified, all elements groups will be used.

If **control_mesh_element_group_apply** is specified it overrules this **mesh_element_group_apply** record.

6.820 mesh_gid_assign_conditions_line *index line_0 line_1 ...*

Assign nodes on gid lines to tochnog **geometry_list** *index*. You can use geometry lists to impose geometrical conditions, see **geometry_list**. The *index* needs to be 11, 12, ..., 20 (start with index 11, then index 12, up to maximal 20).

A simple example is:

```
mesh_gid_assign_conditions_line 11 3 4 (assign gid line 3 and 4 to geometry_list 11)

bounda_dof 10  -geometry_list 11 -velx -vely   (set velocities to 0 on geometry_list 11)
```

See also **control_mesh_gid_batch**.

6.821 mesh_gid_assign_conditions_point *index point_0 point_1 ...*

Assign nodes on gid points to tochnog **geometry_list** *index*. You can use geometry lists to impose geometrical conditions, see **geometry_list**. The *index* needs to be 1, 2, ..., 10 (start with index 1, then index 2, up to maximal 10).

See also **control_mesh_gid_batch**.

6.822 mesh_gid_assign_conditions_surface *index surface_0 surface_1 ...*

Assign nodes on gid surfaces to tochnog **geometry_list** *index*. You can use geometry lists to impose geometrical conditions, see **geometry_list**. The *index* needs to be 21, 22, ..., 30 (start with index 21, then index 22, up to maximal 30).

See also **control_mesh_gid_batch**.

6.823 mesh_gid_arc_coord *index x_0 y_0 x_1 y_1 x_2 y_2*

Arc coordinates of first, second and third point. See also **control_mesh_gid_batch**.

6.824 mesh_gid_circle_coord *index x y*

Circle middle coordinates. See also **control_mesh_gid_batch**.

6.825 mesh_gid_circle_element_group *index group*

Group number. See also **control_mesh_gid_batch**.

6.826 mesh_gid_circle_hollow *index switch*

SWitch for hollow circle.

6.827 mesh_gid_circle_radius *index radius*

Circle radius. See also **control_mesh_gid_batch**.

6.828 mesh_gid_cylinder_coord *index x y z*

Circle base middle coordinates. See also **control_mesh_gid_batch**.

6.829 mesh_gid_cylinder_element_group *index group*

Group number. See also **control_mesh_gid_batch**.

6.830 mesh_gid_cylinder_height *index height*

Cylinder height. See also **control_mesh_gid_batch**.

6.831 mesh_gid_cylinder_hollow *index switch*

Set *switch* to **-yes** if you want the cylinder to act as a hollow zone, typically inside another zone (for example a volume zone). So this option comes handy when you want to study, for example, cylindrical excavation zones in a soil.

6.832 mesh_gid_cylinder_normal *index normal_x normal_y normal_z*

Cylinder normal. See also **control_mesh_gid_batch**.

6.833 mesh_gid_cylinder_radius *index radius*

Cylinder radius. See also **control_mesh_gid_batch**.

6.834 mesh_gid_line_structured_concentrate *index weight_start weight_end*

Concetrate elements for structured mesh near start or end of line. The *weight_start* and *weight_end* can be specified between -1 and +1. These are the mesh concentration factors for the line start and end respectively. With 0 there is no concentration. With -1 the concentration is low. With +1 the concentration is high.

Dedault, if **mesh_gid_line_structured_concentrate** is not specified, both weight factors are 0. See also **control_mesh_gid_batch**.

6.835 mesh_gid_line_element_group *index group*

Group number. See also **control_mesh_gid_batch**.

6.836 mesh_gid_line_point *index point_0 point_1*

Line points. See also **control_mesh_gid_batch**.

6.837 mesh_gid_line_size *index size*

Size of elements at line. See also **control_mesh_gid_batch**.

6.838 mesh_gid_line_structured_nel *index nel*

Number of elements for structured line. See also **control_mesh_gid_batch**.

6.839 mesh_gid_line_structured_size *index size*

Size of elements at structured line. See also **control_mesh_gid_batch**.

6.840 mesh_gid_point_coord *index x y z*

Point coordinates. In 2D you only need to specify *x* and *y*. See also **control_mesh_gid_batch**.

6.841 mesh_gid_rectangle_coord *index x_0 x_1 y_0 y_1*

Rectangle coordinates of first and second point. See also **control_mesh_gid_batch**.

6.842 mesh_gid_rectangle_element_group *index group*

Group number. See also **control_mesh_gid_batch**.

6.843 mesh_gid_rectangle_hollow *index switch*

Set *switch* to **-yes** if you want the rectangle to act as a hollow zone, typically inside another zone (for example a surface zone). So this option comes handy when you want to study, for example, rectangular excavation zones in a soil.

6.844 mesh_gid_size *element_size*

Size of elements. See also **control_mesh_gid_batch**.

6.845 mesh_gid_sphere_coord *index x y z*

Sphere middle coordinates. See also **control_mesh_gid_batch**.

6.846 mesh_gid_sphere_element_group *index group*

Group number. See also **control_mesh_gid_batch**.

6.847 mesh_gid_sphere_hollow *index switch*

Set *switch* to **-yes** if you want the sphere to act as a hollow zone, typically inside another zone (for example a volume zone). So this option comes handy when you want to study, for example, a hollow space in a soil.

6.848 mesh_gid_sphere_radius *index radius*

Sphere radius. See also **control_mesh_gid_batch**.

6.849 mesh_gid_surface_element *index element_type*

Element type for surface. You can use one of **-tria3**, **-tria6**, **-quad4**, **-quad8**, **-quad9**, **-tet4**, **-tet10**, **-hex8**, **-hex20** and **-hex27**. If this record is not specified linear elements are generated as default, triangles in 2D and tets in 3d. See also **control_mesh_gid_batch**.

6.850 mesh_gid_surface_element_group *index group*

Group number. See also **control_mesh_gid_batch**.

6.851 mesh_gid_surface_line *index line_0 line_1 ...*

Surface lines. This option will generate 1 new surface. See also **control_mesh_gid_batch**.

6.852 mesh_gid_surface_structured_nel *index nel_0 nel_1 ...*

Number of elements on lines of structured surface. Specify a number for each of the lines. Specify a positive number if you want to set the number of elements for the line. Specify a 0 for each of the opposing lines. See also **control_mesh_gid_batch**.

6.853 mesh_gid_surface_structured_size *index size*

Size of elements on structured surface. See also **control_mesh_gid_batch**.

6.854 mesh_gid_volume_element_group *index group*

Group number. See also **control_mesh_gid_batch**.

6.855 mesh_gid_volume_surface *index surface_0 surface_1 ...*

Volume surfaces. This option will generate 1 new volume. See also **control_mesh_gid_batch**.

6.856 mesh_interface_triangle_coordinates *index coord_x_0 coord_y_0 coord_z_0 coord_x_1 coord_y_1 coord_z_1 coord_x_2 coord_y_2 coord_z_2 ...*

With this option you can generate interface elements in a 3d mesh with tet4 elements. You specify the triangulated plane of the interface as sets of triangles in 3d space. For each triangle you specify for the three corner points the coordinates. For example *coord_x_0 coord_y_0 coord_z_0* are the coordinates of the first corner point, *coord_x_1 coord_y_1 coord_z_1* are the coordinates of the second corner point and *coord_x_2 coord_y_2 coord_z_2* are the coordinates of the third corner point. The combination of all triangles specifies the plane which will be intersected with the 3d tet4 mesh to generate the interface elements.

With **mesh_interface_triangle_element_group** you specify the group which will be attributed to the interface elements. With **control_mesh_interface_triangle** you specify the control index for which the generation should be done.

A typical input file looks like:

```
...
group_type 1 -materi
group_interface 1 -yes
group_interface_materi_memory 1 -total_linear
```

group_interface_materi_elasti_stiffness 1 1.e11 0.5e11 0.5e11
...
mesh_interface_triangle_coordinates 0. 0. 0.6 100. 0. 0.6 0. 100. 0.6
mesh_interface_triangle_element_group 1
...
control_mesh_interface_triangle 10 -yes
...

6.857 mesh_interface_triangle_element_group *index element_group*

See **mesh_interface_triangle_coordinates**.

6.858 message *switch*

If *switch* is set to **-yes** the introduction message (executable name, date, conditions) will be printed. If *switch* is set to **-no** it will not be printed. Default *switch* is **-yes**.

You can also set this **message** as environment symbol to **-no** if you want to suppress messages for all calculations.

6.859 mpc_apply *switch*

If *switch* is set to **-yes** then mpc conditions will be used. If *switch* is set to **-no** then mpc conditions will not be used. Default, if **mpc_apply** is not specified, *switch* is set to **-yes**.

See also **control_mpc_apply**.

6.860 mpc_element_group *index element_group_0 element_group_1*

Each node of element of group *element_group_0* that is also located in an element of group *element_group_1* will be tied to that group by means of multi point constraints. The multi point constrains will be consistent with the shape functions at the specific isoparametric coordinates of the location of that node in the element of group *element_group_1*. For *element_group_1* you can only use isoparametric elements. As a special option you can use **-all** for *element_group_1*, so that all other element groups are selected.

See also **mpc_element_group_always**, **mpc_element_group_closest** and **control_mpc_element_gro**

6.861 mpc_element_group_always *index switch*

If *switch* is set to **-yes** the mpc's will be generated always. If *switch* is set to **-no** the mpc's will only be generated if the considered node is not a member of the node list of the element of group *element_group_1* (this ensures that mpc's will only be generated if the node is completely loose from the other element). You can use the *switch* is **-no** option if you are not sure if *element_group_0* is connected to, or not connected to, *element_group_1*; with **-no** you will not get mpc's if the groups are connected; see **mpc_*** in the dbs file to check if mpc's are generated. So if you are not sure if surfaces are connected in gid, a typical strategy would be:

- run tochnog with **mpc_element_group** ... and **mpc_element_group_always -no**
- if you get **mpc_*** records in the dbs, run again with **mpc_element_group** ... and **mpc_element_group_always -yes**
- if you do not get **mpc_*** records remove **mpc_element_group** and **mpc_element_group_always**

Default, if **mpc_element_group_always** is not specified, *switch* is set to **-yes**.

6.862 mpc_element_group_closest *index switch*

If *switch* is set to **-yes** the mpc's will also be generated if no element of *element_group_1* is found; then the closest element of *element_group_1* will be used.

6.863 mpc_element_group_coord_geometry *index switch*

If *switch* is set to **-yes** the mpc's will only be generated if the coordinate of the node of *element_group_0* is above the lowest node of *element_group_1*.

A typical example is when you mpc the nodes of soil with *element_group_0* to pile elements with *element_group_1*. Then only soil nodes above the toe of the pile should be mpc'd. A piece of input file will look like:

```
...
start_define
  pile_group 1
end_define
start_define
  soil_interface_group 2
end_define
...
start_define
```

```
  pile_edge geometry_line 10
end_define
pile_edge ......
...
mpc_element_group 10  soil_interface_group pile_group (mpc soil nodes to pile)
mpc_element_group_geometry 10  -pile_edge (for soil nodes located on the pile edge)
mpc_element_group_closest 10  -yes (the soil node should be mpc'd to the closest pile element)
mpc_element_group_coord_geometry 10  -yes (do this only for soil nodes above the toe of the pil
mpc_element_group_dof 10  -velx -vely (in 2D mpc the velocities, and thus displacements)
...
```

6.864 mpc_element_group_dof *index dof_0 dof_1 ...*

The *dof_0 dof_1 ...* in **mpc_element_group_dof** specify the dof's that should be set equal, e.g. **-velx**, **-vely** etc. Default, if **mpc_element_group_dof** is not specified, all principal dofs will be set equal.

6.865 mpc_element_group_eps_iso *index eps*

With *eps* you can specify the tolerance on the isoparametric coordinates for the element of *element_group_1* below which a node of *element_group_0* is considered to be located in *element_group_1*. Default, if **mpc_element_group_eps_iso** is not specified, *eps* is set to **1.e-4**.

6.866 mpc_element_group_geometry *index geometry_entity_item geometry_entity_index*

Select a geometry for nodes of *element_group_0*.

6.867 mpc_element_group_keep *index switch*

If *switch* is set to **-yes** the generated mpc's will kept in the remainder of the calculation. As a typical application you can use this option to save computing time if you know that the mpc's need not to be changed during time steps. Or as another example you can use this option if you want that the mpc remains active even if the element for which the mpc is generated gets outside the specified geometry of **mpc_element_group_geometry**.

6.868 mpc_geometry *index geometry_entity_item_0 geometry_entity_index_0 geometry_entity_item_1 geometry_entity_index_1*

See also **mpc_geometry_method**.

If *method* in **mpc_geometry_method** is set to **-method0** the following mpc's will be generated. This record automatically generates **mpc_node_number** and **mpc_node_factor** records such that dof's in the second geometry *geometry_entity_item_1 geometry_entity_index_1* become equal to the dof's in the first geometry *geometry_entity_item_0 geometry_entity_index_0*. The *switch_x switch_y switch_z* in **mpc_geometry_switch** specify the coordinates that should be checked to judge if a node in the second geometry is considered to have the same position as a node in the first geometry, and thus should get the same dof's. Only the coordinate for which the corresponding switch is set to **-yes** will be checked. For example in 3D if **-yes -no -no** are used then a node in the second geometry gets the same dof's of a node in the first geometry in it has (almost) equal x-coordinate; the y and z-coordinate are irrelevant. In 2D only *switch_x switch_y* need to be specified. With **mpc_geometry_tolerance** you can set the tolerance beneath which nodes of the first geometry and second geometry are assumed to have the same coordinate. If **mpc_geometry_tolerance** is not specified then a tolerance of 1.e-4 is used.

If *method* in **mpc_geometry_method** is set to **-method1** the following mpc's will be generated. You should only specify the first geometry. The dof's of the nodes in this first geometry become equal. The first node of this first geometry becomes the master, all other nodes in this first geometry become slave. If you want to know which node is the first node in this first geometry, use a **control_print ... -node** with a **print_filter** for the first geometry.

If *method* in **mpc_geometry_method** is set to **-method2** the following mpc's will be generated. You should only specify the first geometry. Unknowns of the nodes with equal coordinate in this first geometry become equal.

6.869 mpc_geometry_method *index method*

See **mpc_geometry**. If this **mpc_geometry_method** is not specified then *method* will be set to **-method0**.

6.870 mpc_geometry_switch *index switch_x switch_y switch_z*

See **mpc_geometry**.

6.871 mpc_geometry_tolerance *index tolerance*

See **mpc_geometry**.

6.872 mpc_geometry_dof *index dof_0 dof_1 ...*

The *dof_0 dof_1 ...* in **mpc_geometry_dof** specify the dof's that should be set equal, e.g. **-velx**, **-vely** etc.

6.873 mpc_linear_quadratic *switch*

If *switch* is set to **-yes** this option is activated.

If you have a mesh with both linear elements and quadratic elements, the mesh is not compatible at the places where the linear elements and quadratic elements meet at a common interface. There some of the quadratic element nodes are not attached to the linear elements, and so non-compatible solution fields occur.

This **mpc_linear_quadratic** option allows you to automatically prevent the non-compatible solution fields. Tochnog imposes a multi point constraint on all non-compatible solution fields between the linear and quadratic elements, so that the extra nodes of the quadratic elements are forced to follow the solution field of the linear elements, and so compatibility is ensured again.

This option typically can be used to model structural parts like beams, sheet piles, tunnel shells etc with quadratic elements, and the surrounding soil with linear element. Use one quadratic element in the structural part thickness direction, and extra one quadratic soil element attached to the structural element. For the remaining soil elements use linear elements. In this way, the stiff structural elements can deform flexible enough, and you save computer time by modeling most of the soils with linear elements.

