SSLS115 - Composite square plate under uniform pressure

Abstract:

One treats the case of a square plate sort-layers, simply supported and subjected to a uniform pressure. The skins consist of an orthotropic homogeneous material, as well as the heart (same axes of orthotropy). The moduli E and G of the heart are ten times weaker than those of the skins.

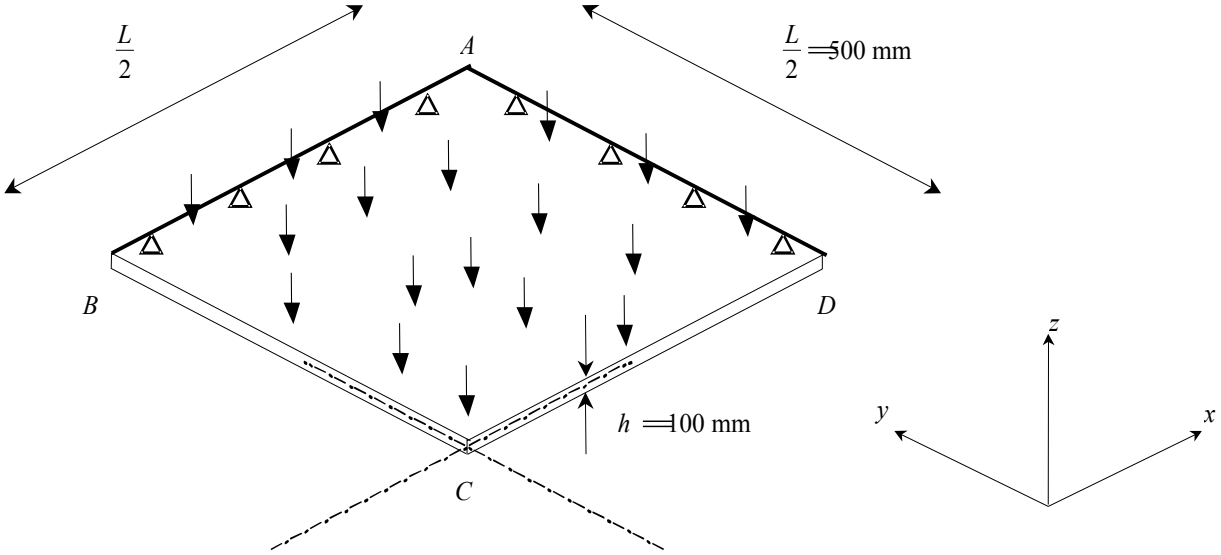
One calculates displacement in the center as well as the stresses with the lower and higher interfaces of the skins.

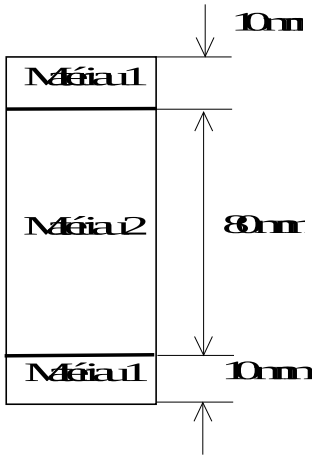
The test gathers eight modelizations: with regard to the four first, the got results are compared for meshes surface triangular the then quadrangular ones, in two different references user. The four last modelizations make it possible to measure the sensitivity of the results meshes the directional sense of triangular in the two references user.

1 Problem of reference

1.1 Geometry

Because of the geometrical and physical symmetry of the problem, only the quarter of the plate is modelled.





Slenderness: $\frac{L}{h}=10$: the plate is relatively thick.

1.2 Material properties

	Material 1	Material 2
$E_L(10^{11}N/m^2)$	3.4156	0.34156
$E_T(10^{11}N/m^2)$	1.793	0.1793
$G_{LN}(10^{11}N/m^2)$	0.608	0.0608
$G_{TN}(10^{11}N/m^2)$	1.015	0.1015
$G_{LT}(10^{11}N/m^2)$	1.0.0.1	
NU_T	0.44	0.44

1.3 Boundary conditions and loadings

simple Plate bearing

Boundary conditions:	AB :	$DZ=0.$	$DRY=0.$	
	AD :	$DZ=0.$	$DRX=0.$	
Symmetry	BC :	$DX=0.$	$DRY=0.$	$DRZ=0.$
	CD :	$DY=0.$	$DRX=0.$	$DRZ=0.$

Loading:

Uniform	FORCE_COQUE Pressure	$P=1\mathrm{N}/m^2$

2 Reference solution

2.1 Reference solution

the numerical solution obtained with a theory of plate multi-layer in orthotropic linear elasticity is given in the reference [bib1] page 341.

