

Single phase media

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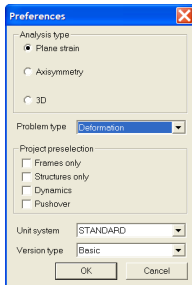
Outline of this lecture.

- ① Project preselection menu
- ② Obligatory and optional model components
- ③ Drivers
- ④ Material models for soils
- ⑤ Material models for rocks
- ⑥ Handling in situ effective stress state
- ⑦ Handling gravity load
- ⑧ Effective vs total stress analysis

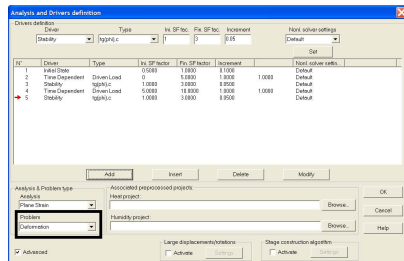


Setting options in preselection menu.

- **Deformation** mode can be set in the preselection dialog just on start or by invoking it from menu *Control/Project preselection*



- **Deformation** mode can be modified in the **Analysis & Drivers dialog** invoked from main menu *Control/Analysis & Drivers*





Obligatory and optional components of the model.

① Obligatory components:

- **Geometrical model** (mesh) [video](#)
- **Boundary conditions** (fixities+<loads>) [video](#)
- **Driver(s)** [video](#)
- **Material definition** (models+properties) [video](#)

② Optional components:

- **Load time functions** [video](#)
to handle evolution of loads/imposed displacements but also material properties in time
- **Existence functions** [video](#)
(associated with elements/boundary conditions) to handle excavation/stage construction
- **Initial conditions** [video](#)
to set in situ effective stress state in explicit manner
- **Data super-elements** [video](#)
to handle spatial variation of the data e.g. E modulus with depth

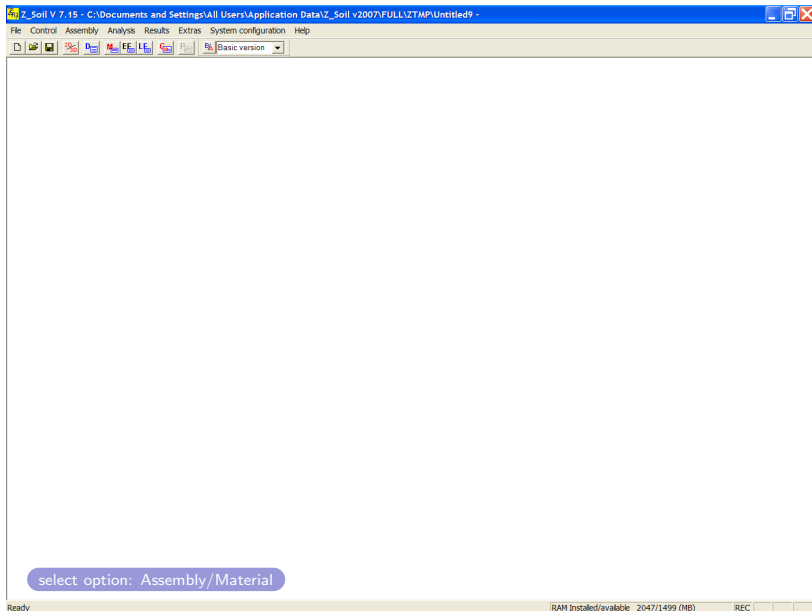


Drivers: General information.