6.874 mpc_node_factor *index factor_10 factor_11 ...factor_20 factor_21 ...*

See **mpc_node_number**.

6.875 mpc_node_number *index node_0 dof_0 node_1 dof_10 dof_11 ...node_2 dof_20 dof_21 ...*

This Multi Point Constraint record **mpc_node_number** allows you to set constraints between dof's at different nodes. The *dof_0* specifies the dofat node number *node_0* which will be constrained. It will be constrained to dof's *dof_10*, *dof_11*, ... of *node_1* and *dof_20*, *dof_21*, ... of *node_2*, etc. Only principal dof's can be specified. Principal dof's are material velocities, groundflow pressure, temperature in the convection diffusion equation, etc.; see the start of the data section for a definition of principal dof's. With

mpc_node_factor you can set multiplication factors for the constraints. If you don't specify **mpc_node_factor** a 1 is used for all factors.

Example:

```
...
mpc_node_number 10 1 -velx 2 -velx 3 -vely
mpc_node_factor 10 7. 9.
```

In this example the velx_1 = 7. * velx_2 + 9. * vely_3 where velx_1 is the x-velocity at node 1 etc. Node number *node_0* is this slave node which depends on nodes *node_1* etc. which are the master nodes.

Boundary conditions with **bounda_dof** and **bounda_time** cannot be specified for slave nodes.

See also **mpc_geometry** for easy generation of multi point constraints.

6.876 node *index coord_0 coord_1 coord_2*

Coordinates of node *index*. In 1D, only *coord_0* should be specified, etc..

You are not allowed to put free nodes (not attached to any element) in your model. These free nodes will be removed automatically.

6.877 node_boundary *index switch*

The *switch* will be set to **-yes** if the node with index *index* is located on the boundary of the mesh.

This record will only become available if **mesh_boundary** is set to **-yes**. This record is meant for printing only, it should not be set by the user.

6.878 node_bounded *index indicator_dof_0 indicator_dof_1 ...*

This record is for printing only, it is not an input record. This record indicates if dof's in the node are bounded via a **bounda_dof** record; then the corresponding indicator is set to 1, else it remains 0.

6.879 node_bounded_index *index bounda_dof_index_0 bounda_dof_index_1 ...*

This record is for printing only, it is not an input record. This record list the index of the **bounda_dof** record by which the dof's are bounded. This index is only filled if the dof 's really bounded, so if the corresponding value in the **node_bounded** record is set to 1.

6.880 node_convection_apply *index switch*

If *switch* is set to **-no** convection contributions in node *index* are de-activated in case they are activated for the whole mesh by **convection_apply** or **control_convection_apply**.

6.881 node_damping *index damping_x damping_y damping_z*

This record adds a discrete damper to node *index* in x, y and z direction respectively. In 1D only *damping_x* needs to be specified, etc. The damper will lead to a nodal force of the size $damping\_x * v\_x$ where v_x is the velocity in x direction. The same holds for the y and z direction.

6.882 node_deformed_mesh *index coord_0 coord_1 coord_2*

After the calculation, this record will contain deformed coordinates of node *index*.

If **materi_displacement** is initialised these are the initial start coordinates **node_start_refined** plus the displacements.

If **materi_velocity_integrated** is initialised and the node follows the material with **-follow_material** these are the current coordinates of the node **node**.

If **materi_velocity_integrated** is initialised and the node is fixed in space with **-fixed_in_space** these are the initial start coordinates **node_start_refined** plus the integrated velocities.

Else these are equal to the current node **node**.

In 1D, only *coord_0* is filled, etc..

6.883 node_dof *index dof_0 dof_1 ...*

dof_0 dof_1 ... are the degrees of freedom (dof's) at the node with number *index*. The total number and type of the dof's depends on the initialization part. Each node has the same dof's.

Unknowns like pressure, temperature, etc. are primary dof's. The other dof's, space derivatives and the time derivative, are not primary dof's. In the example below, **-temp** is 1., **-xtemp** is 0.2 and **-ttemp** is 0.1 in node 6

```
...
number_of_space_dimensions 1
derivatives
condif_temperature
end_initia
...
node_dof 6 1.0 0.2 0.1
...
```

Default all values in the **node_dof** records are set zero at the start of the calculation.

These **node_dof** records contain principal dof's for all elements (displacements, temperatures, etc). Other dof's like strains, stresses etc. are only filled for the normal isoparametric elements; thus, for example, strain and stress results for interfaces elements are not placed in the **node_dof** records.

See also: **dof_label** and **post_point**.

6.884 node_dof_calcul *index ...*

See **post_calcul**.

6.885 node_dof_start_refined *index dof_0 dof_1 ...*

This record will be filled with *dof_0 dof_1 ...*, which are the degrees of freedom (dof's) as specified at the start of the calculation. at the node with number *index*.

If the mesh has been refined, these start values hold for the refined mesh.

See also **node_dof** and **node_start_refined**.

6.886 node_dynamic_pressure *index value*

With this record you can specify for node *index* the dynamic pressure. Thus, the dynamic pressure as normally calculated will be overruled with this *value*.

6.887 node_force *index force_x force_y force_z*

With this record you can input a discrete nodal force at node *index*. In 1D you only should specify the force in x-direction. In 2D you only should specify the force in x- and y-direction.

6.888 node_geometry_present *index geometry_item_name_0 geometry_item_index_0 geometry_item_name_1 geometry_item_index_1 ...*

This record lists for node *index* the geometries in which it is present. So it is a print record only, for checking if the geometries include exactly the nodes that you want. You can switch on or off filling of these records by setting **print_node_geometry_present** to **-yes** or **-no**.

6.889 node_inertia *index inertia_dof_0 inertia_dof_1 ...*

This record will be filled with calculated inertia terms degrees of freedom (dof's) as specified at the start of the calculation. at the node with number *index*. For material velocity that is the mass inertia term in the node.

6.890 node_mass *index mass_x mass_y mass_z*

This record adds a discrete mass to node *index* in x, y and z direction. In 1D only the x-mass needs to be specified, etc. The mass will lead to a nodal force of the size $mass\_x * \dot{v}$ where $\dot{v}\_x$ is the acceleration, and to a gravity force if **force_gravity** is specified. The same holds for the y and z direction.

6.891 node_mesh *index ...*

Same as **mesh**, but now specified per node however. The *index* specifies the node number. If this **node_mesh** record is specified for a node, it overrules the **mesh** record.

6.892 node_rhside *index rhside_0 rhside_1 ...*

This record will contain after the calculations the unbalance forces.

For the temperature equation, this will give the heat flow normal to the outer surface (the heat flux to the environment) at prescribed temperatures. For velocity dof's, this will give the force vector at prescribed displacements. For the pressure in the ground flow equation,

this will give the ground flow to the environment at prescribed pressures. For non-prescribed dofs the record will contain the numerical unbalance, and should be close to zero.

The *index* is the node number.

6.893 node_slide *index slide_number*

With **node_slide** you can specify of a specific node *index* if it belongs to a sliding geometry with index *slide_number*. For the sliding geometry **slide_geometry** is not needed anymore because the **node_slide** already specifies which nodes belong to the sliding geometry.

6.894 node_static_pressure *index value*

With this record you can specify for node *index* the static pressure. Thus, the static pressure as normally calculated will be overruled with this *value*.

6.895 node_start_refined *index coord_0 coord_1 coord_2*

After the calculation, this record will contain coordinates of node *index* as specified at the start of the calculation. If the mesh has been refined this record with contain the start coordinates for the refined mesh. In 1D, only *coord_0* is filled, etc..

6.896 node_stiffness *index stiffness_x stiffness_y stiffness_z*

This record adds a discrete stiffness to node *index* in x, y and z direction respectively. In 1D only *stiffness_x* needs to be specified, etc. The stiffness will lead to a nodal force of the size $stiffness\_x * u\_x$ where u_x is the displacement in x direction. The same holds for the y and z direction. Condition: also **materi_velocity_integrated** or **materi_displacement** should be initialized.

6.897 node_support_edge_normal_plasti_tension_status *index status*

This record will contain after a calculation the status of a node for the **support_edge_normal_plasti_tension** or **support_edge_normal_plasti_tension_double** option. If the node is opened due to tension plasticity the status is set to **-opened**. If the node is closed the status is set to **-closed**.

6.898 **node_total_pressure** *index value*

With this record you can specify for node *index* the total pressure. Thus, the total pressure as normally calculated will be overruled with this *value*.

6.899 **nonlocal** *nonlocal_radius*

By specifying this record in combination with a viscoplastic model , like **group_materi_plasti_visco_power**, a nonlocal yield rule fn will be used in the viscoplastic law. The nonlocal yield rule needs to be initialized as dof by the **materi_plasti_f_nonlocal** record in the initialization part. The nonlocal yield rule fn in a point is determined by an averaging of the local yield rule f in neighboring points and using gauss weighting functions for this (i.e. the larger the distance the less the neighboring point contributes to the nonlocal yield rule). The averaging is done over a region with radius *nonlocal_radius*.

In this way, you can prevent unlimited localization and so mesh dependency, in calculations with softening plasticity.

See also **nonlocal_name**.

6.900 **nonlocal_name** *name*

With *name* you specify the name of the plasticity model that should be treated nonlocal, eg **-group_materi_plasti_mohr_coul**. You can only specify one name, so only one plasticity model can be used as nonlocal model.

6.901 **plasti_apply** *switch*

If *switch* is set to **-no**, any plasticity data in the input file will be ignored. This is done for all timesteps.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with plasticity data. See also **control_plasti_apply**.

6.902 **post_apply** *index switch*

Setting *switch* to **-no** prevents post processing commands to be evaluated. Postprocessing commands have **post** in the name (only the **post_node_rhside_ratio** will be evaluated always, independent of **post_apply**).

Default, if **post_apply** is not specified, the switch is set to **-yes**.

6.903 post_calcul *dof_ 0 operat_ 0 dof_ 1 operate_ 1 ...*

This records activates calculation post results. The *dof_ 0 dof_ 1* etc. refers to a *dof*, and possibilities for *dof* are listed below. The *operat_ 0 operat_ 1* etc. refers to an *operat*, and possibilities for *operat* are listed below.

Here *dof* can be one of the matrices
-materi_stress,
-materi_strain_elasti,
-materi_strain_plasti,
-materi_strain_plasti_compression,
-materi_strain_plasti_diprisco,
-materi_strain_plasti_druckprag,
-materi_strain_plasti_hardsoil,
-materi_strain_plasti_tension,
-materi_strain_plasti_vonmises,
-materi_strain_total or *dof* can be one of the vectors **-materi_velocity**, **-materi_displacement**, or *dof* can be one of the scalars **-condif_temperature**, **-groundflow_pressure**.

The results of these calculations are stored for each **node_dof** record in a **node_dof_calcul** record, and are stored for each **post_point_dof** record in a **post_point_dof_calcul** record, and are stored for each **post_line_dof** record in a **post_line_dof_calcul** record, and are stored for each **post_quadrilateral_dof** record in a **post_quadrilateral_dof_calcul** record.

We denote a matrix *dof* with A_{ij} and denote a vector *dof* with A_i, and denote a scalar *dof* with a. If *operat* is **-absol** then the absolute value of a scalar a is calculated.

If *operat* is **-average** then $\frac{1}{3}(A_{11}+A_{22}+A_{33})$ is calculated for a matrix or $\frac{1}{3}(A_1+A_2+A_3)$ is calculated for a vector.

If *operat* is **-negative** then the average of the negative principal values for a matrix is calculated. If **materi_strain_plasti** is taken for the matrix A_{ij}, then this operator typically can be used as a measure for the amount of compression failure (crunching).

If *operat* is **-positive** then the average of the positive principal values for a matrix is calculated. If **materi_strain_plasti** is taken for the matrix A_{ij}, then this operator typically can be used as a measure for the amount of tensile failure (cracking).

If *operat* is **-prival** then three principal values of a matrix A_{ij} are calculated. Each principal value contains the size of the principal vector. The principal values are ordered (the first value is the smallest one, and the last value is the largest one).

If *operat* is **-privec** then three principal vectors of a matrix A_{ij} are calculated. Each principal vector contains the x, y and z component of the principal vector. The same ordering as used for **-prival** is used here also.

If *operat* is **-size_tot** then $\sqrt{A_{ij}A_{ij}}$ is calculated for a matrix or $\sqrt{A_iA_i}$ is calculated for a vector. This measures the size of a matrix or the size of a vector.

If *operat* is **-size_dev** then $\sqrt{B_{ij}B_{ij}}$ is calculated where B_{ij} is the deviatoric part of a matrix A_{ij}: $B_{ij} = A_{ij} - \delta_{ij}\frac{A_{11}+A_{22}+A_{33}}{3}$ where δ_{ij} is 1 if $i = j$ and is 0 otherwise. This measures the size of the deviatoric part of the matrix.

Specially for **-quad4**, **-quad9**, **-hex8** and **-hex27** elements you can set *operat* to **-force** in case *dof* is **-materi_stress**. Then forces and moments are calculated in these isoparametric elements. See also **post_calcul_materi_stress_force_element_group**.

Specially for geotechnics you can set *operat* to **-total_pressure** in case *dof* is **-materi_stress**. Then the total stress is calculated from the effective stress and the groundflow total pressure. This option is not valid in combination with undrained pressures as obtained by **group_materi_undrained_capacity**.

Specially for geotechnics you can set *operat* to **-static_pressure** in case *dof* is **-groundflow_pressure**. Then the static pressure is calculated.

Specially for geotechnics you can set *operat* to **-dynamic_pressure** in case *dof* is **-groundflow_pressure**. Then the dynamic pressure is calculated.

Specially for geotechnics you can set *operat* to **-k0** in case *dof* is **-materi_stress**. Then the ratio of horizontal and vertical stresses is calculated. If 2D this is the ratio $0.5\frac{\sigma_{xx}+\sigma_{zz}}{\sigma_{yy}}$. If 3D this is the ratio $0.5\frac{\sigma_{xx}+\sigma_{yy}}{\sigma_{zz}}$.

Specially for geotechnics you can set *operat* to **-young_apparent** in case *dof* is **-materi_stress**. Then the apparant Young modulus is calculated from the incremental strains and incremental stresses. If determination is not possible (for almost zero incremental strains) the apparent young is put to 0. See also **post_calcul_apparent_total**.

Specially for geotechnics you can set *operat* to **-poisson_apparent** in case *dof* is **-materi_stress**. Then the apparent Poisson ratio is calculated from the incremental strains and incremental stresses. If determination is not possible (for almost zero incremental strains) the apparent poisson is put to 0. See also **post_calcul_apparent_total**.

Specially for geotechnics you can set *operat* to **-total_pressure** in case *dof* is **-groundflow_pressure**. Then the total pressure is calculated.

Specially for geotechnics you can set *operat* to **-safety_lifting** in case *dof* is **-materi_stress**. Then the hydraulic safety factor $\frac{\sigma_{\mathrm{vertical}}+p\_\mathrm{total}}{p\_\mathrm{total}}$ is calculated. In 1D $\sigma_{\mathrm{vertical}} = \sigma_{\mathrm{xx}}$, in 2D $\sigma_{\mathrm{vertical}} = \sigma_{\mathrm{yy}}$ and in 3D $\sigma_{\mathrm{vertical}} = \sigma_{\mathrm{zz}}$; see also **post_calcul_safety_method**.

Specially for geotechnics you can set *operat* to **-safety_piping** in case *dof* is **-materi_stress**. Then the hydraulic safety factor $\frac{\sigma_{\mathrm{vertical}}+p\_\mathrm{dynamic}}{p\_\mathrm{dynamic}}$ is calculated; see also **post_calcul_safety_method**.

