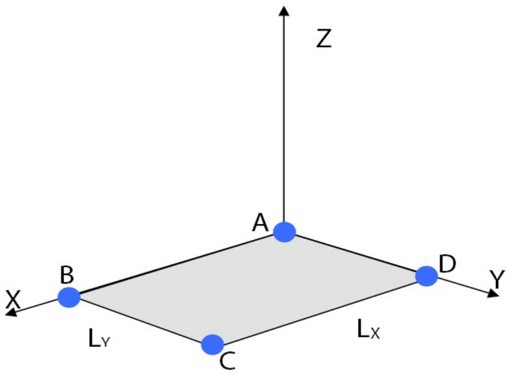
ZZZZ294 – Validation of the position of the subpoints of the plates 3D

Summarized:

This test validates the computation of the position of the subpoints of integration in the total reference for modelizations DKT, DST, COQUE_3D and GRILLE_EXCENTRE. An elementary mechanical computation is carried out in order to allow the creation of an array with CREA_TABLE from result. Only the coordinates of some subpoints are tested in the array.

1 Problem of reference

1.1 Geometry



Plates 3D:

Length X : $L_X=2.0\,m$

Length Y : $L_Y=1.0\,m$

Thickness: $e=0.5\,m$

Local coordinates of the points A B, C and D

$X_A=0.0\,;Y_A=0.0\,;Z_A=0.0$

$X_B=2.0\,;Y_B=0.0\,;Z_B=0.0$

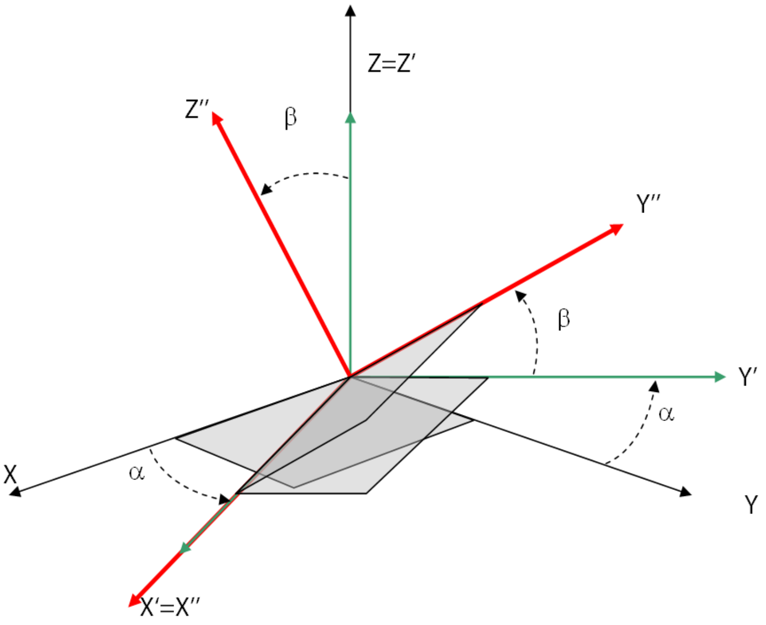
$X_C=2.0\,;Y_C=1.0\,;Z_C=0.0$

$X_D=0.0\,;Y_B=1.0\,;Z_B=0.0$

the directional sense of the plate in the total reference is obtained by two rotations:

$\alpha=30°$ around Z

$\beta=60°$ around the new axis X'



$X\,;Y\,;Z$: total axes

$X''\,;Y''\,;Z''$: local axes in final position

1.2 Properties of the materials

Concrete:

Young's modulus: $E=3.7272^{10}\,Pa$

Poisson's ratio: $\nu=0.0$

1.3 Boundary conditions and loadings

On the points A and B one and the blocks displacements X, Y, Z according to rotations around the axes X, Y, Z :

$$D_X^A=0.0\,;\,D_Y^A=0.0\,;\,D_Z^A=0.0\,;\,DR_X^A=0.0\,;\,DR_Y^A=0.0\,;\,DR_Z^A=0.0$$

$$D_X^B=0.0\,;\,D_Y^B=0.0\,;\,D_Z^B=0.0\,;\,DR_X^B=0.0\,;\,DR_Y^B=0.0\,;\,DR_Z^B=0.0$$

To the points C and D one applies a loading according to Z :