- ① Drivers give an instruction to the program what is to be computed and in which order
- ② By default the **Initial State** driver is set up as the first and the only one in the list for execution (it always yields zero deformation !)
- ③ Available drivers:
 - **Initial state**
 - **Stability**
 - **Time Dependent**
 - **Pushover** ()
 - **Dynamics** ()

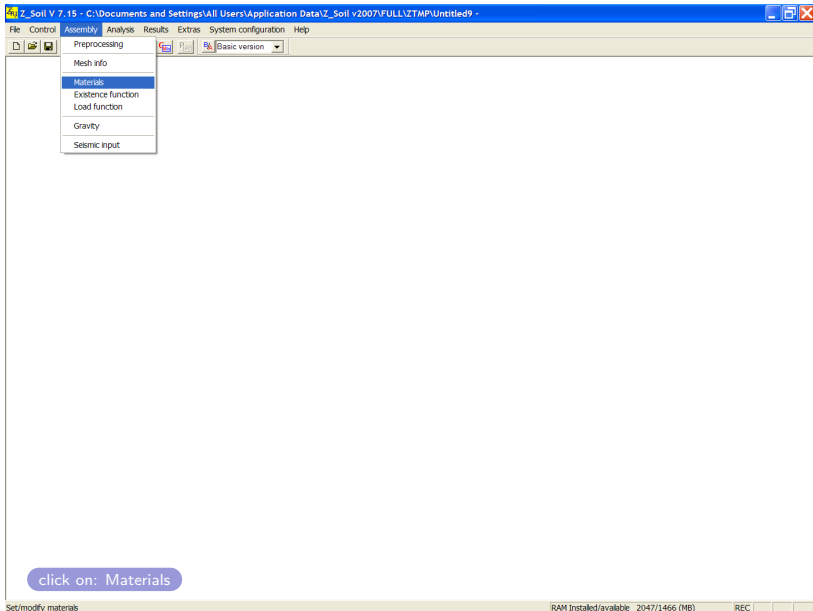


Structure types/Material formulations



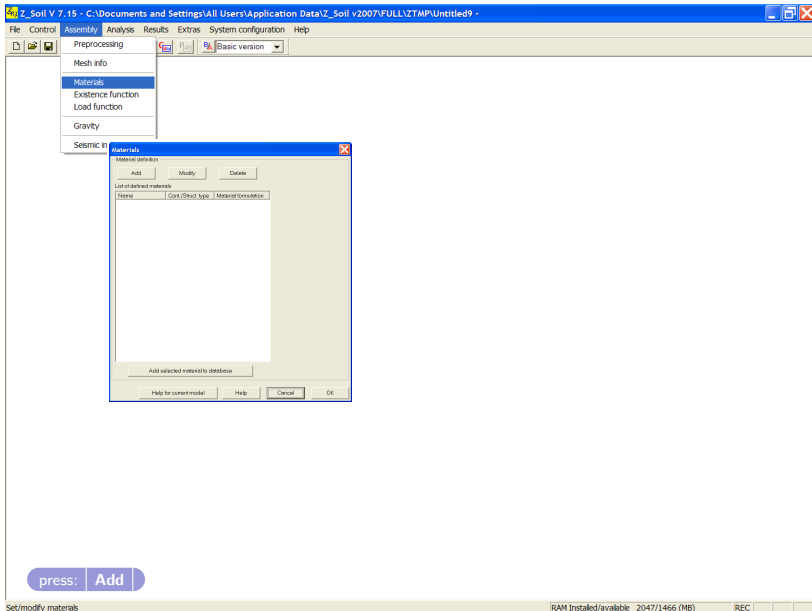


Structure types/Material formulations





Structure types/Material formulations





Structure types/Material formulations

Z_Soil V 7.15 - C:\Documents and Settings\All Users\Application Data\Z_Soil v2007\FULL\ZTMP\Untitled9 -

File Control Assembly Analysis Results Extras System configuration Help

Preprocessing Mesh info Materials Existence function Load function Gravity Seismic In

Materials

Material definition

Add Modify Delete

List of defined materials

Name	Cont./Struct. type	Material formulation
------	--------------------	----------------------

Add/update material

Number: 1 Name: No name

Continuum & structure type: Material formulation: Elastic

Take material from database

OK Cancel

Unroll combo box: Continuum & structure type

Set/modify materials RAM Installed/available: 2047/1466 (MB) REC



Structure types/Material formulations

Z_Soil V 7.15 - C:\Documents and Settings\All Users\Application Data\Z_Soil v2007\FULL\ZTMP\Untitled9 -

File Control Assembly Analysis Results Extras System configuration Help

Preprocessing Mesh info Materials Existence function Load function Gravity Seismic In

