DISROC

Materials Catalogue

General Notation

For each material type, the code is composed of 5 digits:

The first digit is 1, 2,3, 4 for designating the elements nature:
- 1 for bar elements,
- 2 for joint elements (interfaces, cracks and fractures),
- 3 for surface elements (bulk materials),
- 4 for bolt elements.

This second digit is 1 or 2 to designates the phenomena which is concerned:
- 1 for Mechanics,
- 2 for Hydraulics.

The other 3 digits define the constitutive model.

For each material constitutive model, first the number of parameters, Nb, and then the values of the Nb parameters are specified.

I) Mechanics

I.1) Mechanics - **BARS**

11100 : Linear elastic bar element

Nb = 1
Param1 = E_s (The product $E \times S$ of the Young modulus and the section of the bar. Dimension : force)

Constitutive Relation : $F = E_s \, \varepsilon$
F : axial force
ε : axial deformation

11110 : Linear elastic-plastic bar element

Nb = 2
Param1 = E_s (Product $E \times S$ of the Young modulus and the section of the bar. Dimension : force)
Param2 = Y_s (Product $\sigma_y S$, limit elastic force)

Constitutive Relation : $F = E_s \, (\varepsilon - \varepsilon^p)$
$d\varepsilon^p = 0$ if $\sigma < Y_s$ or if $\sigma = Y_s$ and $d\sigma < 0$
F : axial force
ε : axial deformation
ε^p : axial plastic deformation

I.2) Mechanics - **ROCKJOINTS & FRACTURES**

21100 : Linear elastic joint

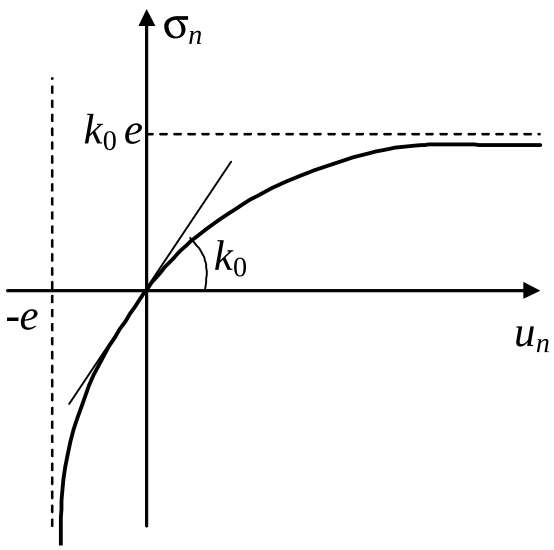
Constitutive Relation : $\underline{\sigma} = \boldsymbol{K} \, \underline{u}$,
$$\begin{pmatrix} \tau \\ \sigma_n \end{pmatrix} = \begin{bmatrix} K_t & K_{tn} \\ K_{nt} & K_n \end{bmatrix} \begin{pmatrix} u_t \\ u_n \end{pmatrix}$$

Nb = 3
Param1 = K_t (tangent stiffness)
Param2 = K_n (normal stiffness)
Param3 = $K_{nt} = K_{tn}$ (non diagonal stiffness term, defining dilatancy)

21200 : Non linear hyperbolic elastic

The closure displacement is limited by the initial thickness e of the interface. The stress tends to infinity when closure displacement u_n tends to $-e$ and to $k_0 e$ for great positive openings:

$$\sigma_n = \frac{k_0 u_n}{1 + u_n / e}$$



The tangent behavior is linear:

$$\begin{cases} \sigma_t = k_t u_t + k_{nt} u_n \\ \sigma_n = k_{nt} u_t + \dfrac{k_0 u_n}{1 + u_n / e} \end{cases}$$

The normal stiffness k_n is u_n-dependant and given by:

$$k_n = \frac{k_0}{1 + u_n / e}$$

Nb = 4
Param1 = K_t (tangent stiffness)
Param2 = k_0 (normal stiffness)
Param3 = $K_{nt} = K_{tn}$ (non diagonal stiffness term causing dilatancy)
Param4 = e (maxium closure or physical thickness of the interface)

21120 : Linear elastic with Mohr-Coulomb plasticity

$$\underline{\sigma} = \boldsymbol{K} (\underline{u} - \underline{u}^p)$$

Elasticity: The mdoel 21100
Plasticity : Mohr-Coulomb criterion:

$$f(\underline{\sigma}) = |\tau| + \sigma_n \tan\phi - c \le 0$$

Nb = 5
Param1 = K_t
Param2 = K_n
Param3 = $K_{nt} = K_{tn}$
Param4 = c (cohesion)
Param5 = ϕ (in degrees, the friction angle)

