ZZZZ336 – Validation of the taking into account of the variables of orders at the under-points

Summary:

The objective of this test is to validate the taking into account of the variables of orders at the under-points while providing to the keyword AFFE_VARC order AFFE_MATERIAU a field or result created by method SOUS_POINT order PROJ_CHAMP.

Modelings considered are the elements DKT, GRILLE_EXCENTREE, POU_D_EM and POU_D_TGM.

For the elements DKT and GRILLE_EXCENTREE , the checking consists in projecting a field of temperatures resulting from a thermal calculation linear 3D on a flagstone made up of multi-layer elements DKT and from an offset grid. The arrow of the flagstone due to the heat gradient is calculated in linear thermoelasticity.
The reference solution is resulting from an identical calculation with the method CREA_RESU option PREP_VRC1.

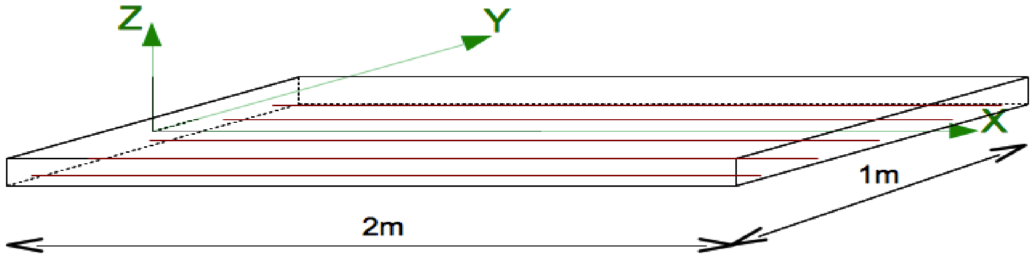
For modelings POU_D_EM and POU_D_TGM, the validation is done in two times. One first of all subjects a beam mono-material in support to a field of temperature varying according to axis Z. the results are compared with the same problem modelled by elements 3D. One treats then the case bi--material, always on a beam in support, while varying the temperature so that taking into account as of various materials, the thermal deformation is the same one on each fibre. One should then find no inflection.

This test also validates the options EPVC_ELGA, EPME_ELGA and EPSP_ELGA for the elements listed above.

1 Problem of reference: Hulls and grids

1.1 Geometry and grids

One considers a concrete slab length $2\,m$, of width $1\,m$ and thickness $10\,cm$. It comprises a steel tablecloth directed according to the axis X, made up of bars of diameter $8\,mm$ spaced $20\,cm$ whose axis is located at $2.5\,cm$ below average plan.



1.2 Properties of materials

For thermal calculation linear 3D (on the concrete only) the properties are:

$\rho C_p = 0$

$\lambda = 2\,W/m^2/K$

For mechanical calculation the materials are elastic linear:

Concrete: $E = 30\,GPa$ steel: $E = 200\,GPa$

$\nu = 0.2$ $\nu = 0.3$

$\alpha = 10^{-5}\,K^{-1}$ $\alpha = 2.10^{-5}\,K^{-1}$

In the third calculation in which one wishes to validate the option EPSP_ELGA, one passes to the law VMIS_ISOT_TRAC whose parameters are the following ones:

Concrete: D_SIGM_EPSI : 1E10 steel: D_SIGM_EPSI : 5E10

SY : 5E6 SY : 1E7

1.3 Boundary conditions and loading

For thermal calculation, the temperature is imposed on the lower face and the higher face:

$T_{inf} = 20\,°C$ and $T_{\sup} = 50\,°C$

The initial temperature is $T_{ini} = 20\,°C$

For mechanical calculation, the flagstone is simply pressed on its two supports parallel with Y :

- on the edge $X = 0$: $DX = DZ = 0$
- on the edge $X = 1\text{m}$: $DZ = 0$
- for the corner $Y = -0.5\text{m}$: $DY = 0$

The loading consists in imposing the temperature resulting from thermal calculation 3D.

2 Reference solution: Hulls and grids

2.1 Method of calculating

In the reference solution, the thermal field is imposed using the order CREA_RESU option PREP_VRC1 for the multi-layer hulls and the offset grids. The field of temperature, linear in the thickness, varies $20°C$ opposite lower than $50°C$ opposite higher.