Materials

Material definition

Add Modify Delete

List of defined materials

Name	Cont./Struct. type	Material formulation
------	--------------------	----------------------

Add/update material

Number: 1 Name: No name

Continuum & structure type: Material formulation: Elastic

Material from database

OK Cancel

Continuum
Continuum for structures
Shells
Membranes
Beams
Truss
Continuum
Seepage
Heat convection
Humidity convection
Infinite media

Next slide

Set/modify materials RAM Installed/available 2047/1466 (MB) REC



Materials for continuum: common data groups

1 **Elastic**

2 **Unit weight**

3 **Flow/2D**

Flow/3D

4 **Creep**

5

Init. state K_0 (2D)

Init. state K_0 (3D)

6 **Heat**

7 **Humidity**

Obligatory

Material

Elastic parameters

Young modulus E 100000 [kN/m²]

Poisson ratio ν 0.3 []

OK

Cancel

Help

Data mode Standard

Next slide



Materials for continuum: common data groups

Obligatory

- 1 Elastic
- 2 Unit weight
- 3 Flow/2D
Flow/3D
- 4 Creep
- 5 Init. state K_0 (2D)
Init. state K_0 (3D)
- 6 Heat
- 7 Humidity

Unit weights / masses

Weight / unit volume	γ	19	[kN/m ³]	Mass / unit volume	ρ	1937.46080	[kg/m ³]
Multiplier for body forces		1		Multiplier for mass matrix		1	
Fluid weight / unit volume	γ_f	10	[kN/m ³]	Fluid mass / unit volume	ρ_f	1019.71621	[kg/m ³]
Initial void ratio	e_0	0					

Global gravity direction

N.B.
for deformation (single phase) analysis in total stresses specify the saturated specific weight γ_{sat} below the water table and the dry specific weight γ_D above;
in effective stress analysis specify buoyant weight $\gamma_b = \gamma_{sat} - \gamma_w$;
for deformation+flow (two-phase) specify γ_D (dry) and initial void ratio e_0 ;
 γ will be computed as $\gamma = \gamma_D + n S \gamma_w$; $n = e_0 / (1 + e_0)$; S - saturation ratio.

Data mode: Standard

OK Cancel Help

NB. Mass and body force multipliers visible only if Dynamics is activated in the project preselection

Next slide



Materials for continuum: common data groups

1 Elastic

2 Unit weight

3 Flow/2D

Flow/3D

4 Creep

5 Init. state Ko (2D)

Init. state Ko (3D)

6 Heat

7 Humidity

Next slide

Not meaningful for single-phase

2D Flow [X]

Fluid bulk modulus β_F 3.37e+038 [kN/m²]

Darcy's coefficient

Darcy's coefficient K_x 1 [m/day]

Darcy's coefficient K_y 1 [m/day]

Inclination angle <x',x> β 0 [deg]

Saturation

Residual saturation ratio S_r 0

Saturation constant α 2 [1/m]

Help OK Cancel

Data mode Standard [v] ☒ Advanced



Materials for continuum: common data groups

1 Elastic

2 Unit weight

3 Flow/2D

Flow/3D

4 Creep

5

Init. state K_0 (2D)

Init. state K_0 (3D)

6 Heat

7 Humidity

Not meaningful for single-phase

3D Flow [X]

Fluid bulk modulus [kN/m²]

Residual saturation S_r

Seepage alpha α [1/m]

Axis	k		Direction X	Direction Y	Direction Z
1	1	[m/day]	1	0	0
2	1	[m/day]	0	1	0
3	1	[m/day]	0	0	1

Data mode ☒ Advanced

Next slide



Materials for continuum: common data groups

- 1 Elastic
- 2 Unit weight
- 3 Flow/2D
Flow/3D
- 4 **Creep**
- 5 Init. state Ko (2D)
Init. state Ko (3D)
- 6 Heat
- 7 Humidity

Next slide

Optional

Power

Power

Exponential

Hyperbolic

Logarithmic

Swelling

Curve type : Power

Ad 0 [1/kN*m^2] Av 0 [1/kN*m^2]