The next piece of input file

```
...
materi_stress
```

materi_strain_plasti
end_initia
...
post_calcul -materi_stress -size_dev -materi_strain_plasti -size_tot
...
control_timestep 1 ...
control_print 1 -node_dof_calcul

will print records like

node_dof_calcul *index 0.2 1.1e-4*

Here the 0.2 is the equivalent Von Mises stress and *1.1e-4* measures the plastic strain matrix.

See also **post_calcul_absolute** and **post_calcul_label**.

6.904 post_calcul_absolute *switch*

If *switch* is set to **-yes** all results of **post_calcul** are set to be positive values. This may be done if you prefer positive values in your presentation of results.

6.905 post_calcul_apparent_total *switch*

If *switch* is set to **-yes**, the total strains and total stresses (as opposed to incremental) will be used to calculate the apparent young modulus and poisson ratio. If *switch* is set to **-no**, the incremental strains and incremental stresses will be used. Default, if **post_calcul_apparent_total** is not specified, the *switch* is set to **-no**.

6.906 post_calcul_label *doflabel_0 label_1 ...*

This record will be filled with the names of the data that is calculated by means of the **post_calcul** option. The first name comes from the first *dofoperat* in **post_calcul**, the second name comes from the second *dofoperat* in **post_calcul**, etc. You can find this record in the dbs file after a calculation.

6.907 post_calcul_limit *lower_0 upper_0 lower_1 upper_1 ...*

With this record you can specify the lower and upper allowed values for all calculated results. With *lower_dof_0* you specify the lower allowed value for the first result. With

upper_ dof_ 0 you specify the upper allowed value for the first result. Etc.

6.908 post_calcul_materi_stress_force_average *switch*

See first **post_calcul_materi_stress_force_element_group**.

This **post_calcul_materi_stress_force_average** option is only available for **quad9** and **hex27** elements. It can be used if forces and moments are primarily calculated in two opposing end faces of the **quad9** and **hex27** element. If *switch* set to **-yes**, the forces and moments of nodes in the plane between the two end faces will be set to the averaged values from the forces and moments on the two opposing end faces. If *switch* set to **-no** this is not done. Default *switch* is **-yes**.

6.909 post_calcul_materi_stress_force_direction_exclude *dir_x dir_y dir_z*

See first **post_calcul_materi_stress_force_element_group**.

In 3D, Tochnog needs to know for which element sides it should determine forces and moments. For this purpose you need to specify this direction *dir_x dir_y dir_z*. All element sides with normals in this direction will be neglected; no forces and moments will be determined for such sides.

Typically, in a tunnel calculation you take the tunnel length direction as *dir_x dir_y dir_z*.

6.910 post_calcul_materi_stress_force_direction_exclude_epsilon *eps*

With *eps* you can influence which normals are considered to be in the specified exclude direction. A small *eps* specifies that only very precise normals in the specified direction will be excluded. A large *eps* specifies that also not precise normals in the specified direction will be excluded. In fact *eps* is the difference from inproduct between the specified exclude direction with the normal direction and 1. Default *eps* is $1.e-8$.

6.911 post_calcul_materi_stress_force_direction_include *dir_x dir_y dir_z*

See first **post_calcul_materi_stress_force_element_group**.

In 3D, Tochnog needs to know for which element sides it should determine forces and moments. For this purpose you need to specify this direction *dir_x dir_y dir_z*. All

element sides with normals perpendicular to this direction will be neglected; no forces and moments will be determined for such sides.

Typically, in a sheet pile calculation you take the sheet pile height direction as *dir_x dir_y dir_z*.

6.912 post_calcul_materi_stress_force_direction_include_epsilon *eps*

With *eps* you can influence which normals are considered to be perpendicular to the specified include direction. A small *eps* specifies that only normals precisely perpendicular to the specified direction will be excluded. A large *eps* specifies that also normals not precisely perpendicular to the specified direction will be excluded. In fact *eps* is the difference from inproduct between the specified include direction with the normal direction and 0. Default *eps* is $1.e-8$.

6.913 post_calcul_materi_stress_force_element_group *element_group_0 element_group_1 ...*

With the **post_calcul -materi_stress -force** option the normal force, shear force and moment(s) are calculated for the isoparametric elements **-quad4**, **-quad9**, **-hex8** and **-hex27**. This option is meant for structures like sheet piles, tunnel shells, etc. where there is only 1 element over the thickness of the structure. Thus the element has a thickness equal to the complete thickness of the structure, and the length of the element is a part of the total length of the structure (e.g. tunnel length).

In the following definitions of forces and moments, n denotes the normal to an element side, t denotes the thickness direction in the side, and l denotes the length direction. The 2D and 3D normal force **nor** results is defined by the normal stresses $sigma_{nn}$ integrated over the thickness. The 2D and 3D shear force **she** results is defined by the shear stresses $sigma_{nt}$ integrated over the thickness. The 2D moment **mom** and 3D moment **mom1** are defined by the moment contributions of normal stresses $sigma_{nn}$ with a distance in thickness direction d_t relative to the middle of the element, integrated over thickness direction (radial bending moment in tunnel shell, thickness bending moment in sheet pile, etc.). The 3D moment **mom2** is defined by the moment contributions of normal stresses $sigma_{nn}$ with a distance in length direction d_l relative to the middle of the element, integrated over thickness direction (bending moment in tunnels, sheet piles, etc.).

The forces and moments will be calculated per unit length l of the isoparametric element, where l is the size of the element in length direction. In a 3D calculation, the length of an element is determined from the nodal coordinates differences in length direction. In a axi-symmetric 2D calculation, the length of the elements is set to 2 * PI * radius by Tochnog (notice that with this definition values cannot be calculated at the symmetry axis with zero

radius). In a plane 2D calculation, the length of the elements is set to 1 by Tochnog.

The normal force and moment(s) are given the proper sign (plus or minus). For example, a positive normal force means that the structure is under tension. For the shear force, however, always a positive value is calculated by Tochnog, so only the size of the shear force is available (and not the direction of the shear force).

For all of the forces and moment vectors, we want to display the vector in thickness direction of the structure, to get a clear view in postprocessors (e.g. GID). Thus, the components in global x- and y-direction are determined such that the vector direction is in thickness direction of the structure. Because of this, the components by themselves are not the real physical components of the force or moment; they are only convenient values for getting clear plots in postprocessors. However, the size of the vector formed by these components (square root of components squared), indeed is the real physical size of the force or moment, so the size can indeed be used for design purposes. For your convenience, the size of each vector is also calculated automatically be Tochnog. For example, for the normal forces Tochnog calculates **-norx_sig**, **-nory_sig** and **-nors_sig** which are the global plot vector x-component, y-component and the physical real size respectively.

The enable a correct force or moment direction in either the positive of negative thickness direction, Tochnog wants you to specify **post_calcul_materi_stress_force_reference_point**.

In 3D, you need to specify either **post_calcul_materi_stress_force_direction_exclude** or **post_calcul_materi_stress_force_direction_include**. With these records you can determine for which element sides forces and moments should be determined. The direction and element should be such that for each element for which you want to determine forces and moments exactly 4 sides should be consistent with the specified direction. Otherwise the present option for determination of forces and moments is not available for the element. Only one of **post_calcul_materi_stress_force_direction_exclude** and **post_calcul_materi_stress_force_direction_include** should be specified, not both.

The *element_group_0 element_group_1 ...* of this **post_calcul_materi_stress_force_element_group** specify the groups of isoparametric elements for which the forces and moments should be determined by Tochnog.

Summary of conditions for the **post_calcul -materi_stress -force** option to work well:

- Only 1 element in thickness direction.
- Elements in 3D should be regular shaped in length direction. That is, the element sides perpendicular to the length direction should be completely parallel.
- At least 1 timestep should be done (since element forces needed for this option are setup in a timestep)

6.914 post_calcul_materi_stress_force_reference_point *x_0 y_0 z_0 x_1 y_1 z_1 ...*

See first **post_calcul_materi_stress_force_element_group**.

For example tunnels typically are of circular or piecewise circular geometry. To get a correct direction of the calculated forces and moments, Tochnog needs to know the approximate middle point of the tunnel, so that it can put all negative forces and moments and positive forces and moments consistently outwards or inwards in thickness direction of the structure. Thus, you need to specify with this **post_calcul_materi_stress_force_reference_point** record the approximate middle point of the tunnel that you are evaluating for each of the element groups. In case you have a sheet pile, you should specify a reference point on a large perpendicular distance away from the sheet pile.

You need to specify a reference point for each element group specified in **post_calcul_materi_stress_force_ele**

In 3D you need to specify the x, y and z value for each reference point. In 2D you only need to specify the x and y value for each reference point.

See also **post_calcul_materi_stress_force_plot_switch**.

6.915 post_calcul_materi_stress_force_outer *switch*

If *switch* is set to **-yes**, the forces and moments are only calculated for the nodes at the outer sides of the elements; these are the nodes which have the furthest distance relative to the reference point. This will give a bit more nice vector plots.

Default, if **post_calcul_materi_stress_force_outer** is not specified, *switch* is set to **-no**. This will give a bit more nice contour fill plots.

6.916 post_calcul_materi_stress_force_plot_switch *switch_0 switch_1 ...*

If you don't like the direction in which tochnog draws the vectors (outward or inward), you can switch the direction by setting the corresponding switch to **-yes**. In 2D you need to specify a switch for the normal force, shear force and moment. In 3D you need to specify a switch for the normal force, shear force and two moments.

6.917 post_calcul_materi_stress_force_thickness_switch *switch_element_group_0 switch_element_group_1 ...*

See first **post_calcul_materi_stress_force_element_group**.

In 3D Tochnog normally assumes that the shortest element direction in the side where forces

and moments are calculated is the structure thickness direction. If that is not the case, e.g. if you have very short elements in a tunnel length direction, then you need to explain Tochnog that it should switch to the longest element direction as structural thickness direction, by setting a to **-yes**.

This ensures that the shear force is always really calculated over the structural thickness, and the first moment is really the moment over the structural thickness.

If you specify **post_calcul_materi_stress_force_thickness_switch** you need to give a switch for each element group of **post_calcul_materi_stress_force_element_group**.

6.918 post_calcul_multiply *factor_0 factor_1 ...*

With this record you can specify a multiplication factor for each calculated item. This comes handy when you prefer another definition. If you specify **post_calcul_multiply** , you need to give a factor for each item.

6.919 post_calcul_safety_default *eps value*

Specifically for safety lifting and piping calculations division by pressure values equal to zero can occur. With this **post_calcul_safety_default** record you can prevent such division. If the absolute of the pressure value for the division is smaller than the specified *eps*, the safety factor will be set to the user specified *value*.

In case this record is not specified we set *eps* to something very small, and *value* to 0.

6.920 post_calcul_safety_maximum *value*

Specifically for safety lifting and piping calculations you can limit the calculated safety factor to this specified maximum *value*. This comes convenient if you get excessive large values in a calculation due to numerical accuracy in the calculation.

In case this record is not specified we set *value* to something very large.

6.921 post_calcul_safety_method *method*

You can determine with this option how the hydraulic piping and lifting safety should be determined. If you set *method* to **-vertical** the safety factors will be determined using the vertical stress (zz-stress in 3D, yy-stress in 2D, xx-stress in 1D); this is the default, as described in the **post_calcul** command. Thus you get one value for the safety piping and one value for the safety lifting.

If you set *method* to **-prival** the safety factors will be determined using the three principal stresses (principal stress 0, principal stress 1, principal stress 2). Thus you get three values for the safety piping and three values for the safety lifting.

If you set *method* to **-global** the safety factors will be determined using the three global normal stresses (xx-stress, yy-stress, zz-stress). Thus you get three values for the safety piping and three values for the safety lifting.

Setting *method* to **-vertical** is the classical definition used in most text books. However since the critical direction in complex calculations will not always be in the vertical direction, it is also of interest to study the hydraulic safety factors with the principal stress values (**-prival**). And for some situation, like soil near a retaining wall, it may be of interest to study the hydraulic safety factors with global normal stresses (**-global**).

In the dbs file after a calculation you can see in the **post_calcul_label** record the naming of the calculated hydraulic safety factors.

6.922 post_calcul_static_pressure *static_pressure*

With this option you can directly specify the static pressure to be used in postprocessing by **post_calcul -groundflow_pressure -static_pressure** for the complete domain.

See also **post_calcul_static_pressure_height** if you want to specify a static pressure height instead.

6.923 post_calcul_static_pressure_height *coord_min,0 coord_max,0 height_ref,0 coord_min,1 coord_max,1 height_ref,1 ...*

Using this option the static pressure as required by **post_calcul -groundflow_pressure -static_pressure** is determined relative to the reference height, and not anymore to a groundwater level. Thus, the Δz in the equation for $p_{\text{static}} = \rho g \Delta z$ is taken relative to the specified reference height in this **post_calcul_static_pressure_height** record.

You can specify multiple regions. The first region is between vertical coordinate *coord_min,0* and *coord_max,0*. The *coord_min,0* and *coord_max,0* themselves are included as part the region. If a node is inside this region the *height_ref,0* is used as phreatic level height in the equation for the static pressure. The second region is between vertical coordinate *coord_min,1* and *coord_max,1*. The *coord_min,1* and *coord_max,1* themselves are included as part the region. If a node is inside this region the *height_ref,1* is used as phreatic level height in the equation for the static pressure.

If a node is not inside any of the regions, and if the groundflow phreatic level itself is not specified, the static pressure cannot be determined and remains zero.

See also **post_calcul_static_pressure_height_element_group**.

6.924 post_calcul_static_pressure_height_element_group *element_group_0 element_group_1 ...*

Restrict the regions of **post_calcul_static_pressure_height** to specific element groups. The region between *coord_min,0* and *coord_max,0* is valid for element group *element_group_0*. The region between *coord_min,1* and *coord_max,1* is valid for element group *element_group_1*. Etc.

You need to specify an element group for each and every region. As a special option you can specify **-all** for an element group number; then the corresponding region is valid for all element groups.

6.925 post_count *dataitem_name_0 dataitem_name_1 ...*

With this **post_count** record you can specify data items for which the number of active indices should be counted. The results will be placed in the record **post_count_result**.

For example count the number of active elements, nodes and geometry points by:

```
...
post_count -element -node -geometry_point ...
```

6.926 post_data *index dataitem_name_0 dataitem_index_0 dataitem_number_0 dataitem_name_1 dataitem_index_1 dataitem_number_1 ...*

The specified data items are taken, and each is multiplied with its corresponding factor in **post_data_factor** and added to **post_data_result**. This allows you to conveniently follow the sum of data item, each multiplied with some factor.

6.927 post_data_factor *index factor_0 factor_1 ...*

See **post_data**.

6.928 post_data_result *index result*

See **post_data**.

6.929 post_element_force *index dir_normal_x dir_normal_y dir_normal_z dir_shear0_x dir_shear0_y dir_shear0_z dir_shear1_x dir_shear1_y dir_shear1_z middle_x middle_y middle_z*

With this record you can calculate the normal force, shear force and moments in cross sections. Only cross sections at the side of elements are allowed; so that typically is the common side between two elements, or the side at the edge of a domain; a cross section through the interior of elements is not allowed. Below we will describe how you can select elements. For the combination of selected elements nodal forces will be used to determine cross section forces and moments.

The *middle_x middle_y middle_z* should contain the exact middle coordinates of the cross section. You can use this **post_element_force** option however also to get the soil forces on the shaft or toe of a pile; then use a *middle_x middle_y middle_z* point below the bottom of the pile.

