COMP011 – Thermomechanical validation of the laws for the concrete

Summary

This test makes it possible to validate the taking into account of the temperature variation in the laws of behavior for the concrete. These tests make it possible to check the two following points:

- Thermal dilation is well calculated (with taking into account of the variation of thermal dilation with the temperature)
- The variation of the coefficients material with the temperature is correct, in particular in the incremental resolution of the behavior,

The laws of behaviors validated are the following ones:

- Modeling a: this modeling makes it possible to validate the model BETON_REGLE_PR ,
- Modeling b: this modeling makes it possible to validate the model MAZARS ,
- Modeling C: this modeling makes it possible to validate the model BETON_UMLV_FP ,
- Modeling D: this modeling makes it possible to validate the model BETON_DOUBLE_DP .
- Modeling E: this modeling makes it possible to validate the model ENDO_ISOT_BEYOUR .
- Modeling F: this modeling makes it possible to validate the model BETON_BURGER_FP .

1 Methodology

It is about a double simulation, the first into thermomechanical, the second in pure mechanics. The first will be validated in comparison with the second, by supposing of course that the behavior tested provides a correct solution in pure mechanics.

1.1 Simulation 1

The first simulation (thermomechanical solution which one seeks to validate) consists in applying a temperature variation to a material point, by blocking the deformations according to x : $\varepsilon_{xx}=0$. The imposed temperature is increasing linearly according to time. The temperature varies $T_0=20°C$ with $T_{max}=500°C$. The transient is made up of `NCAL` pas.La temperature of reference is of $T_{réf}=20°C$.

1.2 Simulation 2

The second simulation (which must be equivalent to the first) consists in applying to the same material point a deformation imposed according to x : $\varepsilon_{xx}=-\varepsilon^{th}=-\alpha(T)(T-T_{ref})$, in pure mechanics. With each calculation i , the imposed loading is made up by the thermal deformation $\varepsilon_{xx}=-\varepsilon_{th}=-\alpha(T)(T_i-T_{réf})$. The initial loading is made up by the strains, stresses and internal variables of preceding mechanical calculation.

Indeed, for any behavior (while supposing the additive decomposition of the deformations):
$\sigma_{xx}=E(T)(\varepsilon_{xx}-\varepsilon^{th}-\varepsilon_{xx}^{p})$

in the first case, $\sigma_{xx}=E(T)(0-\varepsilon^{th}-\varepsilon_{xx}^{p})$, and in the second: $\sigma_{xx}=E(T)(\varepsilon-\varepsilon_{xx}^{p})$.

It is thus enough, at every moment to apply, for mechanical calculation, $\varepsilon_{xx}=-\varepsilon^{th}=-\alpha(T)(T-T_{ref})$.

Moreover, to get the same results in both cases, it is necessary, with each step of time of the second simulation, to carry out pure mechanical calculation with coefficients whose values are interpolated according to the temperature at the current moment. This interpolation is carried out in the command file of the test, in a loop in time external with `STAT_NON_LINE` .

2 Interpretation of the results

It is a question of checking that the result obtained at every moment mechanical transient thermo of the first simulation is identical to the result got with the second simulation.

The validation is done by the comparison between the computed fields with each step of the transient on the one hand and the result of a mechanical calculation on the other hand, Lhas value of reference being the component of the field extracted to a given moment i the first thermomechanical simulation carried out on `NCAL` moments. The computed value is that obtained at the end of mechanical calculation $i+1$ loop on `NCAL`.

3 Modeling A

3.1 Law of behavior and parameters materials

The law of behavior tested is ' BETON_REGLE_PR ', is documented in documentation [U4.43.01]. This law of concrete behavior is known as "right-angled parabola".

The elastic parameters are the following:

$E(T)$, $\nu(T)$ and $\alpha(T)$

The elastoplastic parameters are the following:

E_T , σ_y^t , σ_y^c , ε_C and n

Values of the parameters used

Parameters	$T=20°C$	$T=500°C$
$E(T)$	$30\,000.MPa$	$10\,000.MPa$
$\nu(T)$	$0.$	$0.$
$\alpha(T)$	$0.5\times10^{-5}K^{-1}$	$0.8\times10^{-5}K^{-1}$
E_T	$-10\,000.MPa$	$-10\,000.MPa$
σ_y^t	$3.MPa$	$3.MPa$
σ_c^t	$30.MPa$	$30.MPa$
ε_C	$1.\times10^{-3}$	$1.\times10^{-3}$
n	$2.$	$2.$

3.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	Tolerance
RESU_19	VMIS (MPa)	AUTRE_ASTER	3.0E7	10 E-6
RESU_19	TRACE (MPa)	AUTRE_ASTER	-3.0E7	10 E-6

4 Modeling B

4.1 Law of behavior and parameters materials

The law of behavior tested is ' MAZARS ', is documented in Doc. [R7.01.08] . This law fragile rubber band, makes it possible to give an account of the softening of the concrete and distinguishes the damage in traction and compression.