21220 : Non linear Bandis elasticity with Mohr-Coulomb plasticity

$$\underline{\sigma} = \boldsymbol{K} (\underline{u} - \underline{u}^p)$$

Elasticity: The mdoel 21200
Plasticity : Mohr-Coulomb criterion:

Nb = 6
Param1 = K_t
Param2 = k_0
Param3 = $K_{nt} = K_{tn}$
Param4 = e
Param5 = c
Param6 = ϕ (degrees)

I.3) Mechanics - **MATERIALS**

31100 : Linear elastic and isotropic material

Nb = 2
Param1 = E (Young’s modulus)
Param2 = ν (Poissson’s ratio)

31101 : Linear elastic and isotropic material with weight forces

Lineair elastic and isotropic model for a problem with volume forces (gravity or seismic acceleration forces)

Nb = 3
Param1 = E (Young’s modulus)
Param2 = ν (Poissson’s ratio)
Param3 = ρ (specific mass)

31110 : Elastic-plastic isotropy with Drucker-Pragar criterion

$$\dot{\boldsymbol{\varepsilon}} = \dot{\boldsymbol{\varepsilon}}^e + \dot{\boldsymbol{\varepsilon}}^p$$

Linear elasticity with parameters *E* and ν (see the model 31100)

Plasticity with Drucker-Prager criterion : $F(\boldsymbol{\sigma}) = \gamma I_1 + \sqrt{J_2} - K$

$$I_1 = \sigma_{ii}\ , \quad S_{ij} = \sigma_{ij} - \frac{1}{3}\sigma_{kk}\delta_{ij}\ , \quad J_2 = \sqrt{\frac{1}{2} S_{ij} S_{ij}}$$

γ and *K* are two material constants.

Nb = 4

Param1 = *E*

Param2 = ν

Param3 = γ

Param4 = *K*

31111 : Elastic-plastic isotropy with Drucker-Prager criterion, weight

Linear elasticity with parameters *E* and ν (see the model 31100), and Plasticity with Drucker-Prager criterion (see the model 31110) and weight forces

Nb = 5

Param1 = *E*

Param2 = ν

Param3 = γ

Param4 = *K*

Param5 = ρ (specific mass)

31120 : Elastic-plastic isotropic material with Mohr-Coulomb criterion

$$\dot{\boldsymbol{\varepsilon}} = \dot{\boldsymbol{\varepsilon}}^e + \dot{\boldsymbol{\varepsilon}}^p$$

Linear elasticity with parameters *E* and ν (see the model 31100)

Plasticity with Mohr-Coulomb criterion:

$$F(\boldsymbol{\sigma}) = \frac{\sigma_1 - \sigma_3}{2} + \frac{\sigma_1 + \sigma_3}{2}\sin\phi - C\cos\phi \ \leq\ 0\ , \text{ where } \quad \sigma_1 \geq \sigma_2 \geq \sigma_3 \text{ principal stresses.}$$

(In Disroc, compressions are negative, and the above model is equivalent to Soil Mechanics convention, where compressions are positive, and then the Mohr-Coulomb criterion reads

$$F(\boldsymbol{\sigma}) = \frac{\sigma_1 - \sigma_3}{2} - \frac{\sigma_1 + \sigma_3}{2}\sin\phi - C\cos\phi \ \leq\ 0\ , \text{ where } \sigma_1 \geq \sigma_2 \geq \sigma_3 \text{ principal stresses).}$$

Nb = 4

Param1 = *E*

Param2 = ν

Param3 = *C*

Param4 = ϕ

31121 : Elastic-plastic isotropic material with Mohr-Coulomb criterion, weight

Linear elasticity with parameters E and ν (see the model 31100)
Plasticity with Mohr-Coulomb criterion (see the model 31120)

Nb = 5
Param1 = E
Param2 = ν
Param3 = C
Param4 = ϕ
Param5 = ρ (specific mass)

31130 :Viscoelastic isotropic material : Linear elasticity and Norton-Hoff creep law

$$\dot{\boldsymbol{\varepsilon}} = \dot{\boldsymbol{\varepsilon}}^e + \dot{\boldsymbol{\varepsilon}}^v$$

$$\dot{\boldsymbol{\varepsilon}}^e = \frac{1+\nu}{E}\dot{\boldsymbol{\sigma}} - \frac{\nu}{E} tr(\dot{\boldsymbol{\sigma}})\,\boldsymbol{\delta}\,, \qquad \dot{\boldsymbol{\varepsilon}}^v = \frac{3}{2} a \left(\frac{\sigma_e}{\sigma_0}\right)^n \frac{1}{\sigma_e}\,\mathbf{s}$$