The nodal force components in the *dir_normal_x dir_normal_y dir_normal_z* direction are summed to give a normal force *normal_force*. The nodal force components in the *dir_shear0_x dir_shear0_y dir_shear0_z* direction are summed to give the first shear force *shear0_force*. The nodal force components in the *dir_shear1_x dir_shear1_y dir_shear1_z* direction are summed to give the second shear force *shear1_force*. The nodal force components in the *dir_normal_x dir_normal_y dir_normal_z* direction are multiplied with the distance in *dir_shear0_x dir_shear0_y dir_shear0_z* direction as measured from the *middle_x middle_y middle_z* vector, and this is summed to give the first bending moment *moment0*. The nodal force components in the *dir_normal_x dir_normal_y dir_normal_z* direction are multiplied with the distance in *dir_shear1_x dir_shear1_y dir_shear1_z* direction as measured from the *dir_shear0_x dir_shear0_y dir_shear0_z* vector, and this is summed to give the first bending moment *moment1*. The results for the normal force, two shear forces and two moments will be placed in the record **post_element_force_result**.

In 3D you need to specify the complete **post_element_force** record and you get the normal force, two shear forces and two bending moments in the **post_element_force_result** record. The directions *dir_shear0_x dir_shear0_y dir_shear0_z* and *dir_shear1_x dir_shear1_y dir_shear1_z* should be perpendicular.

In 2D you need to specify only a partial record **post_element_force** as *index dir_normal_x dir_normal_y dir_shear0_x dir_shear0_y middle_x middle_y* and you get the normal force, one shear force and one bending moment in the **post_element_force_result** record.

In 1D you need to specify only a partial record **post_element_force** as *index dir_normal_x middle_x* and you get the normal force in the **post_element_force_result** record.

You can restrict with **post_element_force_geometry** with the same index that the **post_element_force** is only evaluated for nodes on a specific geometry. This **post_element_force** option always checks if the initial node location is located on this geometry (so not the location of moved nodes after displacement of the nodes).

You can restrict with **post_element_force_group** with the same index that the **post_element_force** is only evaluated for certain element groups.

You can restrict with **post_element_force_number** with the same index that the **post_element_force** is only evaluated for certain element numbers.

You can restrict with **post_element_force_normal** with the same index that the **post_element_force** is only evaluated for elements in positive normal direction *dir_normal_x dir_normal_y dir_normal_z*. If you don't specify **post_element_force_normal** elements on both sides will be used if present.

You can require by setting the *switch* in **post_element_force_force** with the same index that also the external forces (like gravity and edge loads etc.) are added to the result.

You can require by setting the *switch* in **post_element_force_inertia** with the same index that also the inertia forces is added to the result.

If you are not hapy with the sign or units with which the forces are calculated, you can use a multiply factor in **post_element_force_multiply_factor** with the same index to get what you want.

Please realise that in calculation with groundwater the calculated forces contain the force due to effective stresses and also due to groundwater total pressure (pore pressure).

We now give some examples for a 2D vertical pile driven into the soil in a dynamic **inertia ...** calculation, and including gravity **force_gravity ...** and an external force **force_element_edge ...** at the top of the pile. Below *x_pile* is the x-coordinate at the middle of the pile, *y_pile_middle* is the y-coordinate at the middle of the pile, *y_pile_bottom* is the y-coordinate at the bottom of the pile and *pile_group* is the group number of the pile.

The force in a cross section (force resulting from normal stress in cross section):

```
...
post_element_force 10 0. 1. 1. 0. x_pile y_pile
post_element_force_geometry 10 -pile_cross_section
post_element_force_group 10 pile_group
...
...
```

Here *pile_cross_section* is a geometry line through the cross section of the pile,

The force along the shaft (force resulting from shear stress along shaft):

```
...
post_element_force 10 0. 1. 1. 0. x_pile y_pile_bottom
```

post_element_force_geometry 10 *-pile_shaft*
post_element_force_group 10 *pile_group*
post_element_force_force 10 -yes
post_element_force_inertia 10 -yes
...
...

Here *pile_shaft* is a geometry line containing only nodes of the pile shaft,

The force at the pile toe (force resulting from normal stress at pile tip):

...
post_element_force 10 0. 1. 1. 0. *x_pile y_pile_bottom*
post_element_force_geometry 10 *-pile_toe*
post_element_force_group 10 *pile_group*
post_element_force_force 10 -yes
post_element_force_inertia 10 -yes
...
...

Here *pile_toe* is a geometry line containing only nodes of the pile toe,

The complete force on the pile:

...
post_element_force 10 0. 1. 1. 0. *x_pile y_pile_bottom*
post_element_force_geometry 10 *-pile_complete*
post_element_force_group 10 *pile_group*
post_element_force_force 10 -yes
post_element_force_inertia 10 -yes
...
...

Here *pile_complete* is a geometry line containing all nodes of the pile,

Also see the example calculation **force14.dat** and **force17.dat**.

6.930 post_element_force_force *index switch*

See **post_element_force**.

6.931 post_element_force_geometry *index geometry_item_name geometry_item_index*

See **post_element_force**.

6.932 post_element_force_group *index element_group_0 element_group_1 ...*

See **post_element_force**.

6.933 post_element_force_inertia *index switch*

See **post_element_force**.

6.934 post_element_force_multiply_factor *index multiply_factor*

See **post_element_force**.

6.935 post_element_force_normal *index switch*

Set *switch* to **-yes** if you want to select elements in positive normal direction. See **post_element_force**.

6.936 post_element_force_number *index number_0 number_1 ...*

See **post_element_force**.

6.937 post_element_force_result *index normal_force shear0_force shear1_force moment0 moment1*

See **post_element_force**.

6.938 post_global *switch*

With this **post_global** you can ask for global information to be determined if you set *switch* to **-yes**. The following information will then be determined:

- **-post_bounda_force_summed** (total force following from **-bounda_force** records, number of principal dofvalues)
- **-post_element_mass_summed** (total global mass)
- **-post_element_summed** (total number of elements)
- **-post_element_volume_summed** (total elements volume without empty elements)
- **-post_group_summed** (total number of elements in group 0, group 1, etc.)
- **-post_materi_inertia_summed** (sum of material nodal inertia, so of **node_inertia**)
- **-post_slide_force_summed** (sum of slide forces in global axes, so of **node_slide_force**)
- **-post_node_summed** (total number of nodes)
- **-post_node_dof_average** (average values for dof's)
- **-post_node_dof_maximum** (maximum values for dof's)
- **-post_node_dof_minimum** (minimum values for dof's)
- **-post_force_edge_summed** (total force following from **-force_edge** integrated over edges in x,y,z directions, *number_of_space_dimensions* values)
- **-post_force_edge_normal_summed** (total force following from **-force_edge_normal** integrated over edges in x,y,z directions, *number_of_space_dimensions* values)
- **-post_force_edge_projected_summed** (total force following from **-force_edge_projected** integrated over edges in x,y,z directions, *number_of_space_dimensions* values)
- **-post_support_edge_normal** (total force following from **-support_edge_normal** integrated over edges in x,y,z directions, *number_of_space_dimensions* values)
- **-post_solver_diagonal_minimum_value** (minimum diagonal term total matrix, only for pardiso solver)
- **-post_solver_diagonal_minimum_node** (node number at which the minimum value is found)
- **-post_solver_diagonal_maximum_value** (maximum diagonal term total matrix, only for pardiso solver)
- **-post_solver_diagonal_maximum_node** (node number at which the maximum value is found)
- **-post_solver_diagonal_ratio** (ratio maximum/minimum diagonal terms total matrix, only for pardiso solver)
- **-post_solver_iterations** (total number of iterations of iterative linear equation solver, only for bicg solver)

If you set *switch* to **-no** then the information will not be determined (this saves a little bit of computer time). Default, if **post_global** is not specified, *switch* to **-yes**.

6.939 post_group_volume_summed *volume_group_0 volume_group_1 ...*

This record will be filled with the total volume of the elements in each group. So *volume_group_0* is the summed volume of the elements in element group 0, etc.

6.940 post_integrate *index data_item_name data_item_index data_item_number ...*

Here you can specify results that should be integrated over time. The integrated results will be placed in the **post_integrate_result** record with the same index.

An example looks like:

```
...
groundflow_pressure
groundflow_velocity
end_initia
...
post_node 1 -average -geometry_line 4
...
post_integrate 3 -post_node_result 1 -gvely
...
...
```

Here the **post_node** record first takes care that the average groundflow y-velocity at nodes on a line are determined, among other dof's. The **post_integrate** record integrates that average groundflow y-velocity over time. In this way the total groundflow debit volume over a line is registered.

6.941 post_integrate_result *index result*

See **post_integrate**.

6.942 post_line *index x_0 y_0 z_0 x_1 y_1 z_1*

This record specifies a line in space for which the average or sum of the dof values will be calculated. The values are placed in a record **post_line_dof** with the same *index*. Internally in TOCHNOG, **post_point** records are used to evaluate the dof's on the line.

In 1D only *x_ 0* and *x_ 1* should be specified, etc.. In the example below, the average of the x-velocity between the points (3,1) and (3,7) will be printed

```
...
number_of_space_dimensions 2
materi_velocity
...
end_data
...
post_line 1 3. 1. 3. 7.
...
print_filter 0 -post_line_dof 1 -velx
...
control_timestep 1 1. 100.
control_print 1 -post_line_dof
```

The coordinates are defined in the initial mesh. See also: **post_line_n** and **post_line_operat**.

6.943 post_line_operat *index operat*

If *operat* is set to **-average** then the average is calculated for the **post_line** record with the same index. If *operat* is set to **-sum** then the sum is calculated for the **post_line** record with the same index.

If this **post_line_operat** is not specified, then *operat* is set to **-average**.

6.944 post_line_dof *index dof_ 0 dof_ 1 ...*

Average dofvalues at a selected line. See **post_line**.

6.945 post_line_dof_calcul ...

See **post_calcul**.

6.946 post_line_n *index n*

Use n **post_point** records to evaluate the dof's along the line. Default n is 5. See **post_line**.

6.947 post_node *index data_item operat geometry_entity_name geometry_entity_index*

If *operat* is set to **-sum**, results for the nodal *data_item* are summed. For example, you can take for *data_item* the **-node_rhside** and for *operat* you take **-sum** so that the total external force on a boundary is determined.

If *operat* is set to **-average**, results for the nodal *data_item* are averaged.

If *data_item* is set to **-node_rhside** and *operat* is set to **-moment**, the moment is determined around the origin (x=0,y=0) in a 2D calculation; this is done by calculating in the nodes the tangential force extracted from **-node_rhside** and multiplying it with the radial distance from the origin.

This operation is done for nodes which are placed on the geometrical entity *geometry_entity_name geometry_entity_index*. Instead of a geometrical entity you can also use **-all** to tell that all nodes should be used. Instead of a geometrical entity you can also use **-ra** .. **-ra** to tell that the nodes of the range should be used.

The result of this **post_node** record is put into the **post_node_result** record (with the same *index*).

6.948 post_node_factor *index factor*

You can multiply the result of **-post_node** with *factor*. Default, if **post_node_factor** is not specified, we take *factor* equal to 1.

6.949 post_node_result *index result_0 result_1 ...*

See **post_node**.

6.950 post_node_rhside_fixed *value_0 value_1 ...*

This record will be filled with the sum of **node_rhside** for those dof's which are prescribed (eg with a **bounda_dof**). For example, in a calculation with only velocities (displacements) as primary dof's, this record contains the sum of the reaction force at the nodes in which the velocity is prescribed. Values are only filled for principal dof's (materi velocity, groundflow pressure, condif temperature, ...).

6.951 post_node_rhside_free *value_0 value_1 ...*

Same as **post_node_rhside_fixed**, now for free values however. For example, in a calculation with only velocities (displacements) as primary dof's, this record contains the sum of the unbalance force at the nodes in which the velocity is not prescribed.

6.952 post_node_rhside_ratio *ratio*

This record gives during a calculation a measure for the inaccuracy of the calculation. For each primary dof the ratio between the size of the right-hand-side (nodal forces or nodal fluxes ...) in fixed nodes and free nodes.

If the size for the fixed nodes is below 1.e-10 the *ratio* is directly filled the result for free nodes. See also **post_node_rhside_ratio_dof_type**.

6.953 post_node_rhside_ratio_dof_type *dof_type_0 ...*

With this option you can specify a list of doftypes which should be used in the calculation of the **post_node_rhside_ratio** result. For example, if both **groundflow_pressure** and **condif_temperature** are initialised, then you can use only the groundflow pressure in the accuracy ratio determination by specifying **post_node_rhside_ratio_dof_type -groundflow_pressure**.

If **post_node_rhside_ratio_dof_type** is not specified and **materi_velocity** is initialised then automatically **post_node_rhside_ratio_dof_type -materi_velocity** will be used.

6.954 post_node_rhside_ratio_method *method*

By setting *method* to **-post_node_rhside_free** the *ratio* is directly filled with **post_node_rhside_free**. Default, when this **post_node_rhside_ratio_method** record is not specified, the default definition as specified in **post_node_rhside_ratio** is used,

6.955 post_point *index x y z*

This record specifies a point in space for which dof values will be calculated. The values are placed in a record **post_point_dof** with the same *index*. The values are obtained by determining in which element the point is located and then using the element's interpolation functions. In 1D only x should be specified, etc.. The coordinates are defined in the initial mesh. This option is only available for isoparametric elements.

6.956 post_point_element_group *index element_group*

Limit the search for the element in which the post point with the same *index* is located to the specified *element_group*.

6.957 post_point_dof *index dof_0 dof_1 ...*

Unknown values at a selected point. See **post_point**.

6.958 post_point_dof_calcul ...

See **post_calcul**.

6.959 post_point_eps_iso *index eps*

Tolerance with which a **post_point** is accepted to be part of an element. The default value is 1.e-3. You can increase the default value if a **post_point** is exactly on or over the border of the mesh, so that the **post_point** may be not found; typically try 0.1 or so.

6.960 post_point_move *index switch*

If *switch* is set to **-yes** the **post_point** with the same index will be moved along with the velocity field. Thus, with this option you can follow with a **post_point** the dof's of a material particle.

Please realise that this option should only be used if **materi_velocity** is initialised in the initialisation part.

6.961 post_quadrilateral *index x_0 y_0 z_0 x_1 y_1 z_1 x_2 y_2 z_2 x_3 y_3 z_3*

This record specifies a quadrilateral in space for which the average of the dof values will be calculated. The values are placed in a record **post_quadrilateral_dof** with the same *index*. Internally in TOCHNOG, **post_point** records are used to evaluate the dof's on the quadrilateral. In 2D only *x_0 y_0*, *x_1 y_1*, etc. should be specified. The coordinates are defined in the initial mesh. See also: **post_quadrilateral_n**.

6.962 post_quadrilateral_dof *index dof_0 dof_1 ...*

Average dof values at a selected quadrilateral. See **post_quadrilateral**.

6.963 post_quadrilateral_dof_calcul ...

See **post_calcul**.

6.964 post_quadrilateral_element_group *index element_group*

Select the specific element group from which the dof values should be taken.

6.965 post_quadrilateral_n *index n*

Use *n* **post_point** records in each direction to evaluate the dof's along the quadrilateral. Default *n* is 5. See **post_quadrilateral**.

6.966 post_strain_volume_absolute *index volume_increase_absolute*

This record will hold after the calculation the absolute volume increase summed over the elements that are selected in the **strain_volume_element**, **strain_volume_element_group** and **strain_volume_geometry** records (with the same index).

The actual volume increase which you will find in this **post_strain_volume_absolute** record will depend on the relative volume strain or absolute volume increase that you specified, but also on stiffnesses of neighboring zones, boundary conditions, etc.

You can use this **post_strain_volume_absolute** result to decide to manually change the specified relative volume strain or absolute volume increase and rerun the calculation.

6.967 post_strain_volume_initial *index volume_initial*

Initial volume of selected elements.

