ZZZZ328 – Validation of CALC_CHAMP / ENEL_ELEM

Summary:

The objective of this test is to validate the elementary calculation of elastic energy. For each modeling, an unit element is considered of which all the degrees of freedom are imposed, which make it possible to create fields of homogeneous strain and stress on the element. The results are compared with the analytical solution.

1 Problem of reference

1.1 Geometry

One considers an unit element of dimension 2 (quadrangle) or 3 (cubic) according to modeling. The thickness of the element, when it is required, is worth 1m .

1.2 Properties of material

The material is elastic isotropic, whose properties are:

- $E=1000\,MPa$
- $\nu=0.2$

For modeling E, the Poisson's ratio is null.

1.3 Boundary conditions and loadings

1.3.1 Modeling A

The cube of unit size is illustrated on Figure 1.3.1-1 . The displacement of the various nodes is imposed in accordance with Table 1.3.1-1 .

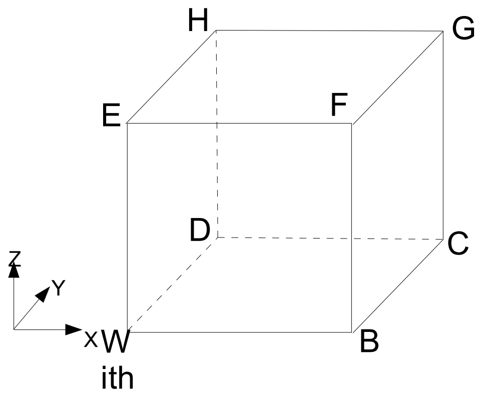

Figure 1.3.1-1: Geometry of modeling A

Nœud	DX	DY	DZ
A	0.0	0.0	0.0
B	1,0E-3	0.0	-6,0E-4
C	2,0E-3	-2,0E-3	-3,0E-3
D	1,0E-3	-2,0E-3	-2,4E-3
E	0.0	2,2E-3	3,0E-3
F	1,0E-3	2,2E-3	2,4E-3
G	2,0E-3	2,0E-4	0.0
H	1,0E-3	2,0E-4	6,0E-4

Table 1.3.1-1: Displacements of NœudS

1.3.2 Modelings B, C E T D

The geometry of the quadrangle of unit size corresponds to the face $ABCD$ (Figure 1.3.1-1). The displacement of the four nodes A, B, C and D is imposed in accordance with Table 1.3.1-1 for the components X and Y, the component Z being worthless. When degrees of freedom in rotation exist, those are blocked at the point A.

1.3.3 Modeling E

The geometry of the quadrangle of unit size corresponds to the face $ABCD$ (Figure 1.3.1-1). It is about an axisymmetric modeling, whose axis is distant of $1\mathrm{m}$ edge AD. Displacements of the nodes are worthless, except the component Y points C and D who is worth $1{,}0\mathrm{E}\text{-}4\,m$.

1.4 Initial conditions

Nothing

2 Reference solution

2.1 Method of calculating

The field of deformation is obtained starting from displacements and the stress field thanks to the law of Hooke. Elastic energy E_{elas} is calculated then by the following formula:

$$E_{elas}=\int_V \frac{1}{2}\sigma:\epsilon\, dV$$

equation 2.1-1

2.1.1 Modeling A

Fields of strain and stress homogeneous on the element are indicated in Table 2.1.1-1 .

Component	X	Y	Z	XY	YZ	ZX
Deformation	0.001	-0.002	0.003	0.0005	-0.0001	-0.0003
Constraint (Pa)	1,3888889E6	-1,1111111E6	3,0555556E6	4,1666667E5	-8,3333333E4	-2,5E5

Table 2.1.1-1: Field of strain and stress

2.1.2 Modeling b: plane deformations

Fields of strain and stress homogeneous on the element are indicated in Table 2.1.2-1 .

Component	X	Y	Z	XY	YZ	ZX
Deformation	0.001	-0.002	0.0	0.0005	0.0	0.0
Constraint (Pa)	5.5555556 E 5	-1.9444444 E6	-2.7777778 E 5	4,1666667E5	-8,3333333E4	-2,5E5

Table 2.1.2-1: Field of strain and stress

2.1.3 Modeling C (plane constraints) and D (elements of hull and plate)

Fields of strain and stress homogeneous on the element are indicated in Table 2.1.3-1 . For the elements of hull and plate, it is the membrane deformation, the curve being worthless.

Component	X	Y	Z	XY	YZ	ZX
Deformation	0.001	-0.002	-0.00025	0.0005	0.0	0.0
Constraint (Pa)	6.25 E 5	-1.875 E6	0.0	4,1666667E5	0.0	0.0

Table 2.1.3-1: Field of strain and stress

2.1.4 Modeling E : axisymmetric.

Fields of strain and stress homogeneous on the element are indicated in Table 2.1.4-1 .