2.2 Results of reference

To the point C, one calculates the following displacement z of the point as well as the stresses σ_x with the lower and higher interfaces of the skins.

2.3 Uncertainty on the numerical

solution Solution.

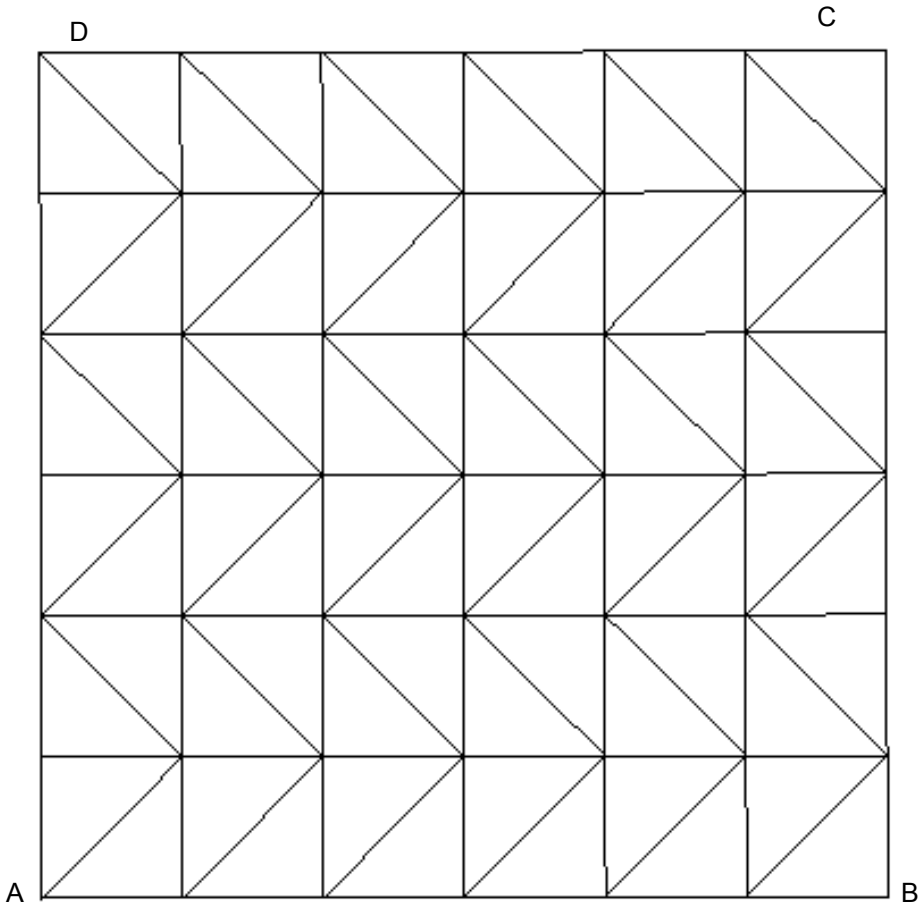
2.4 Bibliographical references

1) BATOZ and DHATT. Modelization of structures by finite elements. Beams and plates. Hermes, 1990.

3 Modelization A

3.1 Characteristic of the modelization

Shell element DST (modelization of a quarter of plate).
The reference user is confused with orthotropic reference.



limiting Conditions:
```
DDL_IMPO
(GROUP_NO=' AB', DZ=0., DRY=0.)
(GROUP_NO=' BC', DX=0., DRY=0.)
(GROUP_NO=' CD', DY=0., DRX=0.)
(GROUP_NO=' DA', DZ=0., DRX=0.)
```

Not C mesh: 72

3.2 Characteristics of the mesh

Many nodes: 56

Number of meshes and types: 72 TRIA3

3.3 Values tested

Not C	Identification	Reference	*Aster*	% Difference
	σ_x on lower layer 3	4.7100E+01	4.7662E+01	1.194