6.968 post_strain_volume_relative *index volume_strain_relative*

Relative volume strain percentage. Otherwise the same as **post_strain_volume_absolute**.

6.969 print_apply *switch*

If *switch* is set to **-no**, then all **control_print_*** records will not be applied. Default, if **print_apply** is not specified, *switch* is set to **-yes**.

6.970 print_arithmetic *switch*

If *switch* is set to **-yes**, all evaluated arithmetics will be printed. See the start of the data part for an explanation about arithmetics. The printing will be done to the file **tochnog_arithmetic.txt**.

6.971 print_control *switch*

If *switch* is set to **-yes**, the control index being evaluated will be printed. Handy for keeping track on what the program is doing.

6.972 print_data_name *switch*

If *switch* is set to **-yes**, all possible data names will be printed. The printing will be done to the file **tochnog_data_name.txt**.

This is convenient to search in the **tochnog_data_name.txt** file fast for options. For example under linux to search all options which have the word **group** in it do **grep group tochnog_data_name.txt**.

The possible data names may include also internal names that Tochnog uses during the calculation; so for each name you can check this users manual if it is a name that you can use as input in the input file, or not.

6.973 print_database_calculation *switch*

If *switch* is set to **-yes**, the database will be written after successful completion of a calculation to the file *name***.dbs**, where *name* is the name of the input file. If *switch* is set to **-no**, the database will not be written.

Default, *switch* is set to **-yes**.

6.974 print_define *switch*

If *switch* is set to **-yes**, all evaluated defines will be printed. See the start of the data part for an explanation about defines. The printing will be done to the file **tochnog_define.txt**.

6.975 print_element_geometry_present *switch*

See **element_geometry_present**. See also **print_element_geometry_present_node_type**. Default *switch* is set to **-no**.

6.976 print_element_geometry_present_node_type *node_type*

If *node_type* is set to **-node_start_refined** the values of **-node_start_refined** are used. If *node_type* is set to **-node** the values of **-node** are used. If *node_type* is set to **-plus_displacement** the values of **-node** plus nodal displacements. Default *node_type* is set to **-node_start_refined**.

6.977 print_failure *switch*

If *switch* is set to **-yes** then failure of elements due to one of the failure criteria (**group_materi_failure_rupture**, etc.) will be reported.

6.978 print_filter *index data_item_name data_item_index number_0 number_1 ...*

The data selected in the records **control_print**, **control_print_dof**, **control_print_dof_rhside** and **control_print_element** will be filtered at output. Thus only a limited amount of data will actually be printed. Here *data_item_name* is the name of the data item to be filtered, e.g. *data_item_name* is **-node_dof**. *data_item_index* is the index of the *data_item_name* record which passes the filter. If, for example, *data_item_index* is 3 then only index 3 passes the filter. If *data_item_index* is **-all** then all indices pass the filter. If, for example, *data_item_index* is **-geometry_line 3** (valid if *data_item_name* is **-node** or another nodal item) then only records with coordinates located on line 3 pass the filter. If, for example, *data_item_index* is **-geometry_line 3** (valid if *data_item_name* is **-element** or another element item) then only element with at least one coordinate located on line 3 pass the filter. If, for example, *data_item_index* is **-ra ...-ra** then indices in this range pass the filter. If, for example, *data_item_index* is **-macro 4** and *data_item_name* is data valid at a node (or element), then only nodes (or elements) generated by the macro number 4 pass the filter (see **control_mesh_macro_*** for macro's). If, for example, *data_item_index* is **-macro -none** and *data_item_name* is data valid at a node (or element) then only nodes (or elements) not generated by any macro pass the filter (see **control_mesh_macro_*** for macro's).

For example, if *number_0* is 3 then the fourth value of a record passes the filter. If *number_0* is **-all** the whole record passes the filter. If, for example, *number_0* is **-velx** while *data_item_name* is **-node_dof** then only x-velocities pass the filter.

Some examples are

print_filter 1 -node_dof -all -temp -sigxx (temperatures and xx-stresses)
print_filter 2 -node -geometry_line 3 0 (x-coordinates on line 3)

With **control_print_filter** you can select if the records **control_print, control_print_dof** or **control_print_dof_rhside** (with the same index) should use specific filters (specify the indices of the filter for *print_filter_index*), should use all filters (specify **-all** for *print_filter_index*), or should use no filter at all (specify **-none** for *print_filter_index*). Default, if **control_print_filter** is not specified, all filters will be used for a print option.

Example:

print_filter 1 -node_dof ...
print_filter 2 -node_dof_all ...
print_filter 3 ...
...
control_print_dof 10 ...
control_print_filter 10 1 2 (only use filter 1 and 2)
...
control_timestep 20 ...
control_print 20 ...
control_print_filter 20 -all (use all filters)

All used filters are placed in-line for a data item; thus only data which passes all used filters for that data item will be printed.

6.979 print_gid_calculation *switch*

If you set *switch* to **-yes** the gid files will be printed at the end of the calculation. If you set *switch* to **-no** the gid files will not be printed at the end of the calculation. Default, if *switch* is not specified, it is set to **-yes**.

6.980 print_frd_freecad *switch*

See **control_print_frd_freecad** , but now for all frd printing however. If both **control_print_frd_freecad** and **print_frd_freecad** are present, the **control_print_frd_freecad** dictates what happens for the specific control index.

If both **print_frd_freecad** and **control_print_frd_freecad** are not specified the *switch* is set to **-no**.

6.981 print_frd_prepomax *switch*

See **control_print_frd_prepomax** , but now for all frd printing however. If both **control_print_frd_prepomax** and **print_frd_prepomax** are present, the **control_print_frd_prepomax** dictates what happens for the specific control index.

If both **print_frd_prepomax** and **control_print_frd_prepomax** are not specified the *switch* is set to **-no**.

6.982 print_gid_contact_spring2 *number_of_nodes*

Set *number_of_nodes* to 2 if you want to draw **contact_spring2** with two nodes, and to 1 if you want to draw **contact_spring2** with one node. Default, if **print_gid_contact_spring2** is not specified, then 1 is used for *number_of_nodes*.

6.983 print_gid_coord *switch*

If *switch* is set to **-yes** the coordinates of nodes is plotted in gid.

6.984 print_gid_define *switch*

If *switch* is set to **-yes** defined names will be used i.s.o. geometry names (when a geometry is defined as a name with **start_define** ... **end_define**). If *switch* is set to **-no** that will not be done. Default, if *switch* is not specified, *switch* is set to **-yes**.

6.985 print_gid_group *switch*

If *switch* is set to **-yes** the element groups are plotted in gid as result field; in gid you can do a **contour_fill** to visualize this result field. If *switch* is set to **-no** the element groups are not plotted in gid as result. Default *switch* is set to **-yes**.

6.986 print_gid_mesh_activate_gravity *switch*

See also **mesh_activate_gravity_time**.

6.987 print_gid_node_method *method*

See **print_gid_node_method**.

6.988 print_gid_spring2 *number_of_nodes*

Set *number_of_nodes* to 2 if you want to draw **spring2** with two nodes, and to 1 if you want to draw **spring2** with one node. Default, if **print_gid_spring2** is not specified, then 1 is used for *number_of_nodes*.

6.989 print_gid_smooth_dof *dof_0 dof_1 ...*

This option allows you to smooth results in gid files. With *dof_0 dof_1 ...* you specify the dof's to be smoothed. As a special option you can specify **-all** so that all dof's will be smoothed.

The smoothing is done a number of times, with increasing smooth results. You can specify this number of times with the optional **print_gid_smooth_n**; if you don't specify this optional number of smoothings it is done 10 times.

6.990 print_gid_smooth_n *index number_of_smoothings*

See **print_gid_smooth_dof**.

6.991 print_group_data *dataitem_name_0 dataitem_name_1 ...*

Print in the gid files **group_*** data items for isoparametric finite elements. As a typical example use **-group_materi_elasti_young**; then you get in the gid plot what the young model distribution is for isoparametric finite elements in the mesh.

For different values of group data in integration points, the value of the last integration point will be used.

For elements which do not have a specific group data item a value 0 will be plotted. Tochnog sets the gid group data information in the timesteps, so only after timesteps have been taken you will see meaningful results for the group data in gid plots.

The values will also be placed in the **element_print_group_data** records.

6.992 print_gmsh_calculation *switch*

If you set *switch* to **-yes** the gmsh files will be printed at the end of the calculation. If you set *switch* to **-no** the gmsh files will not be printed at the end of the calculation. Default, if *switch* is not specified, it is set to **-no**.

6.993 print_gmsh_dummy *switch*

See **control_print_gmsh_dummy**. This **print_gmsh_dummy** holds for all gmsh printing, unless it is overruled by a **control_print_gmsh_dummy**.

6.994 print_gmsh_node_method *method*

See **print_gmsh_node_method**.

6.995 print_mesh_dof *dof_0 dof_1 ...*

This option allows you to print results for dof's (temperatures, groundflow pressures, ...) in a first calculation and use these results later in a second calculation as boundary conditions. This comes handy when you need to run the second calculation multiple times, and the results for the printed dof's can be taken from the first calculation. In this way, the computing time of the second calculation can be smaller, and also a different FE mesh can be used in the first calculation and the second calculation for the different doffields.

In the first calculation you can print the dof's with the command **print_mesh_dof**; the results will be printed in the file **print_mesh_dof.txt**. The *dof_0 dof_1 ...* of **print_mesh_dof** specify the dof's which will be printed. In the first calculation printing of the dof's to the file **print_mesh_dof.txt** will actually be done for when *switch* is set to **-yes** in **control_print_mesh_dof**.

For the second calculation rename the file **print_mesh_dof.txt** into **bounda_mesh_dof.txt**. You can specify which of the dof's in the file **bounda_mesh_dof.txt** will actually be used a prescribed value ('boundary condition') with the *dof_0 dof_1 ...* of **bounda_print_mesh_dof**. You can restrict the nodes to which this will be done by **bounda_print_mesh_dof_geometry** (please realise using a geometry point with a very large tolerance in combination with **geometry_element_group** you can effectively select the geometry formed by an element group).

The FE meshes as used in the first calculation and in the second calculation need not be the same, and are also allowed to vary in time (in building processes, excavations, etc.). Nodes from the second mesh will be located in the first mesh, and doffields will be interpolated from the first mesh to the second mesh. In case a node from the second mesh is not inside any isoparametric element of the first mesh, the value for the dof's as specified in the optional **bounda_print_mesh_dof_values** will be used. In **bounda_print_mesh_dof_values** you need to specify values for each and every dofthat was specified with **print_mesh_dof** in the first calculation. If the node of the second mesh cannot be found in the first mesh and also **bounda_print_mesh_dof_values** is not specified then the dof's will be taken from the closest node of the first mesh.

Results for the second mesh will be linearly interpolated in time from results of the first mesh.

Example first calculation in which only a temperature field is calculated:

echo -yes
number_of_space_dimensions 2
condif_temperature
end_initia
...
print_mesh_dof -temp
...
control_timestep 10 ...
control_print_mesh_dof 10 -yes (print in **print_mesh_dof.txt**)
...

Example second calculation in which the temperature field calculated in the first calculation is imposed:

echo -yes
number_of_space_dimensions 2
condif_temperature
materi_velocity
materi_displacement
materi_stress
end_initia
...
bounda_print_mesh_dof -temp
bounda_print_mesh_dof_values 20. (read from **bounda_mesh_dof.txt**)
...

6.996 print_node_geometry_present *switch*

See **node_geometry_present**. See also **print_node_geometry_present_node_type**. Default *switch* is set to **-no**.

6.997 print_node_geometry_present_node_type *node_type*

If *node_type* is set to **-node_start_refined** the values of **-node_start_refined** are used. If *node_type* is set to **-node** the values of **-node** are used. If *node_type* is set to **-plus_displacement** the values of **-node** plus nodal displacements. Default *node_type* is set to **-node_start_refined**.

6.998 print_precision *number_of_values*

With *number_of_values* you can set for all printing how many values will be used at printing. For example, setting *number_of_values* to **4** the internal tochnog double **98.123456789** will be printed as **98.12** when using **control_print**, **control_print_gid** etc.

6.999 print_tecplot_calculation *switch*

If you set *switch* to **-yes** the tecplot files will be printed at the end of the calculation. If you set *switch* to **-no** the tecplot files will not be printed at the end of the calculation. Default, if *switch* is not specified, it is set to **-yes**.

6.1000 print_vtk_calculation *switch*

If you set *switch* to **-yes** the vtk files will be printed at the end of the calculation. If you set *switch* to **-no** the vtk files will not be printed at the end of the calculation. Default, if *switch* is not specified, it is set to **-yes**.

6.1001 print_vtk_coord *switch*

If *switch* is set to **-yes** the coordinates of nodes is plotted in vtk.

6.1002 print_vtk_group *switch*

If *switch* is set to **-yes** the element groups are plotted in vtk as result field. If *switch* is set to **-no** the element groups are not plotted in vtk as result. Default *switch* is set to **-yes**.

6.1003 print_vtk_node_method *method*

See **print_vtk_node_method**.

6.1004 print_where *switch*

If *switch* is set to **-yes**, information will be printed about the taks that tochnog is performing (evaluation boundary conditions, loop over elements, etc.).

This is convenient for very large calculations, to see what is being done and how the calculation proceeds.

6.1005 **processors** *nproc*

With this record you can set the number of shared memory CPUs you want to use (*nproc*). If your TOCHNOG implementation does not allow for more processors, this record is ignored. In fact, not the number of processors but the number of threads is set (that is, if you use 2 threads while your system only supports 1 processor than those threads are split over that single processor).

Error messages may become confusing when you use more than one processor.

Default *nproc* is 1.

6.1006 **processors_maximum** *switch*

If *switch* is set to **-yes**, the **processors** record will be set to the maximum number as allowed by your computer.

Default *switch* is set to **-yes**. This **processors_maximum** record will not be used if the **processors** record is specified.

6.1007 **processors_partition** *npartition*

The element loop is parallised as follows. The master process gives away small amounts of the total number of elements to child processes, and if a child process is ready it gets a new small amount of the master process. In fact , a child process gets each time an amount of $\frac{nelement}{npartion*processors}$ where *nelement* is the number of elements, *npartition* is specified in **processors_partition**, and *processors* is specified in **processors**. Default, if **processors_partition** is not specified, we set *npartition* to 1.

6.1008 **repeat_save_result** *index result_0 result_1 ...*

See **control_repeat_save**. The index is the number of repetition (index 0 is repeat 0, index 1 is repeat 1, etc.)

6.1009 **repeat_save_calculate_result** *average_0 variance_0 average_1 variance_1 ...*

See **control_repeat_save_calculate**.

6.1010 safety_slip_circle_grid_middle *index x_first y_first x_last y_last*

This record specifies a grid with middles of a circle for safety factor calculations. With *x_first y_first* you specify the first middle. With *x_last y_last* you specify the last middle. With **safety_slip_circle_grid_middle_n** you specify the number of middles that should be evaluated in the safety calculation; all middles together form a equidistant grid between *x_first y_first* and *x_last y_last*.

As a special option you can only specify *x_first y_first* and not specify **safety_slip_circle_grid_middle_n**; then only one middle *x_first y_first* will be evaluated for the circle in the safety calculation.

See also **control_safety_slip**.

6.1011 safety_slip_circle_grid_middle_n *index n*

See **safety_slip_circle_grid_middle**.

6.1012 safety_slip_circle_grid_radius *index r_first r_last*

This record specifies the radius of a circle for safety factor calculations.

With *r_first* you specify the first radius. With *r_last* you specify the last radius. With **safety_slip_circle_grid_radius_n** you specify the number of radius that should be evaluated in the safety calculation; all radius to be evaluated will be put equidistant between *r_first* and *r_last*.