The field EVOL_THER (with under points) is transmitted to mechanical calculation by the keyword AFFE_VARC of AFFE_MATERIAU.

2.2 Sizes and results of reference

The heat gradient in the thickness imposes a mechanical deformation of inflection in the flagstone. The dilation coefficients of the material steel and the material concrete were voluntarily selected very different to generate constraints due to the differential expansion and to test the good performance of the elements thus roasts at the same time as that of the multi-layer hulls.

The generated constraints are uniform in the plans parallel with the plan XY
The sizes tested are:

- the vertical displacement of the node $C5$ in the middle of the edge $Y=-0.5m$
- the constraint σ_{xx} opposite lower the concrete
- the constraint σ_{xx} opposite superior the concrete
- the constraint σ_{xx} in the layer of steel

For the thermal deformations of field EPVC_ELGA, the analytical references are given by the formula $EPTHER_L=\alpha(TEMP-TEMP_{REF})$. LE mechanical field of deformation EPME_ELGA is then validated by difference between the total deflections and the thermal deformations.

For the unelastic deformations EPSP_ELGA, the reference is given by the relation: unelastic deformation = mechanical deformation – elastic strain.
The elastic strain are found starting from the stress field and the coefficient E and NAKED.

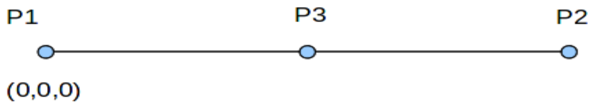
2.3 Uncertainties on the solution

Nothing.

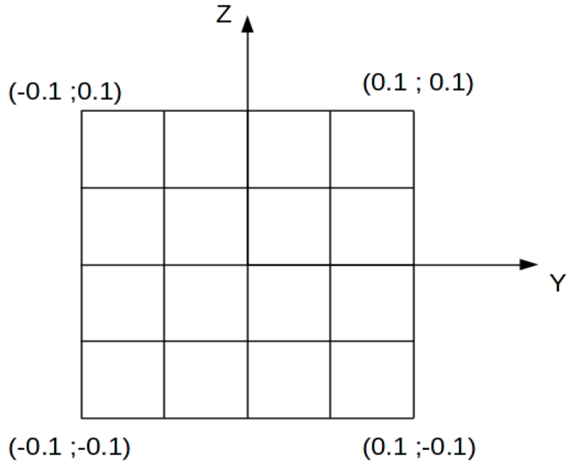
3 Problem of reference: Multifibre beams

3.1 Geometry and grids

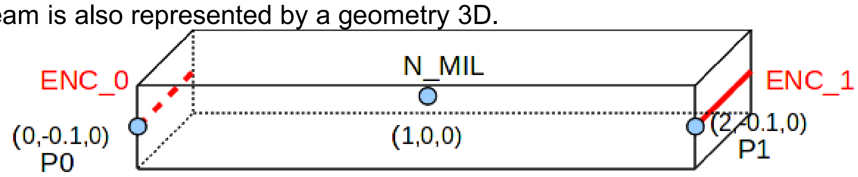
A beam length is considered $2m$ and of square section on side $0.2m$.



For modelings in multifibre beams, the section of the beam comprises 16 fibres laid out as on the following figure:



This same beam is also represented by a geometry 3D.



3.2 Properties of materials

The materials are elastic linear:

Concrete: $E=30\,GPa$ $\nu=0.2$ $\alpha=10^{-5}K^{-1}$

steel: $E=200\,GPa$ $\nu=0.3$ $\alpha=2.10^{-5}K^{-1}$

In the first calculation (mono-material), the beam is entirely out of concrete.
In the second and the third calculations (bi--material), fibres under the axis Y are out of concrete whereas the fibres above are out of steel.

3.3 Boundary conditions and loading

3.3.1 Boundary conditions

Beams calculations 1 and 2:
The node `P1` is blocked in `DX`, `DY`, `DZ`, `DRX` and `DRZ`.
The node `P2` is blocked in `DY` and `DZ`.

Beams calculation 3:
Nodes `P1` and `P2` are embedded.

3D:
Nodes on the segment ENC_0 are blocked in DX and in DZ.
Nodes on the segment ENC_1 are blocked in DZ.
Nodes P0 and P1 are blocked in DY.