The elastic parameters are the following: $E(T)$, $\nu(T)$ and $\alpha(T)$

The elastoplastic parameters are the following: $\varepsilon_0(T)$, $A_C(T)$, $A_T(T)$, $B_C(T)$, $B_T(T)$ and k

Values of the parameters used:

Parameters	$T=0°C$	$T=500°C$
$E(T)$	$32000.\,MPa$	$16000.\,MPa$
$\nu(T)$	0.2	0.18
$\alpha(T)$	$1.2E-5\,K^{-1}$	$2.0E5\,K^{-1}$
$\varepsilon_0(T)$	0.0001	0.00005
$A_C(T)$	1.4	1.0
$A_T(T)$	1.0	0.8
$B_C(T)$	2000.	1000.
$B_T(T)$	10000.	20000.
k	0.7	0.7

4.2 Results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	Tolerance
RESU_19	VMIS (MPa)	AUTRE_ASTER	1.402148E7	0.10%
RESU_19	TRACE (MPa)	AUTRE_ASTER	-1.402148E7	0.10%
RESU_19	V1	AUTRE_ASTER	0.9087143	0.10%
RESU_19	V2	AUTRE_ASTER	1	0.10%
RESU_19	V4	AUTRE_ASTER	2.443761E-3	0.10%

5 Modeling C

5.1 Law of behavior and parameters materials

The law of behavior tested is 'BETON_UMLV_FP', is documented in Doc. R7.01.16 . This law is used for the modeling of the clean creep of the concrete with taking into account of the distinction between voluminal creep and creep deviatoric in order to give an account of the phenomena in the cases of multiaxial creeps. The test is carried out with on modeling D_PLAN (mesh QUAD4) with the order STAT_NON_LINE. The elastic parameters are the following:

$E(T)$, $\nu(T)$ and $\alpha(T)$

The parameters of the viscoplastic law are the following:

K_R^S, K_I^S, K_R^D, η_R^S, η_I^S, η_R^D and η_I^D

Values of the parameters used:

Parameters	$T=0°C$	$T=500°C$
$E(T)$	$11000\,MPa$	$31000\,MPa$
$\nu(T)$	$0.$	$0.$
$\alpha(T)$	$2.\times10^{5}\,K^{-1}$	$2.\times10^{-4}\,K^{-1}$
K_R^S	$2.\times10^{5}\,MPa$	$2.\times10^{5}\,MPa$
K_I^S	$5.\times10^{4}\,MPa$	$5.\times10^{4}\,MPa$
K_R^D	$5.\times10^{4}\,MPa$	$5.\times10^{4}\,MPa$
η_R^S	$4.\times10^{10}\,MPa.s$	$4.\times10^{10}\,MPa.s$
η_I^S	$10^{11}\,MPa.s$	$10^{11}\,MPa.s$
η_R^D	$10^{10}\,MPa.s$	$10^{10}\,MPa.s$
η_I^D	$10^{11}\,MPa.s$	$10^{11}\,MPa.s$

5.2 Results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	Tolerance
RESU_19	PRIN_1 (Pa)	AUTRE_ASTER	-3100.	0.10%

6 Modeling D

6.1 Law of behavior and parameters materials

The law of behavior tested is ' BETON_DOUBLE_DP ', is documented in Doc. R7.01.03 . This law is used for the description of the nonlinear behavior of the concrete. E comprises a criterion of Drücker Prager in traction and a criterion of Drücker Prager out of Co mpression, uncoupled. The two criteria can have a lenitive work hardening.