Stresses	σ_x on higher layer 3	5.8800E+01	5.9577E+01	1.323
	σ_x out of lower layer 2	– 4.7100E+01	– 4.7662E+01	1.194
	σ_x on higher layer 2	4.7100E+01	4.7662E+01	1.194
	σ_x on lower layer 1	– 5.8800E+01	– 5.9577E+01	1.323
	σ_x on layer 1 higher	– 4.7100E+01	– 4.7662E+01	1.194
Displacement	DX	0.0.0.0.0.0		
	DY	0.0.0.0.0.0		
	DZ	4.1920E+01	4.1851E+01	– 0.163

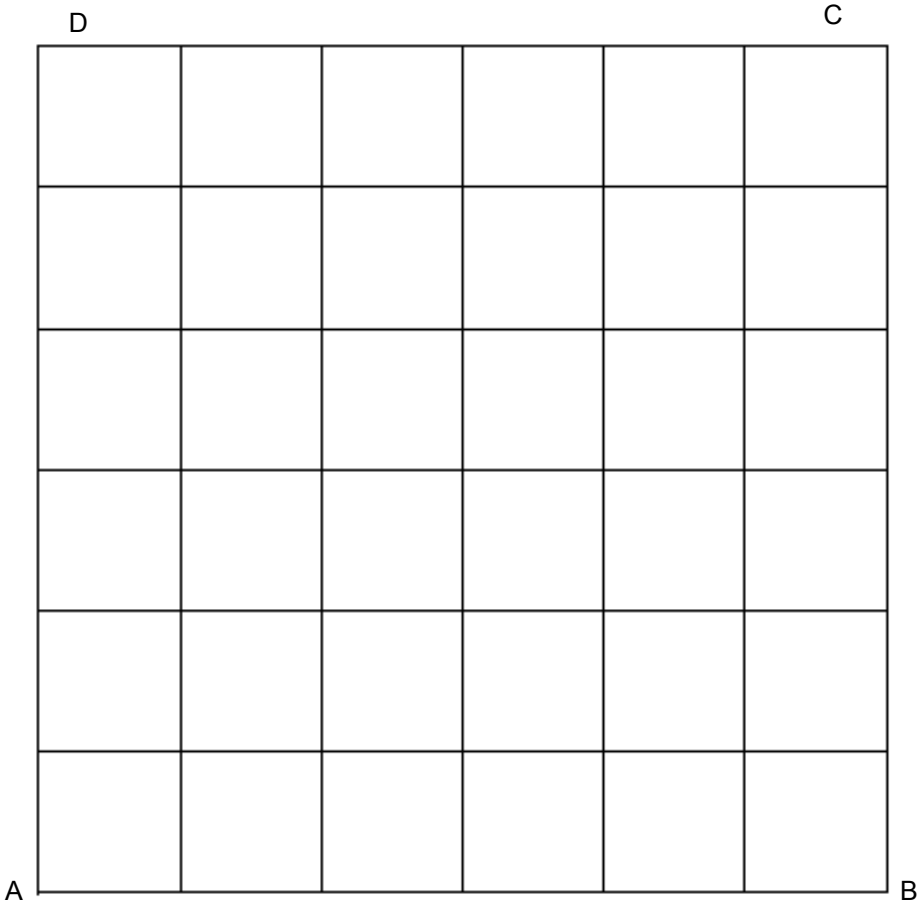
3.4 Contents of the file Values

results than the point of observation of displacements and stresses σ_x.

4 Modelization B

4.1 Characteristic of the modelization

Shell element DST (modelization of a quarter of plate).
The reference user is confused with orthotropic reference.



Boundary conditions :

```
DDL_IMPO
(GROUP_NO='     AB',     DZ=0.,
DRY=0.)
(GROUP_NO='     BC',     DX=0.,
DRY=0.)
(GROUP_NO='     CD',     DY=0.,
DRX=0.)
(GROUP_NO='     DA',     DZ=0.,
DRX=0.)
```

