

Modified LUBBY2 – MODEL

Description

The LUBBY2-model is a creep law including the primary and secondary creep rate. It was developed to simulate creep in salt. Two different approaches are implemented: a strain – hardening and a time-dependent hardening approach.

A detailed description is given in the following publications:

Lux, K.-H. (1984): Gebirgsmechanischer Entwurf und Felderfahrungen im Salzkavernenbau. Stuttgart: Ferdinand Enke Verlag (Germany).

Lux, K.-H., Düsterloh, D., Hou, Z.: Increasing the Profitability of Storage Cavities by Improvement of the Dimensioning Concept including CDM, Technical paper at the Fall Meeting 2001, Solution Mining Research Institute, Albuquerque, New Mexico, USA ‘Solution Mining Research Institute’
(www.solutionmining.org/M01F/Hou%20-%20M01F%20Meeting%20Paper.pdf)

Mathematical formulation

Strain-hardening approach:

$$\dot{\underline{\mathbf{e}}}^V = \frac{3}{2} \cdot \left[\frac{1}{\underline{\mathbf{h}}_K} \cdot \left(1 - \frac{\underline{\mathbf{e}}_V^t}{\underline{\mathbf{s}}_V} \cdot \overline{G}_K^* \right) + \frac{1}{\underline{\mathbf{h}}_M} \right] \cdot \underline{M}_2 \cdot \underline{\mathbf{s}}$$

Time-hardening approach:

$$\dot{\underline{\mathbf{e}}}^V = \frac{3}{2} \cdot \left[\frac{1}{\underline{\mathbf{h}}_K} \cdot \exp\left(-\frac{\overline{G}_K}{\underline{\mathbf{h}}_K}\right) + \frac{1}{\underline{\mathbf{h}}_M} \right] \cdot \underline{M}_2 \cdot \underline{\mathbf{s}}$$

The Matrix \underline{M}_2 is defined as

$$\underline{M}_2 = \begin{bmatrix} 2/3 & -1/3 & -1/3 & 0 & 0 & 0 \\ -1/3 & 2/3 & -1/3 & 0 & 0 & 0 \\ -1/3 & -1/3 & 2/3 & 0 & 0 & 0 \\ 0 & 0 & 0 & 2 & 0 & 0 \\ 0 & 0 & 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 2 \end{bmatrix}$$

The viscosity functions are defined as follows:

$$\underline{\mathbf{h}}_M = \underline{\mathbf{h}}_M^* \cdot e^{m \cdot \underline{\mathbf{s}}_V} \cdot e^{l_0 \cdot T}$$

$$\underline{\mathbf{h}}_K = \underline{\mathbf{h}}_K^* \cdot e^{k_2 \cdot \underline{\mathbf{s}}_V}$$

$$\overline{G}_K = G_K^* \cdot e^{k_1 \cdot \underline{\mathbf{s}}_V}$$

$\underline{\dot{\epsilon}}^V$ is the viscoplastic deformation rate, \mathbf{S} the stress tensor, \mathbf{S}_V the reference stress, t the time, T the temperature, $\mathbf{h}_K, \mathbf{h}_K^*$ are the Kelvin viscosities, $\mathbf{h}_M, \mathbf{h}_M^*$ are the Maxwell viscosities, \bar{G}_K, \bar{G}_K^* are the Kelvin shear modules, k_1, k_2, m, l_0 are constants.

Either the strain-hardening or the time-dependent hardening approach can be selected by setting one of the properties SHardening or THardening to one. The deselected parameter will automatically be set to zero.

Input parameters

Property name	Description	Description in literature	Typical data set (exemplary)	Modifiable
Gk_0	Initial Kelvin shear modulus	\bar{G}_M^*	8,000 MPa	x
etaK_0	Initial Kelvin viscosity	\mathbf{h}_K^*	16667 MPa * day	x
etaK	Kelvin viscosity	\mathbf{h}_K		
etaM_0	Initial Maxwell viscosity	\mathbf{h}_M^*	1.2167e6 MPa * day	x
etaM	Maxwell viscosity	\mathbf{h}_M		
k1		k_1	-0.122 MPa ⁻¹	x
k2		k_2	-0.161 MPa ⁻¹	x
m0		m	-0.2542 MPa ⁻¹	x
n1		n_1	-3.2	x
n2		n_2	3.01	x
l0		l_0	0.0	x
SHardening	Switch for strain-hardening			x
THardening	Switch for time-dependent hardening			x
t_creep	creep time	t_{cr}		
s_eff	reference stress	σ_V		

Practical hints

- The creep and the thermal option are necessary to use the LUBBY2 constitutive model.

Included documents / files

Name	Type	Description
Lubby_1.dat	Flac ^{3D} – Input-File	Single-element test, time-dependent hardening under compression with load cycles
Lubby_2.dat	Flac ^{3D} – Input-File	Single-element test, strain hardening under compression with load cycles
Lubby_3.dat	Flac ^{3D} – Input-File	Single-element test, time-dependent hardening

		under shear loading with load cycles
Lubby_4.dat	Flac ^{3D} – Input-File	Single-element test, strain hardening under shear loading with load cycles
set_bc.fis	Flac ^{3D} – Input-File	Boundary conditions
set_prop.fis	Flac ^{3D} – Input-File	Material properties
history.fis	Flac ^{3D} – Input-File	Histories
Lubby.dll	Dynamic Link Library	Contains the Lubby2 constitutive model

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