Component	X	Y	Z	XY
Deformation	0.0	0.0001	0.0	0.0
Constraint (Pa)	0.0	1,0E5	0.0	0.0

Table 2.1.4-1 : Field of strain and stress

Elastic energy is calculated according to 2.1-1 by expressing ground volume dV in the cylindrical reference mark for a slice infinitesimal thickness $d\theta$:

$$E_{elas}=\int_V \frac{1}{2}\sigma:\epsilon\, dV=\frac{1}{2}\sigma:\epsilon\int_{R_1}^{R_2} rdr\int_{H_1}^{H_2} dz$$

The terminals of the integral are: $R_1=1\mathrm{m}$, $R_2=2\mathrm{m}$, $H_1=0\mathrm{m}$ and $H_2=1\mathrm{m}$.

2.2 Sizes and results of reference

Calculated elastic energy in an analytical way for each modeling is indicated in Table 2.2-1.

Modeling	A	B	C	D	E
Elastic energy	6680.555556 J	2430.555556 J	2395.833333 J	2395.833333 J	$7{,}5\ J.rad$[1]

Table 2.2-1: Elastic energy

2.3 Uncertainties on the solution

None. It is about an analytical solution.

2.4 Bibliographical references

3 Modeling A

3.1 Characteristics of modeling

One uses successively modelings 3D , 3D_SI and 3D_GRAD_EPSI .

3.2 Characteristics of the grid

The grid contains 1 element of the type HEXA8 for modeling 3D and 1 element of the type HEXA20 for modeling S 3D_SI and 3D_GRAD_EPSI .

3.3 Sizes tested and results

One tests the elastic energy stored by the element.

Identification	Type of reference	Value of reference	Tolerance
3D - ENEL_ELEM	'ANALYTICAL'	6680.555556	0.1%
3D_SI - ENEL_ELEM	'ANALYTICAL'	6680.555556	0.1%
3D_GRAD_EPSI - ENEL_ELEM	'ANALYTICAL'	6680.555556	0.1%

4 Modeling B

4.1 Characteristics of modeling

One uses successively modelings D_PLAN , D_PLAN _S I , D_PLAN _GRAD_EPSI , D_PLAN_GRAD_SIGM and PLAN_ELDI .

4.2 Characteristics of the grid

The grid contains 1 element of the type QUAD4 for modelings D_PLAN, D_PLAN_SI and PLAN_ELDI and 1 element of type QUAD8 for Lbe modelingS D_PLAN_GRAD_EPSI and D_PLAN_GRAD_SIGM.

4.3 Sizes tested and results

One tests the elastic energy stored by the element.

Identification	Type of reference	Value of reference	Tolerance
D_PLAN – ENEL_ELEM	'ANALYTICAL'	2430.555556	0.1%
D_PLAN_SI - ENEL_ELEM	'ANALYTICAL'	2430.555556	0.1%
D_PLAN_GRAD_EPSI - ENEL_ELEM	'ANALYTICAL'	2430.555556	0.1%
D_PLAN_GRAD_SIGM - ENEL_ELEM	'ANALYTICAL'	2430.555556	0.1%
PLAN_ELDI - ENEL_ELEM	'ANALYTICAL'	2430.555556	0.1%

5 Modeling C

5.1 Characteristics of modeling

One uses successively modelings C _PLAN , C_ PLAN _S I and C _PLAN _GRAD_EPSI .

5.2 Characteristics of the grid

The grid contains 1 element of the type QUAD4 for modelings C_PLAN and C_PLAN_SI and 1 element of type QUAD8 for Lhas modeling C_PLAN_GRAD_EPSI.

5.3 Sizes tested and results

One tests the elastic energy stored by the element.

Identification	Type of reference	Value of reference	Tolerance
C _PLAN - ENEL_ELEM	'ANALYTICAL'	2395.833333	0.1%
C_PLAN_SI - ENEL_ELEM	'ANALYTICAL'	2395.833333	0.1%
C_PLAN_GRAD_EPSI - ENEL_ELEM	'ANALYTICAL'	2395.833333	0.1%

6 Modeling D

6.1 Characteristics of modeling

One uses successively modelings DKT , DKTG and Q4GG .

6.2 Characteristics of the grid

The grid contains 1 element of the type QUAD4.

6.3 Sizes tested and results

One tests the elastic energy stored by the element.

Identification	Type of reference	Value of reference	Tolerance
DKT - ENEL_ELEM	'ANALYTICAL'	2395.833333	0.1%
DKTG - ENEL_ELEM	'ANALYTICAL'	2395.833333	0.1%
Q4GG - ENEL_ELEM	'ANALYTICAL'	2395.833333	0.1%

7 Modeling E

7.1 Characteristics of modeling

One uses successively modelings AXIS , AXIS_SI and AXIS_ELDI .

7.2 Characteristics of the grid

The grid contains 1 element of the type QUAD4 for Lbe modelingS AXIS and AXIS_ELDI and 1 element of type QUAD8 for modeling AXIS_SI.

7.3 Sizes tested and results

One tests the elastic energy stored by the element.

Identification	Type of reference	Value of reference	Tolerance
AXIS - ENEL_ELEM	'ANALYTICAL'	7.5	0.1%
AXIS_SI - ENEL_ELEM	'ANALYTICAL'	7.5	0.1%
AXIS_ ELDI - ENEL_ELEM	'ANALYTICAL'	7.5	0.1%

8 Summary of the results

The whole of modelings provides results in conformity with the analytical solution. The elementary option of calculation of elastic energy ENEL_ELEM is thus validated.