COMP011 – Thermomechanical validation of the models for the concrete

Summarized

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

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

the validated constitutive laws are the following ones:

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

1 Methodology

It acts of 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 strains according to x : $\varepsilon_{xx}=0$. The imposed temperature is increasing linearly according to time. The temperature varies from $T_0=20°C$ with $T_{max}=500°C$. The transient consists of `NCAL` not. The reference temperature 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 strain imposed according to x : $\varepsilon_{xx}=-\varepsilon^{th}=-\alpha(T)(T-T_{ref})$, in pure mechanics. A each computation i , the imposed loading is made up by the thermal strain $\varepsilon_{xx}=-\varepsilon_{th}=-\alpha(T)(T_i-T_{réf})$. The initial loading is made up by the strains, stresses and local variables of preceding mechanical computation.

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

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

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

Moreover, to get the same results in both cases, it is necessary, with each time step of the second simulation, to carry out pure mechanical computation with coefficients whose values are interpolated according to the temperature at current time. 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 acts to check that result at every moment obtained mechanical transient thermo of the first simulation identical to is result obtained 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 result of a mechanical computation on the other hand, the value of reference being the component of the field extracted to a time given i the first thermomechanical simulation carried out on `urgent` NCAL. The computed value is that obtained at the end of the mechanical computation $i+1$ of the loop on `the NCAL`.

3 Modelization A

3.1 Constitutive law and materials parameters

the constitutive law tested is “ `BETON_REGLE_PR` ”, is documented in documentation [U4.43.01]. This concrete constitutive law is known as “right-angled parabola”.

The elastic parameters are the following:

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

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 Quantities tested and results

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	Tolerance
RESU_19	VMIS (MPa)	AUTRE_ASTER	3.0E7	10 E-6
RESU_19	B TRACES (MPa	)	AUTRE_ASTER	-3.0E7 10

4 E-6 Modelization

4.1 Constitutive law and materials parameters

the constitutive law tested is " MAZARS ", is documented in Doc. [R7.01.08] . This brittle elastic model, makes it possible to give an account of the softening of the concrete and distinguishes the damage in tension and compression.

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

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
$\alpha(T)$	$1.2E-5K^{-1}$	$2.0E5K^{-1}$
$\varepsilon_0(T)$	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 at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	Tolerance
RESU_19	VMIS (MPa)	AUTRE_ASTER	1.402148E7	0.10%
RESU_19	TRACES C (MPa	)	AUTRE_ASTER	-1.402148E7
0.10%	RESU_19	V1	AUTRE_ASTER	0.9087143
0.10%	RESU_19	V2	1	1
0.10%	RESU_19	V4	AUTRE_ASTER	2.443761E-3

5 0.10% Modelization

5.1 Constitutive law and materials parameters

the constitutive law tested is “BETON_UMLV_FP”, is documented in Doc. R7.01.16 . This model is used for the modelization 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 modelization D_PLAN (mesh QUAD4) with command STAT_NON_LINE. The elastic parameters are the following:

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

parameters of the viscoplastic model 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 at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	Tolerance
RESU_19	PRIN_1 (Pa)	AUTRE_ASTER	-3100.	0.10%

6 Modelization D

6.1 Constitutive law and materials parameters

the constitutive law tested is " `BETON_DOUBLE_DP` ", is documented in Doc. R7.01.03 . This model is used for the description of the nonlinear behavior of the concrete. E comprises it a criterion of Drücker Prager in tension and a criterion of Drücker Prager out of Co mpression, decoupled. The two criteria can have a lenitive hardening.

The elastic parameters are the following:

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

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 at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	Tolerance
RESU_19	VMIS (MPa)	AUTRE_ASTER	33.602	0.10%
RESU_19	E TRACES (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

7 0.10% Modelization

7.1 Constitutive law and materials parameters

the constitutive law tested is " ENDO_ISOT_BETON ", it is documented in Doc. R7.01.04 . This model is used for the description of the damage of the concrete, by distinguishing the tension from compression, and in taking into account the reclosing of 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
$\alpha(T)$	$1.\times10^{-5}K^{-1}$	$2.\times10^{-5}K^{-1}$
SYT	$3\ MPa$	$3\ MPa$
SYC	$200\ MPa$	$200\ MPa$
D_SIGM_EPSI	$-6000\ MPa$	$-6000\ MPa$

7.2 Results

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	Tolerance
RESU_19	VMIS (MPa)	AUTRE_ASTER	1.92E+08	0.10%
RESU_19	TRACES F (MPa	)	AUTRE_ASTER	-1.92E+08

8 0.10% Modelization

8.1 Constitutive law and materials parameters

the constitutive law tested is "BETON_BURGER_FP", is documented in Doc. [R7.01.35] . This model is used for the modelization 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 modelization D_PLAN (mesh QUAD4) with command STAT_NON_LINE. The elastic parameters are the following:

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

parameters of the viscoplastic model 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 at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	Tolerance
RESU_19	PRIN_1 (Pa)	AUTRE_ASTER	-3100.	0.10%

9 general Synopsis of the results

For each studied constitutive law, 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 thermal expansion by these constitutive laws, as well as the good dependence of materials parameters with the temperature.

The validated constitutive laws are the following ones:

•Modelization a: this modelization makes it possible to validate the model BETON_REGLE_PR ,
•Modelization b: this modelization makes it possible to validate MAZARS , Modelization
•the model C: this modelization makes it possible to validate BETON_UMLV_FP the model .
•Modelization D: this modelization makes it possible to validate BETON_DOUBLE_DP Modelization
•the model E: this modelization makes it possible to validate ENDO_ISOT_BETON Modelization
•the model F: this modelization makes it possible to validate BETON_BURGER_FP the model .