Bd 0 Bv 0

Existence fct : 0 Existence fct : 0

Non linear creep

a 0

b 4

☒ Advanced

Help Ok Cancel



Materials for continuum: common data groups

1 Elastic

2 Unit weight

3 Flow/2D

Flow/3D

4 Creep

5

Init. state Ko (2D)

Init. state Ko (3D),

6 Heat

7 Humidity

Optional

Initial State Ko [2D] [X]

Value (0.0 ignore Ko)

Ko (x')

Ko (z)

Inclination angle <x',x> [deg]

☒ Advanced

Next slide



Materials for continuum: common data groups

- 1 Elastic
- 2 Unit weight
- 3 Flow/2D
Flow/3D
- 4 Creep
- 5 Init. state Ko (2D)
Init. state Ko (3D)
- 6 Heat
- 7 Humidity

Next slide

Optional

Initial State Ko [X]

Value (0.0 ignore Ko)

Ko (X1')

Ko (X3')

Ko principal Axis

Axis	Direction X	Direction Y	Direction Z
1	1	0	0
2	0	1	0
3	0	0	1

Help

Ok

Cancel



Materials for continuum: common data groups

- 1 Elastic
- 2 Unit weight
- 3 Flow/2D
Flow/3D
- 4 Creep
- 5 Init. state Ko (2D)
Init. state Ko (3D)
- 6 **Heat**
- 7 Humidity

Next slide

Optional

Heat

Solid thermal dilatancy **A** [1/C]

Fluid thermal dilatancy [1/C]

Heat transfer parameters **B**

Heat conductivity : [kN/day/C]

Heat capacity : [kN/m^2/C]

Source term

☒ Source term

H infinite for heat source : [kN/m^2]

a **C** [1/day]

Dormant time [day]

Q/R [C]

Reference temperature [C]

Database Help Ok Cancel

☒ Advanced

NB. For all models except **Aging concrete** only **Heat dilatancy** is meaningful for single-phase

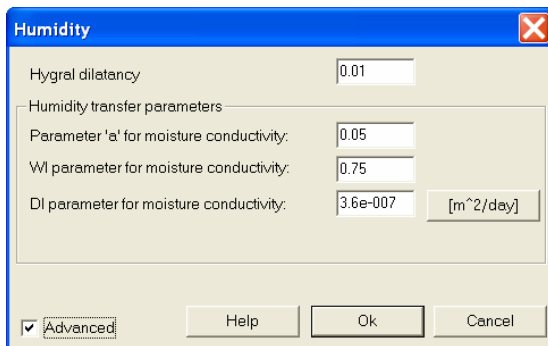


Materials for continuum: common data groups

- 1 Elastic
- 2 Unit weight
- 3 Flow/2D
Flow/3D
- 4 Creep
- 5 Init. state Ko (2D)
Init. state Ko (3D)
- 6 Heat
- 7 **Humidity**

Next slide

Optional



The image shows a software dialog box titled "Humidity" with a blue header bar and a close button (X) in the top right corner. The dialog contains several input fields and a checkbox. The "Hygral dilatancy" field has a value of 0.01. Below it, a section titled "Humidity transfer parameters" contains three more input fields: "Parameter 'a' for moisture conductivity" with a value of 0.05, "Wl parameter for moisture conductivity" with a value of 0.75, and "Dl parameter for moisture conductivity" with a value of 3.6e-007. To the right of the last field is a unit label "[m^2/day]". At the bottom left, there is a checked checkbox labeled "Advanced". To the right of the checkbox are three buttons: "Help", "Ok", and "Cancel".