$F_Z=-100.0\,N$

2 Reference solution

2.1 Method of calculating

One calculates the position of the nodes, points of integration and subpoints of integration from their cordonnées in the local axes in final position of the plate, and of the transition matrixes between the local axes and the total axes

rotation around the axis Z is made from the following matrix:

$$Tz(\alpha)=\begin{bmatrix}\cos(\alpha) & -\sin(\alpha) & 0\\ \sin(\alpha) & \cos(\alpha) & 0\\ 0 & 0 & 1\end{bmatrix}$$

Rotation around the axis X' is made from the following matrix:

$$Tx'(\beta)=\begin{bmatrix}1 & 0 & 0\\ 0 & \cos(\beta) & -\sin(\beta)\\ 0 & \sin(\beta) & \cos(\beta)\end{bmatrix}$$

For any point of initial coordinates (X, Y, Z) one can calculate his coordinates expressed in the total reference (X', Y', Z') after rotations with the following transformation:

$$\begin{bmatrix}X'\\ Y'\\ Z'\end{bmatrix}=[Tz(\alpha)][Tx'(\beta)]\begin{bmatrix}X\\ Y\\ Z\end{bmatrix}$$

2.2 Quantities and results of reference

One calculates the position of the subpoints of integration in the total reference knowing his position expressed in the local axes.

Here one a: $Tx'(\beta)=\begin{bmatrix}1 & 0 & 0\\ 0 & 0.5 & -0.866\\ 0 & 0.866 & 0.5\end{bmatrix}$ and $Tz(\alpha)=\begin{bmatrix}0.866 & -0.5 & 0\\ 0.5 & 0.866 & 0\\ 0 & 0 & 1\end{bmatrix}$

For an element `QUA4` of plate length $L_X=2.0\,m$ and width $L_Y=1.0\,m$, the positions in the plane of the point of integration are, for the modelizations A and B (`DKT and DST`) which have 4 points of integration (see R3.01.01):

Point	x	y
1	0.42264973081037416	0.21132486540518708
2	1.5773502691896257	0.21132486540518708
3	1.5773502691896257	0.78867513459481287
4	0.42264973081037416	0.78867513459481287

And for the modelization C (`COQUE_3D`) which has 9 points of integration (see R3.01.01):

Point	x	y
1	0.22540333075851704	0.11270166537925852
2	1.774596669241483	0.11270166537925852
3	1.774596669241483	0.88729833462074148
4	0.22540333075851704	0.88729833462074148
5	1	0.11270166537925852
6	1.774596669241483	0.5
7	1	0.88729833462 074148
8	0.22540333075851704	0.5
9	1	

the thickness $EP=0.5\,m$, is discretized in 4 layers, which makes 12 subpoints whose heights compared to the average plane (except case modelization D GRILLE_EXCENTREE) are:

Subpoint	z	Item	z
1	-0.250	7	0.000
2	-0.1875	8	0.0625
3	-0.125	9	0.125
4	-0.125	10	0.125
5	-0.0625	11	0.1875
6	0.000	12	0.250

In the case of the modelization D (GRILLE_EXCENTRE), with an eccentring of 0.05, the position of the point = subpoint is:

Subpoint	x	y	z
1	1		0.05

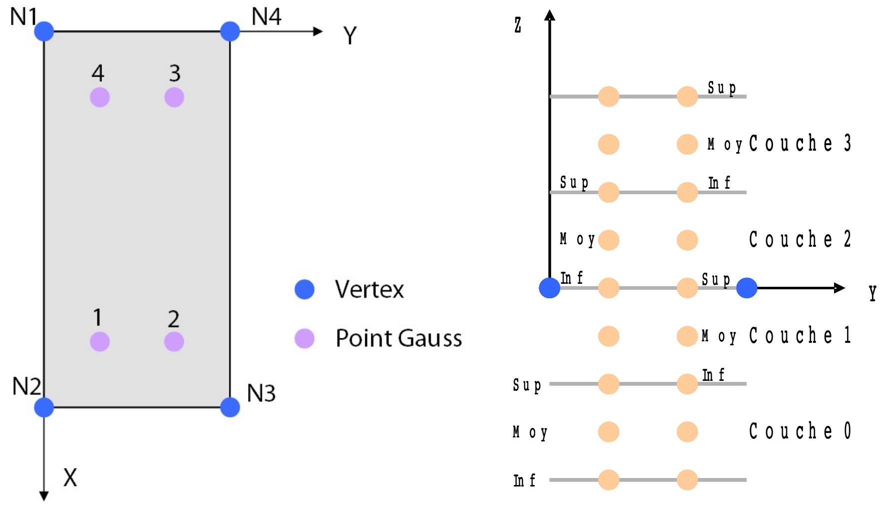
2.3 Uncertainties on the solution

No, exact solution.

3 Modelization A

3.1 Characteristic of the mesh

The mesh is composed of a standard mesh `QUAD4` with four nodes ($N1$ $N2$, $N3$ and $N4$).



For each mesh, there are 4 points of integration

- The nodes group ENC is composed of the nodes $N1$ and $N2$
- The nodes group CHA is compound due nodes $N3$ and $N4$

3.2 Characteristic of the modelization

Modelization:

```
MO=AFFE_MODELE (MAILLAGE=MA,
    AFFE=_F (TOUT=' OUI', PHENOMENE=' MECANIQUE',
        MODELISATION=' DKT',),
)
```

Boundary conditions:

```
BLOCAGE=AFFE_CHAR_MECA (MODELE=MO,
    DDL_IMPO=_F (GROUP_NO=' ENC',
        DX=0.0, DY=0.0, DZ=0.0, DRX=0.0, DRY=0.0, DRZ=0.0,),
)
```

mechanical Loading:

```
CHARGE=AFFE_CHAR_MECA (MODELE=MO,
    FORCE_NODALE=_F (GROUP_NO=' CHA', FX = 0, FY = 0, FZ = -100.),
)
```

Assignment of the characteristics of the elements:

```
PLAQUE=AFFE_CARA_ELEM (MODELE=MO,
    COQUE=_F (GROUP_MA= ("PLA"), EPAIS = 0.5, COQUE_NCOU = 4,),
)
```

3.3 Values tested and results

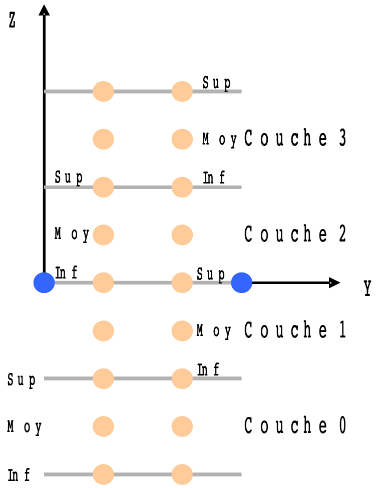
Coordinated mesh QUA1	Not of integration	subpoint	Reference
COOR_X	1	1	0.204941012
COOR_X	1	2	0.232004306
COOR_X	1	3	0.2590676
COOR_X	1	4	0.2590676
COOR_X	1	5	0.286130894
COOR_X	1	6	0.313194187
COOR_X	1	7	0.313194187
COOR_X	1	8	0.340257481
COOR_X	1	9	0.367320775
COOR_X	1	10	0.367320775
COOR_X	1	11	0.394384069
COOR_X	1	12	0.421447363
COOR_Y	1	1	0.490331216
COOR_Y	1	2	0.443456216
COOR_Y	1	3	0.396581216
COOR_Y	1	4	0.396581216
COOR_Y	1	5	0.349706216
COOR_Y	1	6	0.302831216
COOR_Y	1	7	0.302831216
COOR_Y	1	8	0.255956216
COOR_Y	1	9	0.209081216
COOR_Y	1	10	0.209081216
COOR_Y	1	11	0.162206216
COOR_X	1	12	0.115331216
COOR_Z	1	1	0.058012702
COOR_Z	1	2	0.089262702
COOR_Z	1	3	0.120512702
COOR_Z	1	4	0.120512702
COOR_Z	1	5	0.151762702
COOR_z	1	6	0.183012702
COOR_Z	1	7	0.183012702
COOR_Z	1	8	0.214262702
COOR_z	1	9	0.245512702
COOR_Z	1	10	0.245512702
COOR_Z	1	11	0.276762702
COOR_Z	1	12	the 0.308012702