Not C mesh: 36

4.2 Characteristics of the mesh

Many nodes: 57

Number of meshes and types: 36 QUAD4

4.3 Values tested

Not C	Identification	Reference	*Aster*	% Difference
Stresses	σ_x on lower layer 3	4.7100E+01	5.0881E+01	8.028
	σ_x on higher layer 3	5.8800E+01	6.3601E+01	8.166
	σ_x out of lower layer 2	– 4.7100E+01	– 5.0881E+01	8.028
	σ_x on higher layer 2	4.7100E+01	5.0881E+01	8.028
	σ_x on lower layer 1	– 5.8800E+01	– 6.3601E+01	8.166
	σ_x on layer 1 higher	– 4.7100E+01	– 5.0881E+01	8.028
Displacement	DX	0.0.0.0.0.0		
	DY	0.0.0.0.0.0		
	DZ	4.1920E+01	4.2040E+01	0.29

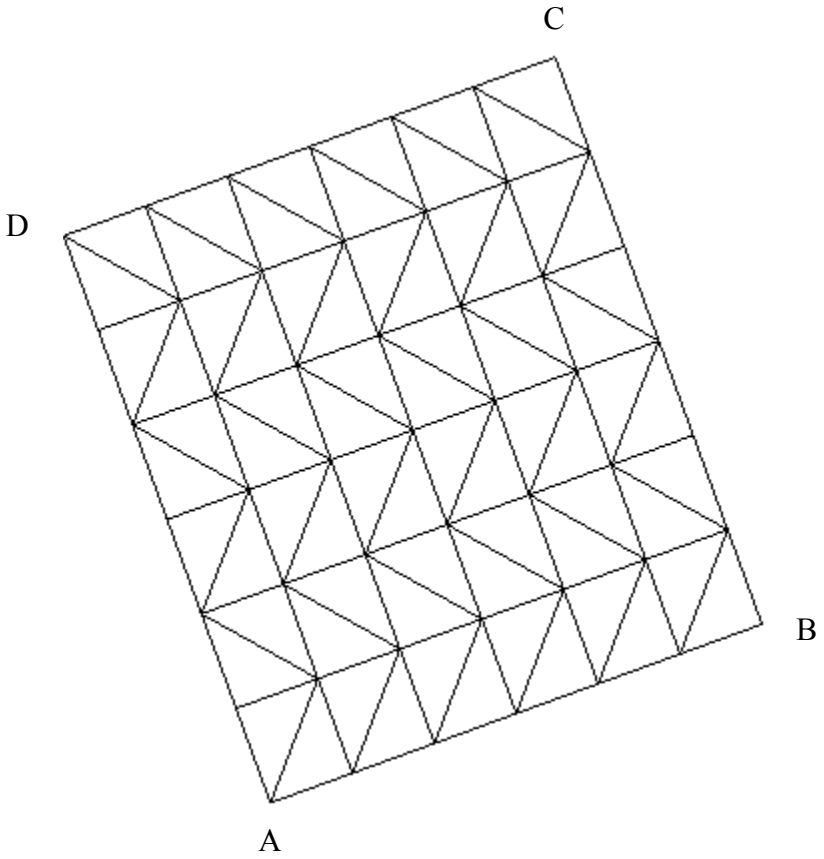
4.4 Contents of the file Values

results than the point of observation of displacements and stresses σ_x.

5 Modelization C

5.1 Characteristic of the modelization

Shell element DST (modelization of a quarter of plate).
The model of plate associated with the modelization A is turned of 20 degrees according to the nautical angle alpha and of 30 degrees according to beta.



Boundary conditions :

```
LIAISON_OBLIQUE
(GROUP_NO=' AB', ANGL_NAUT= (20. , 30. , 0.), DZ=0.,
DRY=0.)
(GROUP_NO=' BC', ANGL_NAUT= (20. , 30. , 0.), DX=0.,
DRY=0.)
(GROUP_NO=' CD', ANGL_NAUT= (20. , 30. , 0.), DY=0.,
DRX=0.)
(GROUP_NO=' DA', ANGL_NAUT= (20. , 30. , 0.), DZ=0.,
DRX=0.)
```