As a special option you can only specify *r_first* and not specify **safety_slip_circle_grid_radius_n**; then only one radius *r_first* will be evaluated for the circle in the safety calculation.

6.1013 safety_slip_circle_grid_radius_n *index n*

See **safety_slip_circle_grid_radius**.

6.1014 safety_slip_circle_grid_result *index x y r safety_factor*

This record will after the calculation be filled with the middle, radius and safety factor for the critical surface (for the slip circles with the same index).

6.1015 safety_slip_circle_grid_segment_n *index n*

With this record you can specify how many segments in the circle will be used in the integration of the safety factor. A high number of segments gives more accuracy but is time consuming. A low number of segments is less accurate but fast. Default, if **safety_slip_circle_grid_segment_n** is not specified, then 90 segments will be used.

6.1016 safety_slip_circle_line_middle *index x_first y_first x_last y_last*

This record specifies a line with middles of a circle for safety factor calculations. With *x_first y_first* you specify the first middle. With *x_last y_last* you specify the last middle. With **safety_slip_circle_line_middle_n** you specify the number of middles that should be evaluated in the safety calculation; all middles together form a equidistant line between *x_first y_first* and *x_last y_last*.

As a special option you can only specify *x_first y_first* and not specify **safety_slip_circle_line_middle_n**; then only one middle *x_first y_first* will be evaluated for the circle in the safety calculation.

See also **control_safety_slip**.

6.1017 safety_slip_circle_line_middle_n *index n*

See **safety_slip_circle_line_middle**.

6.1018 safety_slip_circle_line_radius *index r_first r_last*

This record specifies the radius of a circle for safety factor calculations.

With *r_first* you specify the first radius. With *r_last* you specify the last radius. With **safety_slip_circle_line_radius_n** you specify the number of radius that should be evaluated in the safety calculation; all radius to be evaluated will be put equidistant between *r_first* and *r_last*.

As a special option you can only specify *r_first* and not specify **safety_slip_circle_line_radius_n**; then only one radius *r_first* will be evaluated for the circle in the safety calculation.

6.1019 safety_slip_circle_line_radius_n *index n*

See **safety_slip_circle_line_radius**.

6.1020 safety_slip_circle_line_result *index x y r safety_factor*

This record will after the calculation be filled with the middle, radius and safety factor for the critical surface (for the slip circles with the same index).

6.1021 safety_slip_circle_line_segment_n *index n*

With this record you can specify how many segments in the circle will be used in the integration of the safety factor. A high number of segments gives more accuracy but is time consuming. A low number of segments is less accurate but fast. Default, if **safety_slip_circle_line_segment_n** is not specified, then 90 segments will be used.

6.1022 safety_slip_combined_linear *index x_first,0 y_first,0 x_first,1 y_first,1 ... x_last,0 y_last,0 x_last,1 y_last,1 ...*

This record specifies combined linear lines along which the safety factor should be calculated.

All data with *first* specifies the first combined linear line. The *x_first,0 y_first,0* specifies the first point of the first line piece of the first combined linear line, the *x_first,1 y_first,1* specifies the second point of the first line piece of the first combined linear line The *x_first,2 y_first,2* specifies the first point of the second line piece of the first combined linear line, the *x_first,3 y_first,3* specifies the second point of the second line piece of the first combined linear line etc.

All data with *last* specifies the last combined linear line. The *x_last,0 y_last,0* specifies the first point of the first line piece of the last combined linear line, the *x_first,1 y_first,1* specifies the second point of the first line piece of the last combined linear line The *x_last,2 y_last,2* specifies the first point of the second line piece of the last combined linear line, the *x_first,3 y_first,3* specifies the second point of the second line piece of the last combined linear line etc. This last combined linear line should have an equal number of points as the first combined linear line.

With **safety_slip_combined_linear_n** you specify the number of combined linear lines that should be evaluated in the safety calculation; all combined linear lines to be evaluated will be put equidistant between the first combined linear line and the second combined linear line.

As a special option you can only specify data for the first combined linear line, and specify not data for the last combined linear line and not **safety_slip_combined_linear_n**; then only one combined linear line will be used.

See also **control_safety_slip**.

6.1023 safety_slip_combined_linear_n *index n*

See **safety_slip_combined_linear**.

6.1024 safety_slip_combined_linear_result *index x_0 y_0 x_1 y_1 ... safety_factor*

This record will after the calculation be filled with the combined linear line for the critical surface (for the combined linear lines circles with the same index).

6.1025 safety_slip_combined_linear_segment_n *index n*

With this record you can specify how many segments in a line piece of a combined linear line will be used in the integration of the safety factor. A high number of segments gives more accuracy but is time consuming. A low number of segments is less accurate but fast. Default, if **safety_slip_combined_linear_segment_n** is not specified, then 10 segments will be used.

6.1026 safety_slip_ellipsoide *index middle_x_first middle_y_first middle_z_first base1_x_first base1_y_first base1_z_first base2_x_first base2_y_first base2_z_first a_first b_first c_first middle_x_last middle_y_last middle_z_last base1_x_last base1_y_last base1_z_last base2_x_last base2_y_last base2_z_last a_last b_last c_last*

This record specifies a 3D ellipsoide for which the safety factor should be calculated. The ellipsoide equation is $\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$, where x, y and z are local coordinates in the ellipsoide. The ellipsoide is specified by 12 parameters in tochnog.

All parameters with *first* specifies the first ellipsoide. The *middle_x_first middle_y_first middle_z_first* specifies the ellipsoide middle (for which the local coordinates are 0; $x = 0$, $y = 0$, $z = 0$). The *base1_x_first base1_y_first base1_z_first* specifies the direction of the local x axes in space. The *base2_x_first base2_y_first base2_z_first* specifies the direction of the local y axes in space. Tochnog determines automatically the direction of the local z axes in space. The *a b c* specifies the radii in respective the local x, y and z direction.

All parameters with *last* specifies the last ellipsoide.

With **safety_slip_ellipsoide_n** you specify the number of variations that should be used for each of the specified ellipsoids parameters. All parameters will be interpolated between the values specified for the first and last ellipsoide. In case you want to keep a parameter fixed, thus it should not be varied, simply specify an equal value for the parameter in the first and last ellipsoide.

As a special option you can only specify parameters for the first ellipsoide, and specify not parameters for the last ellipsoide.

See also **control_safety_slip**.

6.1027 safety_slip_ellipsoide_method *index method*

The normal on the ellipsoide surface is uniquely defined, so that the normal stresses are uniquely defined. The slip direction in the surface is not uniquely defined however. Below several possibilities are listed.

If *method* is set to **-safety_slip_ellipsoide**, then the ellipsoide local x direction will be used as slip direction (to be more precise, the projections on the ellipsoide surface will be used everywhere).

If *method* is set to **-materi_displacement** or **-materi_velocity_integrated**, then the last calculated displacements will be used as slip direction (to be more precise, the projections on the ellipsoide surface will be used everywhere).

If *method* is set to **-materi_velocity**, then the last calculated velocities will be used as slip direction (to be more precise, the projections on the ellipsoide surface will be used everywhere).

Default, if **safety_slip_ellipsoide_method** is not specified, *method* is set to **-safety_slip_ellipsoide**.

6.1028 safety_slip_ellipsoide_n *index n*

See **safety_slip_ellipsoide**.

6.1029 safety_slip_ellipsoide_result *index middle_x middle_y middle_z base1_x base1_y base1_z base2_x base2_y base2_z a b c safety_factor*

This record will after the calculation be filled with the ellipsoide for the critical surface and the safety factor.

6.1030 safety_slip_ellipsoide_segment_n *index n*

With this record you can specify how many segments in an ellipsoide will be used in the integration of the safety factor. The ellipsoide is internally in tochnog integrated in a local ϕ and θ direction, over **safety_slip_combined_linear_segment_n** segments each. A high number of segments gives more accuracy but is time consuming. A low number of

segments is less accurate but fast. Default, if **safety_slip_ellipsoide_n** is not specified, then 90 segments will be used.

6.1031 safety_slip_grd *index switch*

If *switch* is set to **-yes**, Tochnog will read a slip surface from the file *index*.**grd**. The file is in .grd format, as used by the **surfer** program from **Golden Software**. Thus the format is:

DSAA
nx ny
xmin xmax
ymin ymax
zmin zmax
... (for first y specify z values for all x)
... (for second y specify z values for all x)
...

This **safety_slip_grd** is only available in 3D.

6.1032 safety_slip_grd_method *index method*

With this record you can specify with which method the slip direction is chosen (this is the direction in which the slip shear force will be determined, to calculate the safety factor).

If *method* is set to **-safety_slip_grd_direction** the direction specified in **-safety_slip_grd_direction** will be used. If *method* is set to **-materi_velocity** the last calculated **-materi_velocity** directions will be used. If *method* is set to **-materi_displacement** the last calculated **-materi_displacement** directions will be used. If *method* is set to **-materi_velocity_integrated** the last calculated **-materi_velocity_integrated** directions will be used. If somewhere the direction is not specified by the above, because the used direction is a null vector, then Tochnog will ask you to specify **safety_slip_grd_method_direction** additionally, and then that direction will be used there.

Default, if **safety_slip_grd_method** is not specified, *method* is set to **-safety_slip_grd_direction**.

6.1033 safety_slip_grd_method_direction *index dir_x dir_y dir_z*

See **safety_slip_grd_method**.

6.1034 safety_slip_grd_segment_n *index n*

With this record you can specify how many segments in each part of the surface of the grd file will be used in the integration of the safety factor. In total the surface has *nx*ny* parts; each of these parts will be integrated with *n*n* segments. Default, if **safety_slip_grd_segment_n** is not specified, then *n* will be set to 10.

6.1035 safety_slip_multi_linear *index x_first,0 y_first,0 x_first,1 y_first,1 ... x_last,0 y_last,0 x_last,1 y_last,1 ...*

This record specifies multi linear lines along which the safety factor should be calculated.

All data with *first* specifies the first multi linear line. The *x_first,0 y_first,0* specifies the first point of the first line piece of the first multi linear line, the *x_first,1 y_first,1* specifies the second point of the first line piece of the first multi linear line which is also the first point of the second line piece of the first multi linear line, etc.

All data with *last* specifies the last multi linear line. The *x_last,0 y_last,0* specifies the first point of the first line piece of the last multi linear line, the *x_first,1 y_first,1* specifies the second point of the first line piece of the last multi linear line which is also the first point of the second line piece of the last multi linear line, etc. This last multi linear line should have an equal number of points as the first multi linear line.

With **safety_slip_multi_linear_n** you specify the number of multi linear lines that should be evaluated in the safety calculation; all multi linear lines to be evaluated will be put equidistant between the first multi linear line and the second multi linear line.

As a special option you can only specify data for the first multi linear line, and specify not data for the last multi linear line and not **safety_slip_multi_linear_n**; then only one multi linear line will be used.

See also **control_safety_slip**.

6.1036 safety_slip_multi_linear_n *index n*

See **safety_slip_multi_linear**.

6.1037 safety_slip_multi_linear_result *index x_ 0 y_ 0 x_ 1 y_ 1 ... safety_factor*

This record will after the calculation be filled with the multi linear line for the critical surface (for the multi linear lines circles with the same index).

6.1038 safety_slip_multi_linear_segment_n *index n*

With this record you can specify how many segments in a line piece of a multi linear line will be used in the integration of the safety factor. A high number of segments gives more accuracy but is time consuming. A low number of segments is less accurate but fast. Default, if **safety_slip_multi_linear_segment_n** is not specified, then 10 segments will be used.

6.1039 safety_slip_set *index index_0 index_1 index_1 ...*

This records defines the indices of safety geometries belong to a set. For all safety geometries of a set, the minimal safety factor will be determined.

As a special option you can also define a range.

6.1040 safety_slip_set_result *index index safety_factor*

This record will be filled after the calculation with the minimal safety factor of the geometries in the set.

6.1041 slide_axisymmetric *index switch*

If *switch* is set to **-yes** the slide defined by the **slide_geometry** is axisymmetric.

6.1042 slide_geometry *index geometry_entity geometry_entity_index*

This record generates slide friction forces when a material slides over the geometry specified by *geometry_entity geometry_entity_index*.

This option comes handy when it is a priori known at which nodes sliding will occur, which is typically the case in an Eulerian calculation.

Also **slide_plasti_friction** should be specified.

See also **node_slide**.

6.1043 slide_plasti_friction *index phi c*

This record specifies friction for the **slide_geometry** option. The maximum friction force between the material and the side surface equals $c + F_n * tan(phi)$ where c is the cohesion, phi is the friction angle in radians and F_n is the normal force.

The plastic yield function will become available in the records **node_slide_f**.

6.1044 slide_plasti_tension *index sig_t*

This record specifies maximum tensile force for the **slide_geometry** option.

The plastic yield function will become available in the records **node_slide_f**.

6.1045 slide_user *index switch*

If *switch* is set to **-yes** the user supplied routine for slide friction is called.

See also the file **user.cpp** in the distribution.

6.1046 slide_damping *index damping_n damping_t*

This specifies the normal damping and tangential damping for sliding. See also **control_slide_damping_apply**.

6.1047 slide_stiffness *index stiffness_n stiffness_t*

This specifies the normal stiffness and tangential stiffness for sliding.

The slide directions will become available in the records **node_slide_direction**. The slide forces will become available in the records **node_slide_force**.

See also **control_slide_stiffness_apply**.

6.1048 solver *solver_type*

You can set here the solver type to one of solvers as specified in **control_solver**. The solver set here holds for the entire calculation (as opposed to the **control_solver** which only holds for the corresponding time steps). In fact, each **control_solver** will be overwritten by a specified **solver**.

When using the bicg solver, consider also setting **solver_matrix_symmetric** to **-yes**, in order to speed up the speed of the bicg solver.

6.1049 solver_bicg_error *error*

With *error* you set the termination error ratio between the initial and final error in the bicg iterations.

See also **control_solver_bicg_error**.

6.1050 solver_bicg_restart *nrestart*

With *nrestart* you set the number of restarts in the bicg iterations.

See also **control_solver_bicg_restart**.

6.1051 solver_bicg_stop *switch*

If *switch* is set to **-yes**, the calculation is stopped if the bicg solver does not converge. If *switch* is set to **-no**, the calculation is not stopped if the bicg solver does not converge.

See also **control_solver_bicg_stop**.

6.1052 solver_matrix_save *switch*

If *switch* is set to **-yes**, the solver saves and applies the decomposed matrix, but not in case Tochnog thinks for some reason that the matrix needs to be decomposed at each timestep. This can save CPU time, since further decompositions of the matrix are not required anymore (only backsubstitution to find the solution vector).

If *switch* is set to **-no**, the solver does not save the decomposed matrix.

If *switch* is set to **-always**, the solver saves and applies the decomposed matrix, even in case Tochnog thinks for some reason that the matrix needs to be decomposed at each timestep.

This option is only available in combination with the pardiso solver. See also **control_solver_matrix_save**.

6.1053 solver_matrix_symmetric *switch*

If *switch* is set to **-yes** then, if needed, matrices are symmetrized so that less memory will be needed and a symmetrical equation solver can be used.

6.1054 solver_pardiso_ordering *ordering*

See also **control_solver_pardiso_ordering**.

6.1055 solver_pardiso_out_of_core *switch*

If *switch* is set to **-yes** the pardiso solver is called with a 'out of core' option. See for further the pardiso solver in the the intel mkl library.

6.1056 solver_pardiso_processors *nproc*

Set the number of processors to be used by the pardiso solver. Only 1 or the maximum number of the computer is allowed, nothing in between. The pardiso solver in the intel mkl library can have problems with parallelisation; so if you use this option check your results.