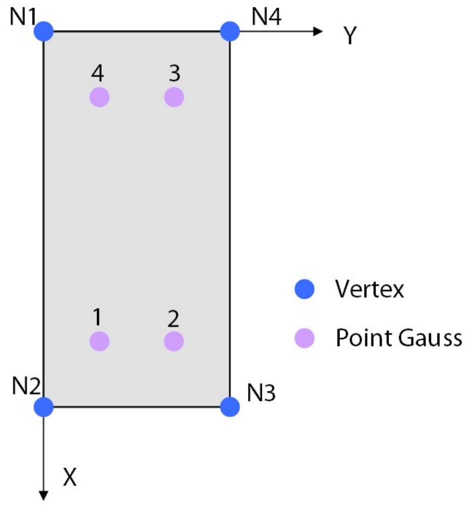
tolerance is of $1.0E-03$ for all the tests.

4 Modelization B

4.1 Characteristic of the mesh

Mesh: the mesh is made up of a standard mesh QUAD4 with four nodes ($N1$ $N2$, $N3$ and $N4$).





For each mesh, there are 4 points of integration:

- The nodes group ENC is composed of the nodes $N1$ and $N2$
- The nodes group CHA is compound due nodes $N3$ and $N4$

4.2 Characteristic of the modelization

Modelization:

```
MO=AFFE_MODELE (MAILLAGE=MA,
    AFFE=_F (TOUT=' OUI', PHENOMENE=' MECANIQUE',
        MODELISATION=' DST',),)
```

Boundary conditions:

```
BLOCAGE=AFFE_CHAR_MECA (MODELE=MO,
    DDL_IMPO=_F (GROUP_NO=' ENC',
        DX=0.0, DY=0.0, DZ=0.0, DRX=0.0, DRY=0.0, DRZ=0.0,),
)
```

mechanical Loading:

```
CHARGE=AFFE_CHAR_MECA (MODELE=MO,
    FORCE_NODALE=_F (GROUP_NO=' CHA', FX = 0, FY = 0, FZ = -100.),
)
```

Assignment of the characteristics of the elements:

```
PLAQUE=AFFE_CARA_ELEM (MODELE=MO,
    COQUE=_F (GROUP_MA= ("PLA"), EPAIS= 0.5, COQUE_NCOU = 4,),
)
```

4.3 Values tested and results

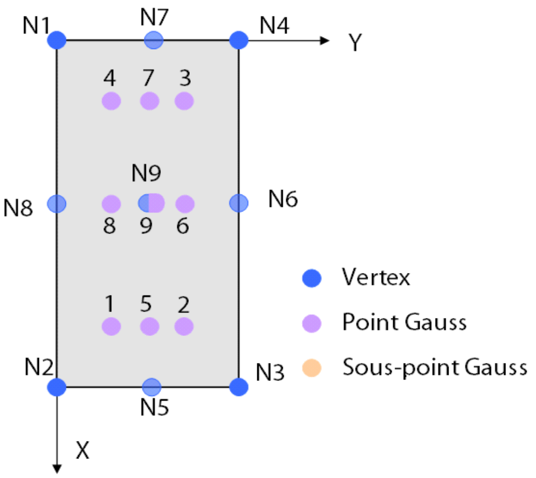
Coordinated mesh QUA1	Not of integration	subpoint	Reference
COOR_X	1	1	0.204941012
COOR_X	1	2	0.232004306
COOR_X	1	3	0.2590676
COOR_X	1	4	0.2590676
COOR_X	1	5	0.286130894
COOR_X	1	6	0.313194187
COOR_X	1	7	0.313194187
COOR_X	1	8	0.340257481
COOR_X	1	9	0.367320775
COOR_X	1	10	0.367320775
COOR_X	1	11	0.394384069
COOR_X	1	12	0.421447363
COOR_Y	1	1	0.490331216
COOR_Y	1	2	0.443456216
COOR_Y	1	3	0.396581216
COOR_Y	1	4	0.396581216
COOR_Y	1	5	0.349706216
COOR_Y	1	6	0.302831216
COOR_Y	1	7	0.302831216
COOR_Y	1	8	0.255956216
COOR_Y	1	9	0.209081216
COOR_Y	1	10	0.209081216
COOR_Y	1	11	0.162206216
COOR_X	1	12	0.115331216
COOR_Z	1	1	0.058012702
COOR_Z	1	2	0.089262702
COOR_Z	1	3	0.120512702
COOR_Z	1	4	0.120512702
COOR_Z	1	5	0.151762702
COOR_z	1	6	0.183012702
COOR_Z	1	7	0.183012702
COOR_Z	1	8	0.214262702
COOR_z	1	9	0.245512702
COOR_Z	1	10	0.245512702
COOR_Z	1	11	0.276762702
COOR_Z	1	12	the 0.308012702