3.3.2 Loading

Calculation mono-material:
One imposes a thermal loading dependent on Z and of time t. The temperature is defined as follows: $T=(-200Z+20)t$. The temperature of reference is 0.

Calculations bi--material:
One imposes a thermal loading dependent on Z and of time t. The temperature is defined as follows:

- $T=20t$ if $Z>0$
- $T=40t$ if $Z<0$

The temperature of reference is 0.

4 Reference solution: Multifibre beams

4.1 Calculation mono-material

4.1.1 Sizes and results of reference

The reference solution is that given by the results of calculation 3D. One tests component DZ of the displacement of the node N_MIL for the 3D and P3 for the beams.

4.1.2 Uncertainties on the solution

Uncertainties related to modeling 3D.

4.2 The first calculation bi--material

4.2.1 Sizes and results of reference

The values coefficients α of two materials and fields of temperature assigned to various fibres have for consequence the same value of thermal deformation on each fibre.
If the temperature at the under-points is correctly taken into account, this loading does not induce an inflection of the beam.

It is thus checked that the component DZ displacement of the node P3 is worthless.

4.2.2 Uncertainties on the solution

None.

4.3 The second calculation bi--material

4.3.1 Sizes and results of reference

The thermal loading is the same one as in preceding calculation, but this time the nodes end are embedded. The total deflection is worthless and the thermal deformation is the same one as in preceding calculation. Moreover as there were no constraints in this calculation the total deflection is equal to the thermal deformation.

One a: $\varepsilon_{th}=8.\mathrm{E}-4$

In the case general one has for each fibre i :

$$\sigma_{xx}=E_i(\varepsilon_{xx}-\varepsilon_{th})$$

thus in this case:

$$\sigma_{xx}=-E_i\varepsilon_{th}$$

From where for concrete fibres:

$$\sigma_{xx}=-2.4\mathrm{E}7$$

and for steel fibres:

$$\sigma_{xx}=-1.6\mathrm{E}8$$

4.3.2 Uncertainties on the solution

None.

5 Modeling A

5.1 Characteristics of modeling

Thermal calculation 3D uses a lumpée modeling (3D_DIAG). However, as the temperature is imposed on the two faces of the element, it is everywhere given. The thermal solvor is used here only to generate the field EVOL_THER to project. Mechanical calculation uses elements DKT multi-layer for the concrete and GRILLE_EXCENTRE for steel. The number of layers in DKT is 10. The temperature resulting from thermal calculation 3D is projected on the layers of the elements DKT and on the elements GRID using the method SOUS_POINT order PROJ_CHAMP.

5.2 Characteristics of the grid

For thermal calculation the grid 3D is composed of only one nets HEXA8.
For mechanical calculation the grid of the average plan is carried out with 30 elements QUAD4. The elements for the grids are generated in the command file with CREA_MAILLAGE.

5.3 Sizes tested and results

The arrow of the point $C5$ is tested:

Not	Component	Value of reference	Tolerance
C5	DZ	-2.282282766283E-03	1.E-6

The constraint in an element DKT (M27) is tested opposite lower (under-point 1, low of layer 1) and opposite higher (under-point 30, high of layer 10). The constraint in an element GRID (AM27) is tested in the single layer (under-point 1).

Mesh	Not	Under-point	Component	Value of reference	Tolerance
M27	1	1	SIXX	7.19992574908E+06	1.E-6
M27	1	30	SIXX	-1.67641728099E+06	1.E-6
AM27	1	1	SIXX	-1.22171342086E+07	1.E-6

One also tests some values of fields EPVC_ELGA, EPME_ELGA and EPSP_ELGA (worthless in this case, because calculation is elastic) on these same meshs.