With the Mises equivalent stress $\sigma_e = \sqrt{3J_2}$, $J_2 = \frac{1}{2} s_{ij} s_{ij}$, **s** stress deviator

The parameter a is deduced from uniaxial creep law: $\dot{\varepsilon} = a \left(\frac{\sigma_e}{\sigma_0}\right)^n$

σ_0 is a reference stress. The auxiliary parameter is defined by: $a' = a\left(\frac{1}{\sigma_0}\right)^n$ then:

$$\dot{\boldsymbol{\varepsilon}}^v = \frac{3}{2} a' \sigma_e^{\,n-1}\,\mathbf{s}$$

Nb = 4
Param1 = E
Param2 = ν
Param3 = a' $= a/(\sigma_0)^n$ (attention to the stress unity)
Param4 = n

31131 : Viscoelastic isotropic material : Linear elasticity and Norton-Hoff creep law, weight

The same model 31130 with mass.
Nb = 5
Param1 = E
Param2 = ν
Param3 = a' $= a/(\sigma_0)^n$ (attention l’effet de l’unité de contrainte)
Param4 = n
Param5 = ρ (masse volumique)

31200 : Linear Elasticity with General Anisotropy

In 2D plane problems, $\varepsilon_{13}= \varepsilon_{23}= \sigma_{13}= \sigma_{23}=0$, and the Hook law reduces to :

$$\begin{bmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \sigma_{12} \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & c_{13} & c_{16} \\ & c_{22} & c_{23} & c_{26} \\ & & c_{33} & c_{36} \\ & & & c_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \varepsilon_{33} \\ 2\varepsilon_{12} \end{bmatrix}$$

The elastic parameters, in the more general case of anisotropy are the 10 followings:

Nb = 10
Param1 = c_{11}, Param2 = c_{12}, Param3 = c_{13}, Param4 = c_{16},
Param5 = c_{22}, Param6 = c_{23}, Param7 = c_{26},
Param8 = c_{33}, Param9 = c_{36},
Param10= c_{66}

31201 : Linear Elasticity with General Anisotropy, weight forces

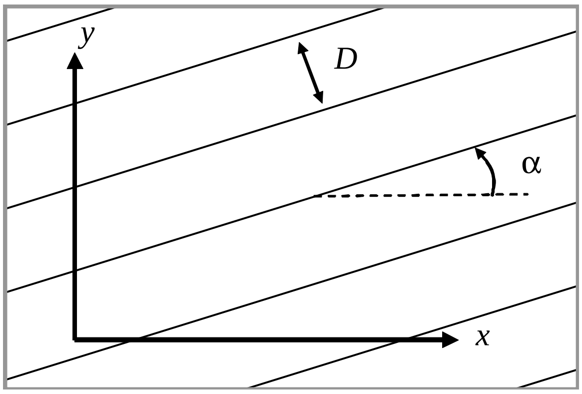
In 2D plane problems, $\varepsilon_{13}= \varepsilon_{23}= \sigma_{13}= \sigma_{23}=0$, and the Hook law reduces to :

$$\begin{bmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \sigma_{12} \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & c_{13} & c_{16} \\ & c_{22} & c_{23} & c_{26} \\ & & c_{33} & c_{36} \\ & & & c_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \varepsilon_{33} \\ 2\varepsilon_{12} \end{bmatrix}$$

The elastic parameters, in the more general case of anisotropy are the 10 followings:

Nb = 11
Param1 = c_{11}, Param2 = c_{12}, Param3 = c_{13}, Param4 = c_{16},
Param5 = c_{22}, Param6 = c_{23}, Param7 = c_{26},
Param8 = c_{33}, Param9 = c_{36},
Param10= c_{66}
Param11 = ρ (specific mass)

31400 : Effective Elastic model (homogenized) for fractured rockmass



Nb = 6
Param1 = E (Young’s modulus of the intact rock)
Param2 = ν (Poisson’s ration of the intact rock)
Param3 = K_n (normal stiffness of fractures)
Param4 = K_t (tangent stiffness of fractures)
Param5 = D (fractures spacing)
Param6 = α (fractures inclination, degrees)

31401 : Effective Elastic model (homogenized) for fractured rockmass, weight forces

Elasticity : the same model that 31400
+ weight forces
Nb = 7
Param1 = E
Param2 = ν
Param3 = K_n
Param4 = K_t
Param5 = D
Param6 = α
Param7 = ρ (specific mass)

31410 : Effective Elastic model (homogenized) for fractured rockmass + Drucker-Prager plastic criterion

$$\dot{\boldsymbol{\varepsilon}} = \dot{\boldsymbol{\varepsilon}}^e + \dot{\boldsymbol{\varepsilon}}^p$$

$$F(\boldsymbol{\sigma}) = \sqrt{J_2} + \gamma I_1 - K$$

Elasticity : the same model that 31400
Plasticity : the same model that 31110

Nb = 8
Param1 = E
Param2 = ν
Param3 = K_n
Param4 = K_t
Param5 = D
Param6 = α
Param7 = γ
Param8 = K