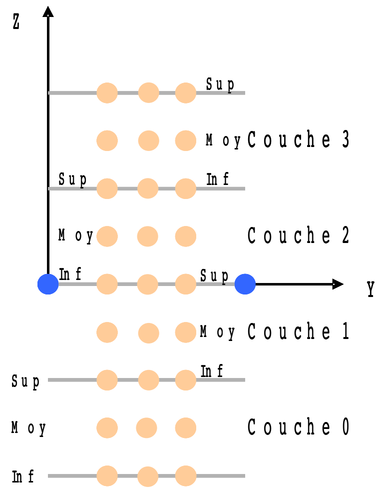
tolerance is of $1.0\mathrm{E}-03$ for all the tests.

5 Modelization C

5.1 Characteristic of the mesh

Mesh: the mesh is composed of a standard mesh QUAD9 with nine nodes ($N1$ $N2$ $N3$ $N4$ $N5$ $N6$ $N7$ $N8$, $N9$).





For each mesh, there are 9 points of integration.

- The nodes group ENC is composed of the nodes $N1$ and $N2$
- The nodes group CHA is composed of the nodes $N3$ and $N4$

5.2 Characteristic of the modelization

Modelization:

```
MO=AFFE_MODELE (MAILLAGE=MA,
    AFFE=_F (TOUT=' OUI', PHENOMENE=' MECANIQUE',
        MODELISATION=' COQUE_3D',),)
```

Boundary conditions:

```
BLOCAGE=AFFE_CHAR_MECA (MODELE=MO,
    DDL_IMPO=_F (GROUP_NO=' ENC',
        DX=0.0, DY=0.0, DZ=0.0, DRX=0.0, DRY=0.0, DRZ=0.0,),
)
```

mechanical Loading:

```
CHARGE=AFFE_CHAR_MECA (MODELE=MO,
    FORCE_NODALE=_F (GROUP_NO=' CHA', FX = 0, FY = 0, FZ = -100.),
)
```

Assignment of the characteristics of the elements:

```
PLAQUE=AFFE_CARA_ELEM (MODELE=MO,
    COQUE=_F (GROUP_MA= ("PLA"), EPAIS = 0.5, COQUE_NCOU = 4,),
)
```