Default *nproc* is set to 1 (no parallelisation).

6.1057 solver_pardiso_processors_maximum *switch*

If *switch* is set to **-yes** the maximum number of processors will be used for the pardiso solver. Else only 1 processor will be used for the pardiso solver. See also **solver_pardiso_processors**.

6.1058 strain_settlement_parameters *index time_global,start time_plus reference_creep_strain_rate reference_time power_n lateral_factor*

With this option data items you can specify an extra vertical settlement creep strain. Think of geotechnics soil dumping as a typical example where after dumping some extra vertical straining shows up over time.

The vertical settlement creep strain of a soil particle is assumed to be:

$$\dot{\epsilon_{zz}} = \frac{\dot{\epsilon}_r}{1 + (\frac{t - t_{plus}}{t_r})^n}$$

The user supplied parameters are: $\dot{\epsilon}_r$ as reference creep rate, t_{plus}, t_r as reference time and n as power constant. Creep strain starts when the global time t_{global} reaches $time\_global, start$. So $time_{age,start}$ can be used to set where in the creep strain curve the material will start with creeping. The time t in this equation is the time elapse after the material has become active (so the time after dumping the material, which typically is different for each finite element).

The horizontal creep strains $\dot{\epsilon_{xx}} = f\dot{\epsilon_{zz}}$ and $\dot{\epsilon_{yy}} = f\dot{\epsilon_{zz}}$ are assumed to be a lateral factor f times the vertical creep strain.

This **strain_settlement_parameters** should be combined with the **mesh_gravity_activate_time** option as follows:

```
...
mesh_activate_gravity_time 10 ...
mesh_activate_gravity_time_strain_settlement 10 -yes
strain_settlement_parameters 20 ...
...
```

The **mesh_activate_gravity_time_strain_settlement** indicates that the mesh activation should not be used by itself, but is only used to determine element activation times needed for the **strain_settlement_parameters** option.

See also **strain_settlement_element_group**.

6.1059 strain_settlement_diagram *index dof_ 0 value_ 0 dof_ 1 value_ 1 ...*

With the records **strain_settlement_diagram**, **strain_settlement_diagram_dof** and **strain_settlement_diagram_number** you can specify parameters of **strain_settlement_parameters** to be dependend on dof values (strains, stresses, ...) or calculated dof values (total pressures, ...).

In **strain_settlement_diagram_dof** you can set a name of **dof_label** (eg **-sigyy**) or of **post_calcul_label** (eg **-to_pres**).

In **strain_settlement_diagram_number** you can set the number of the parameter of **strain_settlement_parameters** to be made dependend (eg 1 for *time_plus*, 2 for *reference_creep_strain_rate* etc.). You are not allowed to specify number 0 (so for *time_global,start*).

In **strain_settlement_diagram** you can set the dependency as sets dof-value. If the dof value is outside the diagram the parameter of the strain settlement will not change.

6.1060 strain_settlement_diagram_dof *dof*

See **strain_settlement_diagram**.

6.1061 strain_settlement_diagram_number *number*

See **strain_settlement_diagram**.

6.1062 strain_settlement_element_group *index element_group_0 element_group_1 ...*

This record specifies the element groups for which the **strain_settlement_parameters** with the same parameters will be used. As a special option you can use **-all**, such that all elements groups will be used.

6.1063 strain_volume_absolute_time *index time_0 volume_increase_absolute_0 time_1 volume_increase_absolute_1 ...*

See **strain_volume_element**.

6.1064 strain_volume_element *index element_0 element_1 ...*

With the **strain_volume_*** data items you can specify an extra volumetric strain component which Tochnog should add to specified elements, element groups or a geometry. Think of geotechnics grouting as a typical example.

If you specify **strain_volume_*** then $\frac{1}{3}$ of the specified volumetric strain is imposed as xx-strain, yy-strain and zz-strain. The actual straining of elements in the calculation will depend on boundary conditions, external forces, etc. For example, if you have a calculation where all displacements are suppressed by boundary conditions, the actual deformation of elements is null, and the specified **strain_volume_*** only leads to stresses. For example, if you have a 3d calculation where elements are free to deform the actual deformation of elements will become equal to the specified **strain_volume_***. For example, if you have a 2d plain strain calculation where elements are free to deform the actual deformation of elements will be smaller than specified **strain_volume_*** (since there is no deformation possible in the third direction).

Use **strain_volume_element** to specify element numbers for which the volume strain should be applied. Use **strain_volume_element_group** to specify element group numbers for which the volume strain should be applied. Use **strain_volume_geometry** to specify a geometry for which the volume strain should be applied.

You can either specify relative volume strains (relative to the initial volume) or absolute volume changes. Use **strain_volume_relative_time** to specify a time versus relative volume strain diagram. These relative volume strains should be specified as percentage (thus, 100 would be a volume strain equal to the initial volume, so 100 percent extra volume). Use **strain_volume_absolute_time** to specify a time versus absolute volume increase diagram. These absolute volume increases should be specified as real volume (thus m^3 if you use would meter m as length unit in your input file). Exactly one of **strain_volume_relative_time** or **strain_volume_absolute_time** should be given in the input file, not both. At times outside **strain_volume_relative_time**, or **strain_volume_absolute_time**, the relative volume strain, or absolute volume increase, are assumed to be zero.

If none of **strain_volume_element**, **strain_volume_element_group** or **strain_volume_geometry** is given then the **strain_volume_relative_time** or **strain_volume_absolute_time** will be applied to all isoparametric elements.

The volumetric strain option presently is available only for small deformation analysis. The volumetric strain can be be applied to isoparametric elements only. The volumetric strain is not available for membrane elements.

See also **post_strain_volume_absolute** and **post_strain_volume_relative**.

6.1065 strain_volume_element_group *index element_group_0 element_group_1 ...*

See **strain_volume_element**.

6.1066 strain_volume_geometry *index geometry_item_name geometry_item_index*

See **strain_volume_element**.

6.1067 strain_volume_relative_time *index time_0 relative_volume_strain_0 time_1 relative_volume_strain_1 ...*

See **strain_volume_element**.

6.1068 support_edge_normal *index stiffness_normal stiffness_tangential*

Distributed support of an edge (winkler foundation). The *stiffness_normal* specifies the normal stiffness of the support per unit length in 2D, and per unit area in 3D. The *stiffness_tangential* specifies the tangential stiffness. This option is meant for 2D and 3D calculations.

Also the record **support_edge_normal_geometry** should be specified.

Attention: this option is only available for linear and quadratic isoparametric elements.

See also **node_support_edge_normal_force**.

6.1069 support_edge_normal_damping *index damping_ normal damping_ tangential*

Distributed damping at an edge. The *damping_ normal* specifies the normal damping of the support per unit length in 2D, and per unit area in 3D. The *damping_ tangential* specifies the tangential damping. This option is meant for 2D and 3D calculations.

If you want to use **support_edge_normal_damping** to absorb stress wave at the boundaries of the mesh (think of vibration or earthquake analysis), there are typical values to be used for the normal and tangential damping.

For absorbing boundaries the *damping_ normal* typically should be set to $C_n \rho V_n$. The parameter C_n typically is chosen as 1. The ρ is the material density. The pressure wave velocity is $V_n = \sqrt{\frac{E_{oed}}{\rho}}$ with oedometric stiffness $E_{oed} = \frac{(1-\nu)E}{(1+\nu)(1-2\nu)}$ where E is the Young's modulus, and ν is Poisson's ratio. For absorbing boundaries the *damping_ tangential* typically should be set to $C_t \rho V_t$. The parameter C_n typically is chosen as 0.25. The shear wave velocity is $V_t = \sqrt{\frac{G}{\rho}}$ with shear modulus $G = \frac{E}{2(1+\nu)}$.

Also the records **support_edge_normal** and **support_edge_normal_geometry** should be specified.

Attention: this option is only available for linear and quadratic isoparametric elements.

See also **control_support_edge_normal_stiffness_freeze** and **node_support_edge_normal_force**. See also **support_edge_normal_damping** for automatic specification of damping properties.

6.1070 support_edge_normal_damping_automatic *index switch*

If you set *switch* to **-yes** this record generates damping just like the **support_edge_normal_damping** record. Now however you do not need to specify the damping properties yourself; they are calculated by Tochnog using the Young value E and the Poisson ratio ν from the isoparametric element attached to the support.

6.1071 support_edge_normal_damping_automatic_apparent *index switch*

If you set *switch* to **-yes** this record generates damping just like the **support_edge_normal_damping** record. Now however you do not need to specify the damping properties yourself; they are calculated by Tochnog using the apparent young and poisson value from the isoparametric element attached to the support.

6.1072 support_edge_normal_density *index density_ normal density_ tangential*

Distributed density at an edge. The *density_ normal* specifies the normal density of the support per unit length in 2D, and per unit area in 3D. The *density_ tangential* specifies the tangential density. This option is meant for 2D and 3D calculations.

Attention: this option is only available for linear and quadratic isoparametric elements.

6.1073 support_edge_normal_element_node *index element_ 0 element_ 1 ...*

Selects the element and local nodes for which the **support_edge_normal** record with the same *index* should be applied.

6.1074 support_edge_normal_element_group *index element_ group*

Restricts the element group to which the **support_edge_normal** record with the same *index* should be applied.

6.1075 support_edge_normal_element_side *index element_ 0 element_ 1 ... side*

Selects the elements and local side number for which the **support_edge_normal** record with the same *index* should be applied.

6.1076 support_edge_normal_factor *index* a_0 a_1 $\ldots a_n$

The same as **force_edge_normal_factor**, now however for the support stiffnesses (and not the force).

6.1077 support_edge_normal_force_initial *index a_ 0 a_ 1*

This record allows you to specify an initial normal force in the support, linear varying in depth direction. The initial normal force actually is $a_0 + a_1 * y$ in 2D, or $a_0 + a_1 * z$ in 3D.

6.1078 support_edge_normal_geometry *index geometry_entity_name geometry_entity_index*

Selects the area for which the **support_edge_normal** record with the same *index* should be applied. For example, **-geometry_line 1** can be used in 2D, indicating that the nodes on line 1 get the distributed support.

6.1079 support_edge_normal_node *index node_0 node_1 node_2 ...*

Selects the nodes for which the **support_edge_normal** record with the same *index* should be applied. The *node_0* etc. specify global node numbers.

6.1080 support_edge_normal_plasti_compression *index normal_force_minimum tangential_force_factor*

With *normal_force_minimum* you can limit the amount of compression force that a support can take. Any compression force lower than this *normal_force_minimum* will actually be set to *normal_force_minimum*. Typically you want to specify a negative value for *index normal_force_minimum*.

With *tangential_force_factor* you can model frictional slip in the tangential direction. The tangential force is limited to *tangential_force_factor* times the normal force. Larger tangential forces are not allowed.

This **support_edge_normal_plasti_compression** will only be used if the normal force does not exceed the maximum tension force as specified in **support_edge_normal_plasti_tension** or **support_edge_normal_plasti_tension_double**.

All forces are per unit length in 2D, and per unit area in 3D.

6.1081 support_edge_normal_plasti_friction *index cohesion friction_coefficient*

With this record you can limit the amount of friction force that a support can take. The maximum allowed friction force is the *cohesion* plus the *friction_coefficient* multiplied with the absolute value of the normal force.

All forces are per unit length in 2D, and per unit area in 3D.

6.1082 support_edge_normal_plasti_tension *index switch*

If *switch* is set to **-yes** and the normal force in the support is tension, then all forces are set to 0. This models gap building between the support and the element edge.

6.1083 support_edge_normal_plasti_tension_double *index normal_force_maximum*

With *normal_force_maximum* you can limit the amount of tension force that a support can take. As opposed to **support_edge_normal_plasti_tension**, you can specify a non-zero value with this option. If a normal force higher than this *normal_force_maximum* occurs it will be set to *normal_force_maximum*, and tangential shear forces will be set to zero. Typically you want to specify zero or a positive value for *index normal_force_maximum*, although a negative value is also allowed.

Not both of **support_edge_normal_plasti_tension** and **support_edge_normal_plasti_tension_doub** can be specified.

All forces are per unit length in 2D, and per unit area in 3D.

6.1084 support_edge_normal_plasti_residual_stiffness *index factor*

In case of plasticity in a support you can require that Tochnog includes a part of the original elastic stiffness in the element stiffness matrix to get more stable iterations. The part of the original stiffness included needs to be specified with *factor*, between 0 and 1. The stiffness is only included in the matrix, and not in the right-hand-side; so it will only influence convergence behaviour, but not the final results if a sufficient amount of steps is taken. Default, if **support_edge_normal_plasti_residual_stiffness** is not specified, *factor* is set to 0.

6.1085 support_edge_normal_time *index time load time load ...*

This record specifies a diagram with a multiplication factor for the support edge force. Linear interpolation is used to extend the *time load* values to the intervals between these pairs. Outside the specified time range a factor 0 is used.

If this record is not specified, a factor of 1 is applied at all times.

6.1086 target_item *index data_item_name data_item_index number*

See also: **target_value**.

6.1087 target_value *index value tolerance*

This allows for testing the results of the calculation. Typically, *data_item_name* is **-node_dof** but also other data items can be tested. The record with index *data_item_index* will be tested. If *data_item_name* is **-node_dof** then *number* can be **-velx**, **-temp**, etc.

(see **dof_label**); else, for example, *number* is 3 states that the fourth value needs to be checked. The result should not differ more from *value* than *tolerance*.

For a calculation with no problems, the tochnog.log file contains a line stating that the calculation did start followed by a line stating that the calculation did end. If this is not precisely the case, some problem did occur or the targeted results differ too much. In the example below it is checked that the pressure in node 6 does not differ more than $1.\ 10^{-5}$.

target_item 0 -node_dof 6 -pres
target_value 0 1.2 1.e-5

The checked value, 1.2 in this case, has been found from a previous computation that is regarded as reliable. The present computed value is compared with the earlier one. If they agree within the specified tolerance, 1.e-5 in this case, then Tochnog is silent. If they do not, then Tochnog writes an error message into the file "tochnog.log".

6.1088 time_calculation *elapsed_time_in_seconds*

Elapsed computer time up to moment of printing (wall clock time).

6.1089 time_current *current_time*

Current time in calculation.

6.1090 timestep_predict_velocity *switch*

Normally tochnog will use as prediction for velocities in a timestep the previous calculated velocities from the previous timestep.

However, if there is no inertia, and **convection_apply** is **-no** tochnog will use as prediction for velocities in a timestep a zero velocity.

You can require that tochnog does the normal prediction from the previous timestep however by setting *switch* to **-yes**; you typically want to do that in eulerian calculations.

6.1091 timestep_iterations_automatic_apply *switch*

If *switch* is set to **-no** any **control_timestep_iterations_automatic** records will be neglected.

6.1092 tochnog_version *index day month year*

This record contains the build day, the build month and the build year.

6.1093 truss_rope_apply *switch*

If *switch* is set to **-no**, any truss rope data in the input file will be ignored. This is done for all timesteps.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with truss rope data. See also **control_truss_rope_apply**.

6.1094 volume_factor a_0 a_1 $\ldots a_n$

This data item defines a polynomial in space in 1D or 2D. The polynomial specifies the cross-sectional area (in 1D) or the thickness (2D) as function of the global x coordinate (1D) or the global x,y coordinates (2D). For example, in a 1D solid calculation it can be used to specify varying cross-sectional areas of bars, or in a 1D flow calculation it can be used to specify the cross- sectional area of a channel.

In 1D the polynomial is $a_0 + a_1 x$ (specify 2 values). In 2D the polynomial is $a_0 + a_1 x + a_2 y$ (specify 3 values).

If this record is not specified, the cross-sectional area is 1 (1D) or the thickness is 1 (2D).