Parameter	Value	Unit
Hygral dilatancy	0.01	
Parameter 'a' for moisture conductivity	0.05	
Wl parameter for moisture conductivity	0.75	
Dl parameter for moisture conductivity	3.6e-007	[m ² /day]

☒ Advanced

Help Ok Cancel

NB. For all models only **Hygral dilatancy** is meaningful for single-phase



Materials for continuum: soils (basic)

- 1 Elastic
- 2 Mohr-Coulomb

- Basic setup

Mohr-Coulomb

☐ Yield

Cohesion C 20 [kN/m²]

Friction angle φ 30 [deg]

☐ Plastic Flow

Dilatancy angle ψ 0 [deg]

☐ Advanced

Data mode Standard Help OK Cancel

- Advanced setup

Mohr-Coulomb

☐ Yield

Cohesion C 20 [kN/m²]

Friction angle φ 30 [deg]

☐ Cut off Rankine τ_r 0 [kN/m²]

☐ Plastic Flow

Dilatancy angle ψ 0 [deg]

☐ Dilatancy cut off

Maximum void ratio e_{max} 0

Initial void ratio e₀ 0

☒ Advanced

Data mode Standard Help OK Cancel

Remark: dilatancy cut-off ()



Materials for continuum: soils (advanced)

- 1 **Drucker-Prager**
- 2 **Cap**
- 3 **Cam-Clay**
- 4 **Duncan-Chang**
- 5 **ECP Hujeux** (only monotonic kernel)()

Remark: For plane-strain applications **Drucker-Prager** model will always yield same safety factors and bearing capacity as the standard Mohr-Coulomb model (plane-strain matching must be used)



Materials for continuum: concrete and rock

- 1 **Elastic**
- 2 **Aging concrete**
- 3 **Rankine** (through standard M-C model)
- 4 **Multilaminate**
- 5 **Hoek-Brown (M-W)**
- 6 **Mohr-Coulomb (M-W)**
- 7 **Rankine (M-W)**



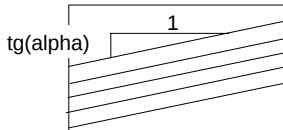
Materials for continuum: Multilaminate model

2D Multilaminate

alpha	phi	psi	cohesion	Cut-off	ft
alpha 1 [deg]	Phi 1 [deg]	Psi 1 [deg]	Cohesion 1 [kN/m ²]	Ft 1 [kN/m ²]	
Plane 1					
30	30	10	50	☒ 10	
Plane 2					
0	0	0	0	☐ 0	
Plane 3					
0	0	0	0	☐ 0	

Matrix material
☐ Advanced
☒ Mohr-Coulomb
☐ Rankine
☐ Hoek-Brown
Set parameters

Help OK Cancel



- 1 To deactivate weakness plane put zeros to all data
- 2 Switch to advanced mode to activate intact rock model



Materials for continuum: Hoek-Brown model

- Basic setup

Hoek-Brown parameters

Yield

Cmpr. Strength f_c 10 [kN/m²]

Tensile strength f_t 1 [kN/m²]

Eccentricity (e) e 0.52

☐ Cut-off Itc 0 [kN/m²]

☒ Advanced

Plastic Flow

☒ Deviatoric

☐ Drucker-Prager

☐ Tensile Meridian

☐ Hoek-Brown

Dilatancy angle 0 [deg]

Softening

☐ Softening

Crack opening at failure W_f 0.001 [m]

Constants

a 5

b 10

Help OK Cancel

- Advanced setup

Hoek-Brown parameters

Yield

Cmpr. Strength f_c 10 [kN/m²]

Tensile strength f_t 1 [kN/m²]

Eccentricity (e) e 0.52

☐ Cut-off Itc 0 [kN/m²]

☒ Advanced

Plastic Flow

☒ Deviatoric

☐ Drucker-Prager

☐ Tensile Meridian

☐ Hoek-Brown

Dilatancy angle 0 [deg]

Softening

☒ Softening

Crack opening at failure W_f 0.001 [m]