Mesh	Not	Under-point	FieldComp	Value of reference	Tolerance
M27	1	8	EPVC/EPTHER_L	22.5E-5	1.E-6
M27	1	15	EPVC/EPTHER_L	15th-5	1.E-6
M27	1	23	EPVC/EPTHER_L	7.5E-5	1.E-6
M27	1	8	EPME/EPXX	0.0001684818089	1.E-6
M27	1	15	EPME/EPYY	-1.84633114e-05	1.E-6
M27	1	8	EPSP/EPXX	0.	1.E-6
M27	1	8	EPSP/EPYY	0.	1.E-6
M27	1	8	EPSP/EPXY	0.	1.E-6
WithM27	1	1	EPVC/EPTHER_L	45E-5	1.E-6
WithM27	1	1	EPME/EXX	-6.108567099e-05	1.E-6
WithM27	1	1	EPSP/EXX	0.	1.E-6

Non-linear calculation:

Mesh	Not	Under-point	FieldComp	Value of reference	Tolerance
M27	1	8	EPSP/EPXX	1.328052439685e-05	1.E-6
M27	1	8	EPSP/EPYY	-7.523580542166e-06	1.E-6
M27	1	8	EPSP/EPXY	-3.992851634680e-06	1.E-6
WithM27	1	1	EPSP/EXX	-4.484820109199e-06	1.E-6

6 Modeling B

6.1 Characteristics of modeling

The thermal model 3D on which the fields of temperature are affected before projection at the under-points of the mechanical model of multifibre beams uses modeling 3D.
The mechanical model 3D also uses modeling 3D.
Modeling POU_D_EM is assigned to the linear model.

6.2 Characteristics of the grid

The grid 3D is composed of 100 meshs HEXA27, 10 in the length, 10 in the thickness and two in the width.
The linear grid of beam is composed of 20 meshs SEG2.

6.3 Sizes tested and results

Calculation mono-material:

Moment	Not	Component	Value of reference	Tolerance
2.0	P3	DZ	-4.01394722938527E-02	4.E-2

Moment	Mesh	FieldComp	Not	Under-point	Value of reference	Tolerance
2.0	M1	EPVC/EPTHER_L	1	8	6.e-3	1.E-6
2.0	M1	EPME/EPXX	1	8	0.	1.E-6

The first calculation bi--material:

Moment	Not	Component	Value of reference	Tolerance
2.0	P3	DZ	0.0	1.E-6

The second calculation bi--material:

Moment	Mesh	Component	Not	Under-point	Value of reference	Tolerance
2.0	M10	SIXX	1	1	-2.400000000E+07	1.E-4
2.0	M10	SIXX	1	9	-1.600000000E+08	1.E-4

Moment	Mesh	FieldComp	Not	Under-point	Value of reference	Tolerance
2.0	M1	EPVC/EPTHER_L	1	8	8.e-4	1.E-6
2.0	M1	EPME/EPXX	1	8	8.e-4	1.E-6
2.0	M1	EPSP/EPXX	1	8	0.	1.E-6

7 Modeling C

7.1 Characteristics of modeling

The thermal model 3D on which the fields of temperature are affected before projection at the under-points of the mechanical model of multifibre beams uses modeling 3D.
The mechanical model 3D also uses modeling 3D.
Modeling POU_D_TGM is assigned to the linear model.

7.2 Characteristics of the grid

The grid 3D is composed of 100 meshs HEXA27, 10 in the length, 10 in the thickness and two in the width.
The linear grid of beam is composed of 20 meshs SEG2.

7.3 Sizes tested and results

Calculation mono-material:

Moment	Not	Component	Value of reference	Tolerance
2.0	P3	DZ	-4.01394722938527E-02	4.E-2

Moment	Mesh	FieldComp	Not	Under-point	Value of reference	Tolerance
2.0	M1	EPVC/EPTHER_L	1	8	6.e-3	1.E-6

The first calculation bi--material:

Moment	Not	Component	Value of reference	Tolerance
2.0	P3	DZ	0.0	1.E-6

The second calculation bi--material:

Moment	Mesh	Component	Not	Under-point	Value of reference	Tolerance
2.0	M10	SIXX	1	1	-2.400E+07	1.E-4
2.0	M10	SIXX	1	9	-1.600E+08	1.E-4

Moment	Mesh	FieldComp	Not	Under-point	Value of reference	Tolerance
2.0	M1	EPVC/EPTHER_L	1	8	8.e-4	1.E-6

8 Summary of the results

The taking into account of the variables of orders at the under-points while providing to AFFE_VARC a field or a result created by the method SOUS_POINT order PROJ_CHAMP is validated for the elements DKT multi-layer, elements GRID, elements POU_D_EM and POU_D_TGM. In the same way, this test validates the options EPVC_ELGA, ELME_ELGA and EPSP_ELGA for the elements present in modelings of this test.