See also **volume_element_factor**.

6.1095 volume_factor_x x_0 fac_{01} x_1 fac_{12} $\ldots x_n$

This specifies an in x-direction changing volume factor for elements. Left from x_0 the factor is 1. From x_0 to x_1 the factor is fac_{01}. Etcetera. And right from x_n the factor is 1 again.

6.1096 zip *switch*

If *switch* is set to **-yes** all ***flavia***, ***msh**, **vtk**, ***.plt** and ***dbs** files are zipped with the **gzip** program. The **gzip** program should be installed on your computer.

This comes convenient in large calculation with lots of output, where you want to use results later and save disk space during the calculation.

If also **control_zip** is specified for a certain control index that overrules this **zip** for that control index.

6.1097 end_data (last record of data part)

7 Runtime file

You can use a runtime file to give to Tochnog data on the fly (while it is running). The runtime file will be read at the start of each time step. The runtime file needs to have the same name as the input file, with the extension **run** instead of **dat** however. Suppose the name of the normal input file is **beam.dat**, then the name of the runtime file is **beam.run**. The runtime file always needs to be ended with two **end_data** statements.

As a typical example you can use this runtime file when you are doing a long calculation and you decide while the calculation is running that you want extra output. Suppose the normal input file **tochnog.dat** contains:

```
...
control_timestep 100 ...
...
```

Then you can decide to get some extra GID plotting files, while Tochnog is already running, by using the runtime file **tochnog.run** with:

```
control_print_gid 100 -yes
end_data end_data
```

When you want to de-activate the printing of GID files again then set the runtime file to:

```
control_print_gid 100 -no
end_data end_data
```

As a special option, you can use **exit_tochnog -yes** in the runtime file; then Tochnog will exit the calculation after printing the complete database and GID files.

After the runtime file is read, it will be automatically deleted by Tochnog.

8 Interaction analyzes and advanced analyzes

8.1 Fluid-structure interaction

If a solid construction interacts with a fluid, both the solid and fluid can be modeled with the materi equation. Interaction forces between solid and fluid will automatically be generated. If required, a temperature field may be imposed. An example of a input file is given below

```
...
materi_velocity
materi_stress
condif_temperature
end_initia
...
element_group -ra -from 0 -to 100 -ra 1
element_group -ra -from 101 -to 200 -ra 2
...
type 1 -materi -condif
group_materi_elasti_young 1 ...
group_materi_memory -updated
group_condif_conductivity 3 ...
...
type 2 -materi
group_materi_elasti_compressibility 2 ...
group_materi_viscosity 2 ...
group_materi_memory -updated_linear
group_condif_conductivity 2 ...
...
```

Elements 0-100 are solids (with temperature) and elements 101-200 are fluids (with temperature).

8.2 Consolidation analysis: ground water flow in deforming solid

The ground water flow equation can be combined with the materi equations. The solid will deform due to the ground water flow pressure gradient and ground water flow pressure will change due to solid volume changes. An example of a input file is given below

```
...
materi_velocity
materi_stress
```

groundflow_pressure
end_initia
...
groundflow_consolidation_apply -yes ...
groundflow_density ...
groundflow_phreatic_level ...
...
group_type 0 -materi -groundflow
group_materi_elasti_young 0 ...
group_materi_memory -updated
group_groundflow_capacity 0 ...
...

The stresses as initialized by **materi_stress** are effective stresses. Internally the program calculates with total stresses (effective stress + total pressure) in the material equilibrium equation. You can obtain the total stresses for postprocessing by means of the **post_calcul** option.

To account for the gravitational stresses, use a density ρ_{sat} in the **group_materi_density** record. Here ρ_{sat} is the saturated density of the groundwater-soil mixture (mass of soil + water per unit volume of the soil-water mixture). Also specify the gravitation in the **force_gravity** record and, if required, also the **force_gravity_time** record to apply the gravitation slowly.

8.3 Heat transport in ground water flow

Heat transport in a ground water flow can be analyzed by combining the convection and diffusion of heat equation with the ground water flow equation. Now the velocity in the convection and diffusion of heat equation is taken from the groundflow velocity field ($\beta_i = v_i{}^{\mathrm{g}}$) if **groundflow_velocity** is initialized. An example of a input file is given below

...
groundflow_pressure
groundflow_velocity
condif_temperature
end_initia
...
type 0 -groundflow -condif
group_groundflow_compressibility 0 ...
group_condif_conductivity 0 ...
...

If both **materi_velocity** and **groundflow_velocity** are initialized, $\beta_i = v_i + v_i{}^{\mathrm{g}}$.

8.4 Heat transport in materials

Heat transport in a material can be analyzed by combining the convection and diffusion of heat equation with the materi equations. In this way thermal stresses or heat induced convection can be analyzed. Now the velocity in the convection and diffusion of heat equation is taken from the velocity field ($\beta_i = v_i$). An example of a input file is given below

```
...
materi_velocity
materi_stress
condif_temperature
end_initia
...
type 0 -materi -condif
group_materi_elasti_young 0 ...
group_materi_expansion 0 ...
group_materi_memory 0 -updated
group_condif_conductivity 0 ...
...
```

8.5 Restart a calculation

You can use a dbs file to restart a calculation. In fact, a dbs file is an input file itself. It contains the record **icontrol** which contains the last control index actually performed with the previous calculation. You can add more **control_*** records and start the file again; it will then continue with these new **control_*** records.

You cannot use dbs files with contain **control_repeat** for restarting a calculation.

9 Final topics (input trouble, save memory /CPU time, ...)

9.1 Environment symbols

Records with a length of 1, and no index, you can also set via an environment symbol. You need to use capital characters in doing so. Typical examples are

- **PROCESSORS 4**
- **PRINT_GID_CALCULATION -no**
- **PRINT_GMSH_CALCULATION -yes**
- **PRINT_NODE_GEOMETRY_PRESENT -yes**

In windows set environment symbols in your advanced system settings. In a linux bash shell set environment symbols in your .bashrc file (eg **export PROCESSORS=4**).

9.2 Checking your geometry_* records

Set **print_node_geometry_present -yes** and set **print_element_geometry_present -yes**. Then look with **gmsh** if the geometries are like you want.

9.3 Continuing an analysis

- Copy the database from the previous calculation to a new file, e.g. **new.dat**.
- Run a new calculation with **new.dat**.

This can also be done with a database that is written as indermediate database in a previous calculation, for example directly after gravity. See also **icontrol**.

9.4 Use -node as geometry entity.

As a special option you can use a node as a geometrical entity. For example the following imposes a boundary condition on the temperature of node 6:

bounda_dof 10 -node 6 -temp

Notice that **-node 6** is used in the format of a geometry entity.

9.5 Use -geometry_list as geometry entity.

As a special option you can use a list as a geometrical entity. For example the following imposes a boundary condition on the nodes of geometry list 6:

geometry_list 6 54 43 26 38 62
bounda_dof 10 -geometry_list 6 -temp

9.6 List input files with options

You can search for input files in your distribution which contain multiple words. For example change to the test/other directory. Suppose you want to see in which files you can see transient consolidation in a deforming soil.

In linux use the following command to list input file:
grep -il materi_velocity *.dat | xargs grep -il groundflow_capacity | xargs grep -il groundflow_consolidation.

In MS Windows use:
windows explorer - Search - Advanced options - File contents
and search for
materi_velocity AND groundflow_capacity AND groundflow_consolidation.

9.7 Geometrically linear material

Either do this:

- Initialise **-materi_velocity** and **-materi_displacement**
- Use **-total_linear** for the material.

or do this:

- Initialise **-materi_velocity** and **-materi_velocity_integrated**
- Use **-fixed_in_space** for **mesh**
- Use **-updated_linear** for the material.

9.8 Dynamic calculations

Dynamic calculations are triggered by setting **inertia_apply -yes**. Take care that you have specified all required data, like material density, etc.

In case you want to reduce numerical damping, you can use the following piece of input file, notice the **materi_dynamic**.

```
...
materi_displacement
materi_velocity
end_initia
...
inertia_apply -yes
materi_dynamic -yes
...
control_timestep ......
...
```

For heavy non-linear calculations this may converge worse than the default euler backward time integration.

To get damping similar to rayleigh damping in structural dynamics use:

```
...
group_materi_damping  ... (similar to rayleigh damping mass term, use
rayleigh alpha * material density )
group_materi_viscosity  ... (similar to rayleigh damping stiffness term, use
rayleigh beta * material young )
...
```

See also **materi_dynamic** to influence numerical damping in dynamic calculations with solid materials.

9.9 Input file syntax

- If you don't understand the syntax of an option, please look in the tochnog/test/other directory for example files. Under linux search for the command, eg **grep control_print_filter *.dat** to get example files with **control_print_filter**.

9.10 Check large calculations

- Set both **solver -none** and **linear_calculation_apply -yes** ; run and check in gid the boundary conditions, forces, change of element groups, etc. In a complex model you can check geometries that you use by imposing an artificial boundary on them, eg **bounda_dof ... -temp** with value 1, and look in gid if you see that boundary condition showing up at the correct nodes.
- Only set **linear_calculation_apply -yes** ; run and check linear solution fields.
- Do not set anything special ; run and check solution fields.

9.11 Diverging calculations

- Try the linear elements **-bar2**, **-quad4** , **-tria3**, **-hex8** and **-tet4** in stead of quadratic elements.
- Try **solver_matrix_save -no** (always setup new system matrix)
- Try **group_materi_plasti_mohr_coul_direct** i.s.o. **group_materi_plasti_mohr_coul**
- Try small fixed timesteps (do not use automatic time stepping).
- Try more iterations with **control_timestep_iterations**.
- Try a lower interface stiffness.
- Try higher water capacity in calculation with consolidation (so water less stiff, anyway not too stiff relative to soil)).
- Set **group_interface_materi_residual_stiffness** to 1.

9.12 Saving CPU time

- Check that the computer doesn't swap to disk (use top in linux, use task manager in windows). In case of swapping lower the memory usage (see the section 'Saving computer memory').
- For large calculations with many **post_*** commands: use **post_apply -no** and use **control_post_apply index -yes** only at the moment that you actually need post results

9.13 Saving computer memory

Try the following steps, in order of priority:

- **solver_matrix_symmetric -yes**.

- **solver -matrix_iterative_bicg**.
- Use **bounda_alternate**.
- If possible, don't use extreme large indices (since memory is allocated for all indices).

9.14 Inaccurate results

- Set the interface stiffness to about 10 times the neigbouring element young divided by the neighbour length.
- If a structure is submerged in water, eg a one-side submerged dam, you need to impose the correct pressure condition; but you also need to impose the water loading by a **force_edge_water**.

9.15 Element sides

This sections defines node numbers for element sides 0, 1, ... respectively.

For a **bar2** element the sides have the nodes numbers 0 and 1.

For a **tria3** element the sides have the nodes numbers 0,1 and 1,2 and 2,0.

For a **tria6** element the sides have the nodes numbers 0,1,2 and 0,3,5 and 2,4,5.

For quad elements the sides are in the order below, upper, left, right; see the pictures in **elements**.

For hex elements the sides are in the order below, upper, front, back, right, left; see the pictures in **elements**.

For a **tet4** element the sides have the nodes numbers 0,1,2 and 0,1,3 and 1,2,3 and 0,2,3.

For a **tet10** element the sides have the nodes numbers 0,1,2,3,4,5 and 0,1,2,6,7,9 and 2,4,5,7,8,9 and 0,3,5,6,8,9.

For a **prism6** element the sides have the nodes numbers 1,2,3 and 4,5,6 and 1,2,4,5 and 0,2,3,5 and 0,1,3,4.

For a **prism15** element the sides have the nodes numbers 0,9,1,11,10,2 and 3,12,4,14,13,5 and 0,9,1,6,7,3,12,4 and 1,10,2,7,8,4,13,5 and 0,11,2,6,8,3,14,5.

For a **prism18** element the sides have the nodes numbers 0,1,2,3,4,5 and 12,13,14,15,16,17 and 0,1,2,6,7,8,12,13,14 and 2,4,5,8,10,11,14,16,17 and 0,3,5,6,9,11,12,15,17.

9.16 Badly shaped elements

Each element should have at maximum one common side with a neigbouring element. For example two neigbouring quad4 elements have only one common side in a proper element mesh; if the neighbouring quad4 elements have two sides in common, the elements are badly shaped.

Some tochnog options will not work correctly if the mesh contains badly shaped elements.

9.17 Youtube

Tutorial movies can be found on **https://www.youtube.com/channel/UC7qvITX-SLwA4RuqMPYBmDQ**

9.18 External programs.

- **http://www.gidhome.com** Commercial pre- and postprocessor; easy. It can write for Tochnog input directly. It can read results both from **control_print_gid** and from **control_print_vtk**. See the **gid** directory in your distribution.
- **http://mecway.com** Commercial finite element program; easy. It can write for Tochnog **input_abaqus**. It can read results from **control_print_gmsh**.
- **http://www.gnuplot.info/** Free x-y plotter; easy. It can read results from **control_print_history** and **control_print_data_versus_data**.
- **http://gmsh.info** Free pre- and postprocessor; complex. It can write for Tochnog **input_abaqus**. It can read results from **control_print_gmsh**.
- **http://www.paraview.org** Free postprocessor; complex. It can read results from **control_print_vtk**.
- **http://www.freecadweb.org/** Free CAD program; complex. It can write for Tochnog **input_abaqus** and read results from **control_print_frd**.
- **http://lace.fs.uni-mb.si/wordpress/borovinsek/?page_id=41** Free prepomax pre- and postprocessor for MS Windows; easy. It can write for Tochnog **input_abaqus** and read results from **control_print_frd**. Isoparametric elements only.
- **http://www.bconverged.com/download.php** Free postprocessor CGX for MS Windows; easy. It can read results from **control_print_frd**.
- **https://www.mikepoweredbydhi.com/products/feflow** Dedicated ground water analysis program. Tochnog can read the mesh and hydraulic pressure heads with **input_feflow_***.
- **https://ngsolve.org/** Free preprocessor in 3D. Tochnog can read the nodes and elements.

9.19 Forces are setup in the element loop in timesteps

The records **force_edge**, **force_edge_normal**, **force_edge_projected**, **force_volume**, **condif_heat_edge_normal**, **condif_convection_edge_normal** and **condif_radiation_edge_normal** are evaluated inside the element loop. Hence, the resulting nodal forces only get their values after a timestep is performed (since the element loop is performed in time steps).

9.20 Running in a Microsoft windows bash shell

When you want to run the linux executable in a Microsoft windows bash shell you need to set the environment symbol KMP_AFFINITY to disabled. So do **export KMP_AFFINITY=disabled** in the windows bash shell.

10 User supplied subroutines

Several skeleton user supplied subroutines are available in the file **user.cpp**. As a special option you can use an ABAQUS **umat.f** (ABAQUS is a trademark of Dassault Systemes; see HTTP://www.abaqus.com for the ABAQUS homepage). See also **group_materi_umat** in this manual. We do not support any compilation, linking or run-time problems with user supplied routines.

We only have available **user.cpp** and **umat.f** on linux 64 bit.
We use ourselves the linux version specified in **linux_version.txt** file in the user supplied distribution. If you want to use the user supplied routines it is convenient to also use the same operating system in order to prevent compiling and linking problems; for this distribution the needed libraries are supplied.

If you insist on using another distribution than we do, you should install yourself the needed libraries (with commands like: sudo apt-get install gcc-7 g++-7). For the distribution of **linux_version.txt** the needed libraries are supplied.

Do the following:

- Download the **tochnog_linux_64_bit_user_supplied.tar.gz** distribution.
- In the user supplied distribution read **README_UMAT_USER.txt**
- In the user supplied distribution look in the **makefile** how to compile.

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