Constants

a 5

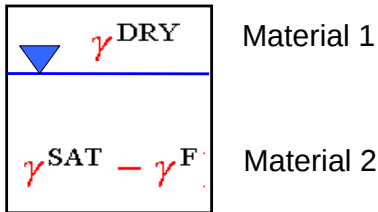
b 10

Help OK Cancel



Effective stress analysis: Simplified treatment of water

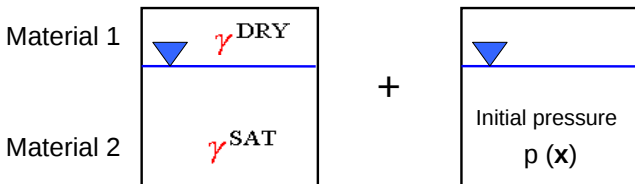
- Equilibrium: $\sigma'_{ij,j} + f_i = 0$
- A different treatment of the gravity is necessary above and below water table
- $f_i = \gamma^{\text{DRY}} b_i$ above water table
- $f_i = (\gamma^{\text{SAT}} - \gamma^{\text{F}}) b_i$ under water table
- Hence two material zones must be distinguished





Total stress analysis: Simplified treatment of water

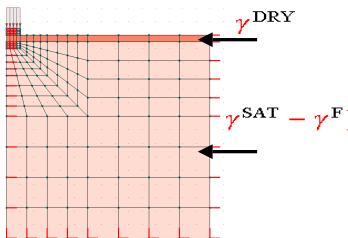
- Equilibrium: $\left(\sigma'_{ij} + \delta_{ij} p \right)_{,j} + f_i = 0$
- A different treatment of the gravity is necessary above and below water table
- $f_i = \gamma^{\text{DRY}} b_i$ above water table
- $f_i = \gamma^{\text{SAT}} b_i$ under water table
- Hence again two material zones must be distinguished



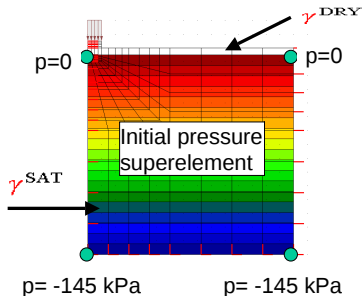


Effective/total stress analysis: Examples

Effective stress: footes.inp



Total stress: footwt.inp



video

- Remark: Both approaches are equivalent

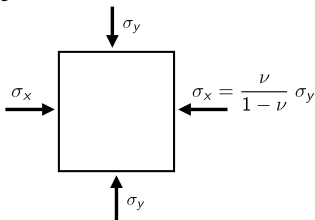


Handling in situ stress: General

Two different approaches can be used

- ① **(A)** Running the **Initial state** driver with optionally additional constraint put on K_o^{insitu}
 - **(A1)** with explicit setting of σ_o as the initial guess
 - **(A2)** without explicit setting of σ_o
- ② **(B)** Explicit setting of σ_o

Note that the initial state computation without prescribed value of K_o^{insitu} will yield



ex. $\nu = 0.2$ will yield

$$K_o^{insitu} = 0.25$$

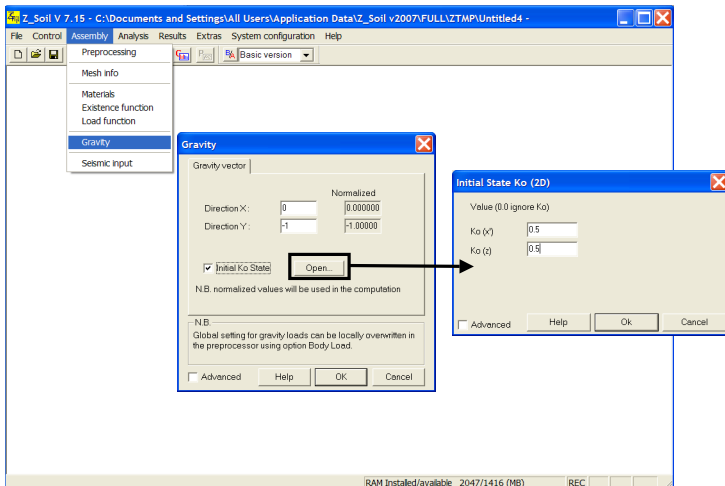
which can be far below the real value



Handling in situ stress: Handling K_o^{insitu} constraint

The K_o^{insitu} constraint is meaningful only for approach (A)

- 1 K_o^{insitu} can be set globally (for all continuum materials)