The elastic parameters are the following:

$E(T)$, $\nu(T)$ and $\alpha(T)$

The elastoplastic parameters are the following:

$f'c(T)$, $f't(T)$, $\beta(T)$, $G_C(T)$, $G_T(T)$ and ϕ

Values of the parameters used

Parameters	$T=0°C$	$T=20°C$	$T=400°C$	$T=800°C$
$E(T)$	37000.MPa	$32000.MPa$	$15000.MPa$	$5000.MPa$
$\nu(T)$	0.			0.
$\alpha(T)$	$1.\times10^{-5}K^{-1}$			$2.\times10^{-5}K^{-1}$
$f'c(T)$	40.		40.	15.
$f't(T)$	4.		4.	1.5
$\beta(T)$	1.16			1.16
$G_C(T)$	10.			10.
$G_T(T)$	0.1			0.1
ϕ	33.3333	33.3333	33.3333	33.3333

6.2 Results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	Tolerance
RESU_19	VMIS (MPa)	AUTRE_ASTER	33,602	0.10%
RESU_19	TRACE (MPa)	AUTRE_ASTER	-33,602	0.10%
RESU_19	V1	AUTRE_ASTER	6.9118E-03	0.10%
RESU_19	V3	AUTRE_ASTER	500.	0.10%
RESU_19	V4	AUTRE_ASTER	1	0.10%

7 Modeling E

7.1 Law of behavior and parameters materials

The law of behavior tested is ' ENDO_ISOT_BETON ', it is documented in Doc. R7.01.04 . This law is used for the description of the damage of the concrete, by distinguishing traction from compression, and by taking of account refermeture of the cracks.

Values of the parameters used

Parameters	$T=0°C$	$T=500°C$
$E(T)$	30000.MPa	$20000.\,MPa$
$\nu(T)$	0.02	0.02
$\alpha(T)$	$1.\times 10^{-5} K^{-1}$	$2.\times 10^{-5} K^{-1}$
SYT	$3\,MPa$	$3\,MPa$
SYC	$200\,MPa$	$200\,MPa$
D_SIGM_EPSI	$-6000\,MPa$	$-6000\,MPa$

7.2 Results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	Tolerance
RESU_19	VMIS (MPa)	AUTRE_ASTER	1.92E+08	0.10%
RESU_19	TRACE (MPa)	AUTRE_ASTER	-1.92E+08	0.10%

8 Modeling F

8.1 Law of behavior and parameters materials

The law of behavior tested is 'BETON_BURGER_FP', is documented in Doc. [R7.01.35] . This law is used for the modeling of the clean creep of the concrete with taking into account of the distinction between voluminal creep and creep deviatoric in order to give an account of the phenomena in the cases of multiaxial creeps. The test is carried out with on modeling D_PLAN (mesh QUAD4) with the order STAT_NON_LINE. The elastic parameters are the following:

$E(T)$, $\nu(T)$ and $\alpha(T)$

The parameters of the viscoplastic law are the following:

K_R^S , K_R^D , η_R^S , η_I^S , η_R^D , η_I^D and κ .

Values of the parameters used:

Parameters	$T=0°C$	$T=500°C$
$E(T)$	$11000\,MPa$	$31000\,MPa$
$\nu(T)$	$0.$	$0.$
$\alpha(T)$	$2.\times10^{5}\,K^{-1}$	$2.\times10^{-4}\,K^{-1}$
K_R^S	$2.\times10^{5}\,MPa$	$2.\times10^{5}\,MPa$
κ	3.0×10^{-3}	3.0×10^{-3}
K_R^D	$5.\times10^{4}\,MPa$	$5.\times10^{4}\,MPa$
η_R^S	$4.\times10^{10}\,MPa.s$	$4.\times10^{10}\,MPa.s$
η_I^S	$10^{11}\,MPa.s$	$10^{11}\,MPa.s$
η_R^D	$10^{10}\,MPa.s$	$10^{10}\,MPa.s$
η_I^D	$10^{11}\,MPa.s$	$10^{11}\,MPa.s$

8.2 Results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	Tolerance
RESU_19	PRIN_1 (Pa)	AUTRE_ASTER	-3100.	0.10%

9 General synthesis of the results

For each studied law of behavior, the results of the thermomechanical transient of the first simulation are compared with those obtained with the second simulation in pure mechanics. The results are concordant, which show the good taking into account of thermal dilation by these laws of behavior, as well as the good dependence of the parameters materials at the temperature.

The laws of behaviors validated are the following ones:

- Modeling a: this modeling makes it possible to validate the model `BETON_REGLE_PR` ,
- Modeling b: this modeling makes it possible to validate the model `MAZARS` ,
- Modeling C: this modeling makes it possible to validate the model `BETON_UMLV_FP` .
- Modeling D: this modeling makes it possible to validate the model `BETON_DOUBLE_DP`
- Modeling E: this modeling makes it possible to validate the model `ENDO_ISOT_BETON`
- Modeling F: this modeling makes it possible to validate the model `BETON_BURGER_FP` .