Not C mesh: 72

5.2 Characteristics of the mesh

Many nodes: 56

Number of meshes and types: 72 TRIA3

5.3 Values tested

Not C	Identification	Reference	*Aster*	% Difference
Stresses	σ_x on lower layer 3	4.7100E+01	4.7662E+01	1.194
	σ_x on higher layer 3	5.8800E+01	5.9577E+01	1.323
	σ_x out of lower layer 2	– 4.7100E+01	– 4.7662E+01	1.194
	σ_x on higher layer 2	4.7100E+01	4.7662E+01	1.194
	σ_x on lower layer 1	– 5.8800E+01	– 5.9577E+01	1.323
	σ_x on higher layer 1	– 4.7100E+01	– 4.7662E+01	1.194
Displacement	DX	1.9696E+01	1.9663E+01	– 0.163
	DY	7.1687E+00	7.1570E+00	– 0.162
	DZ	3.6304E+01	3.6244E+01	– 0.163

5.4 Remarks

the values of reference of displacement to the point C are obtained by projecting the theoretical displacement established for a plate not turned in the new reference user (displacement for a not turned plate being vertical, new displacement is function of the projection of the axis Z). In the local coordinate system, the projection of the axis Z is the following one:

$$\begin{pmatrix} \sin\beta\cos\alpha \\ \sin\beta\sin\alpha \\ \cos\beta \end{pmatrix}, \text{ with } \alpha = 20. \text{ and } \beta = 30.$$

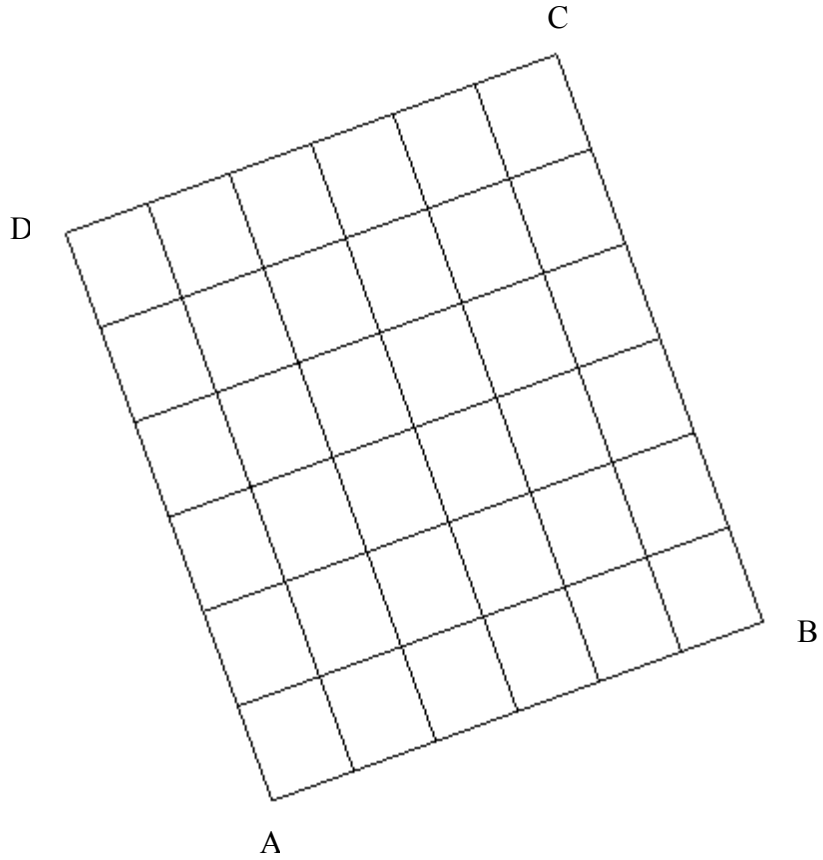
5.5 Contained file Values

results at the point of observation of displacements and stresses σ_x.

6 Modelization D

6.1 Characteristic of the modelization

Shell element DST (modelization of a quarter of plate).
The model of plate associated with the modelization B is turned of 20 degrees according to the nautical angle alpha and of 30 degrees according to beta.