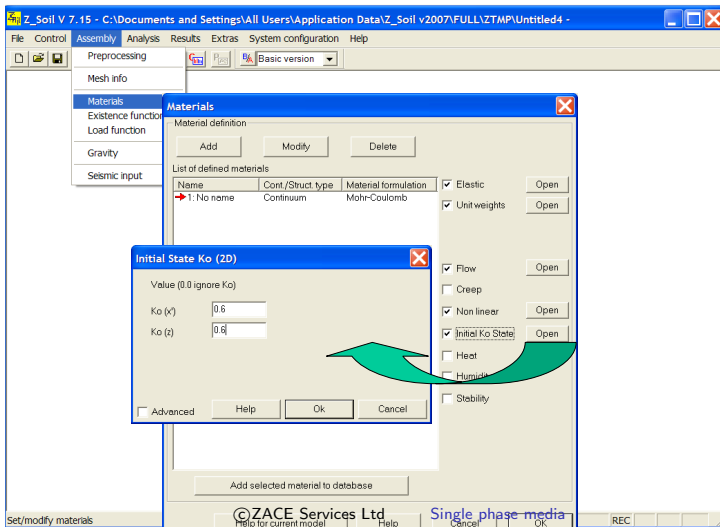




Handling in situ stress: Handling K_o^{insitu} constraint (cont..)

The K_o^{insitu} constraint is meaningful only for approach (A)

- 1 K_o^{insitu} can also be set locally (for all continuum materials)





Handling in situ stress: K_o^{insitu} constraint: Remarks

- 1 For normally consolidated soils or sands we can make use of simplified Jaky formula $K_o^{insitu} = K_o^{NC} = 1 - \sin(\phi)$
- 2 This setting is important in soil structure interaction problems
- 3 Global setting for K_o^{insitu} applies this constraint to all continuum materials
- 4 Local setting for K_o^{insitu} overwrites the global one for the specific material (can be done only at the material level);
- 5 Setting $K_{ox}^{insitu} = 0.0$ and $K_{oz}^{insitu} = 0.0$ cancels the constraint
- 6 In approach **(A)** final initial stresses may differ from the ones specified by the user



Handling gravity loads: option Gravity vector

The screenshot shows the 'Gravity' dialog box with the 'Gravity vector' tab selected. The 'Body load components' section is active, showing 'Direction X' as 0, 'Direction Y' as -1, and 'Direction Z' as 0. The 'Normed values' section shows 0.000000 for X, -1.000000 for Y, and 0.000000 for Z. The 'Initial Ko State' checkbox is checked, and the 'Open...' button is visible. A note at the bottom states: 'N.B. normed values will be used in the computation'.

The screenshot shows the 'Gravity' dialog box with the 'Body load components' tab selected. The 'LTF' section is active, showing 'Direction X' as 0, 'Direction Y' as -1, and 'Direction Z' as 0. The 'Initial Ko State' checkbox is checked, and the 'Open...' button is visible. A note at the bottom states: 'N.B. Global setting for gravity loads can be locally overwritten in the preprocessor using option Body Load'.

- Using this definition user may declare gravity vector $\bar{\mathbf{b}}$ (default is $(0,-1,0)$)
- This vector $\bar{\mathbf{b}}$ is used to compute current body load vector $\mathbf{b} = \gamma \bar{\mathbf{b}}$ at each finite element



Handling gravity loads: option **Body load** components

- Option visible in the ☒ **Advanced** mode
- Using this definition user may declare gravity vector $\bar{\mathbf{b}}$ (default is (0,-1,0)) plus load time functions independently for all directions
- In this case gravity direction vector is not normalized
- Vector $\bar{\mathbf{b}}$ is used to compute current body load components $b_i = \gamma \bar{b}_i LTF_i(t)$ at each finite element



Handling gravity loads: Remarks

- 1 Body load definition may be overwritten, at the element level, during preprocessing session, using option `Body load`
- 2 For pseudo-seismic stability analysis the option `Body load components` has to be used (for instance in 2D models one may assume $\bar{\mathbf{b}} = (0.1, -1.0)$)