31411 : Effective Elastic model (homogenized) for fractured rockmass + Drucker-Prager plastic criterion + weight forces

$$\dot{\boldsymbol{\varepsilon}} = \dot{\boldsymbol{\varepsilon}}^e + \dot{\boldsymbol{\varepsilon}}^p$$

$$F(\boldsymbol{\sigma}) = \sqrt{J_2} + \gamma I_1 - K$$

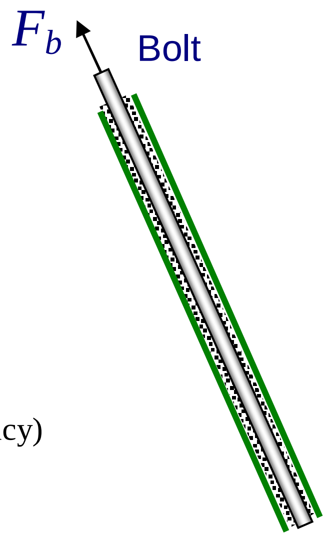
Elasticity : the same model that 31400
Plasticity : the same model that 31110

Nb = 9
Param1 = E
Param2 = ν
Param3 = K_n
Param4 = K_t
Param5 = D
Param6 = α
Param7 = γ
Param8 = K
Param9 = ρ (specific mass)

I.4) Mechanics - **BOLTS**

41100 : Prestressed Elastic Rock Bolt

Axial deformation of the bolt rod: $\varepsilon = \dfrac{F_b - F_0}{ES}$



F_b axial force in the bolt,
F_0 prestress axial force,

Elastic contact between bolt and rock : $\underline{\sigma} = \boldsymbol{K}\, \underline{u}$
(the same model 21100)

Nb = 5
Param1 = ES (Young's modulus (steel) × section)
Param2 = K_t (tangent stiffness)
Param3 = K_n (normal stiffness)
Param4 = $K_{nt} = K_{tn}$ (non diagonal stiffness term causing dilatancy)
Param5 = F_0 (prestress force)

41110 : Prestressed Elastic-Plastic Rock Bolt

Axial deformation of the bolt rod: $\varepsilon - \varepsilon^p = \dfrac{F_b - F_0}{ES}$

In monotonic loading $\varepsilon^p < 0$ if $F_b < Y_s$ where:
$Y_s = \sigma_y S$ with σ_y the plastic limit stress of the rod (steel) and S the bolt rod section

Contact between bolt and rock : $\underline{\sigma} = \boldsymbol{K}\,(\underline{u} - \underline{u}^p)$
Plastic criterion for bolt-rock contact: $f(\underline{\sigma}) = |\tau| + \sigma_n \tan\phi - c \le 0$

Contact model: the same that the model 21120

Nb = 8
Param1 = ES (Young's modulus (steel) × section)
Param2 = K_t (tangent stiffness)
Param3 = K_n (normal stiffness)
Param4 = $K_{nt} = K_{tn}$ (non diagonal stiffness term causing dilatancy)
Param5 = Y_s (plastic limite for the axial force in the bolt)
Param6 = c (cohesion)
Param7 = ϕ (in degrees, the friction angle)
Param8 = F_0 (prestress force)

II) Hydraulic

II.1) Hydraulic - ROCKJOINTS & FRACTURES

22100 : Hydraulic rock joint, *infinite* transverse conductivity

Constitutive law: $q = -C_t \nabla p$

q : debit in the fracture, ∇p : fluid pressure gradient along the fracture line

Nb = 1
Param1 = C_t (tangent conductivity)

22200 : Hydraulic rock joint, *finite* transverse conductivity

Nb = 2
Param1 = C_t (tangent conductivity)
Param2 = C_n (transverse or normal conductivity)

II.2) Hydraulic - MATERIALS

32100 : Darcy flow with isotropic permeability

Constitutive law: $\underline{v} = -k \,\underline{\nabla p}$

v : fluid velocity in the porous material , $\underline{\nabla p}$: fluid pressure gradient vector

Nb = 1
Param1 = k (permeability)

32200 : Darcy flow with anisotropic permeability

Constitutive law: $\underline{v} = -\boldsymbol{k} \,\underline{\nabla p}$

v : fluid velocity in the porous material , $\underline{\nabla p}$: fluid pressure gradient vector

Nb = 3
Param1 = k_{xx}
Param2 = k_{yy}
Param3 = $k_{xy} = k_{yx}$