5.3 Values tested and results

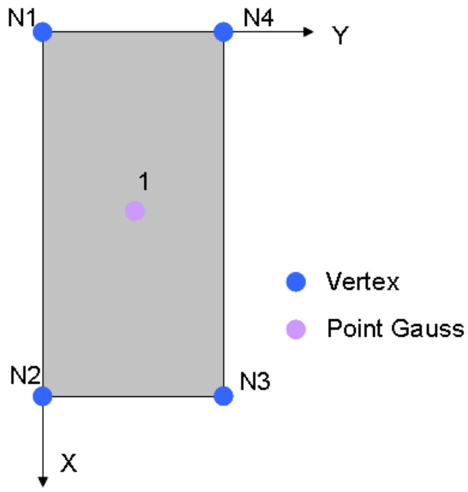
Coordinated mesh QUA1	Not of integration	subpoint	Reference
COOR_X	1	1	0.058776419
COOR_X	1	2	0.085839713
COOR_X	1	3	0.112903006
COOR_X	1	4	0.112903006
COOR_X	1	5	0.139966300
COOR_X	1	6	0.167029594
COOR_X	1	7	0.167029594
COOR_X	1	8	0.194092888
COOR_X	1	9	0.221156182
COOR_X	1	10	0.221156182
COOR_X	1	11	0.248219476
COOR_X	1	12	0.275282770
COOR_Y	1	1	0.349002918
COOR_Y	1	2	0.302127918
COOR_Y	1	3	0.2552529180
COOR_Y	1	4	0.2552529180
COOR_Y	1	5	0.2083779180
COOR_Y	1	6	0.1615029180
COOR_Y	1	7	0.1615029180
COOR_Y	1	8	0.1146279180
COOR_Y	1	9	0.0677529180
COOR_Y	1	10	0.0677529180
COOR_Y	1	11	0.0208779180
COOR_Y	1	12	-0.025997082
COOR_Z	1	1	-0.027397495
COOR_Z	1	2	3.852505E-03
COOR_Z	1	3	0.0351025050
COOR_Z	1	4	0.0351025050
COOR_Z	1	5	0.0663525050
COOR_z	1	6	0.0976025050
COOR_Z	1	7	0.0976025050
COOR_Z	1	8	0.1288525050
COOR_z	1	9	0.1601025050
COOR_Z	1	10	0.1601025050
COOR_Z	1	11	0.1913525050
COOR_Z	1	12	0.2226025050
COOR_Z	9	1	0.3080127020
COOR_Z	9	2	0.3392627020
COOR_Z	9	3	0.3705127020
COOR_Z	9	4	0.3705127020
COOR_Z	9	5	0.4017627020
COOR_z	9	6	0.4330127020
COOR_Z	9	7	0.4330127020
COOR_Z	9	8	0.4642627020
COOR_z	9	9	0.4955127020
COOR_Z	9	10	0.4955127020
COOR_Z	9	11	0.5267627020
COOR_Z	9	12	the 0.5580127020

tolerance is of $1.0\text{E}-03$ for all the tests.

6 Modelization D

6.1 Characteristic of the mesh

Mesh: the mesh is composed of two meshes superimposed of type QUAD4 with four nodes ($N1$ $N2$ $N3$, $N4$). One of meshes is intended to model an element DKT and the other is intended to model an element GRILLE_EXCENTRE.



For the mesh of offset grid has only one point of integration, confused with its only subpoint.

- The nodes group ENC is composed of the nodes $N1$ and $N2$
- The nodes group CHA is compound due nodes $N3$ and $N4$

6.2 Characteristic of the modelization

Modelization:

```
MO=AFFE_MODELE (MAILLAGE=MA,
    AFFE= (
        _F (GROUP_MA=' PLA', PHENOMENE=' MECANIQUE', MODELISATION=' DKT'),
        _F (GROUP_MA=' GRI', PHENOMENE=' MECANIQUE',
            MODELISATION=' GRILLE_EXCENTRE',))
)
```

Boundary conditions:

```
BLOCAGE=AFFE_CHAR_MECA (MODELE=MO,
    DDL_IMPO=_F (GROUP_NO=' ENC',
    DX=0.0, DY=0.0, DZ=0.0, DRX=0.0, DRY=0.0, DRZ=0.0,),
)
```

mechanical Loading:

```
CHARGE=AFFE_CHAR_MECA (MODELE=MO,
    FORCE_NODALE=_F (GROUP_NO=' CHA', FX = 0, FY = 0, FZ = -100.),
)
```

Assignment of the characteristics of the elements:

```
PLAQUE=AFFE_CARA_ELEM (MODELE=MO,
    COQUE=_F (GROUP_MA= ("PLA"), EPAIS=0.05,),
    GRILL=_F (GROUP_MA= ("GRI"), SECTION = 0.01, EXCENTREMENT = 0.05,
        ANGL_REP= (10,10),),
)
```

6.3 Values tested and results

Coordinated mesh QUA2	Not of integration	subpoint	Reference
COOR_X	1	1	0.762676039
COOR_Y	1	1	0.679006351
COOR_Z	1	1	the 0.458012702

tolerance is of $1.0E-03$ for all the tests.

7 The purpose of summary of the results

This test is principal to check if the positions of under points of integration of modelization DKT, DST, COQUE_3D and GRILLE_EXCENTRE are well calculated.

For this modelization, the maximum error found is of $3.0E-07\%$.