Boundary conditions :

```
LIAISON_OBLIQUE
(GROUP_NO=' AB', ANGL_NAUT= (20. , 30. , 0.), DZ=0.,
DRY=0.)
(GROUP_NO=' BC', ANGL_NAUT= (20. , 30. , 0.), DX=0.,
DRY=0.)
(GROUP_NO=' CD', ANGL_NAUT= (20. , 30. , 0.), DY=0.,
DRX=0.)
(GROUP_NO=' DA', ANGL_NAUT= (20. , 30. , 0.), DZ=0.,
DRX=0.)
```

Not C mesh: 36

6.2 Characteristics of the mesh

Many nodes: 57

Number of meshes and types: 36 QUAD4

6.3 Values tested

Not C	Identification	Reference	*Aster*	% Difference
Stresses	σ_x on lower layer 3	4.7100E+01	5.0881E+01	8.028
	σ_x on higher layer 3	5.8800E+01	6.3601E+01	8.166
	σ_x out of lower layer 2	– 4.7100E+01	– 5.0881E+01	8.028
	σ_x on higher layer 2	4.7100E+01	5.0881E+01	8.028
	σ_x on lower layer 1	– 5.8800E+01	– 6.3601E+01	8.166
	σ_x on layer 1 higher	– 4.7100E+01	– 5.0881E+01	8.028
Displacement	DX	1.9696E+01	1.9750E+01	0.290
	DY	7.1687E+00	7.1895E+00	0.291
	DZ	3.6304E+01	3.6409E+01	0.289

6.4 Remarks

the values of reference of displacement than the point C are obtained by projecting the theoretical displacement established for a plate not turned in the new reference user (displacement for a not turned plate being vertical, new displacement is function of the projection of the axis Z). In the local coordinate system, the projection of the axis Z is the following one:

$$\begin{pmatrix} \sin\beta\cos\alpha \\ \sin\beta\sin\alpha \\ \cos\beta \end{pmatrix}, \text{ with } \alpha = 20. \text{ and } \beta = 30.$$

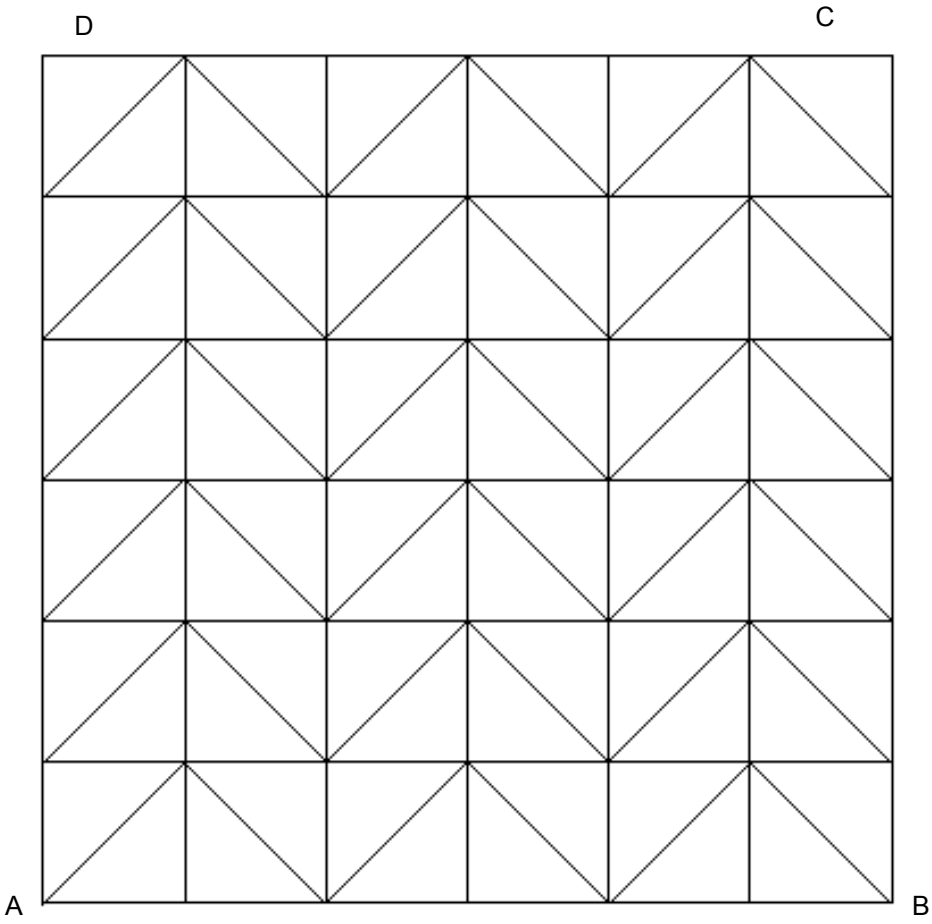
6.5 Contained file Values

results at the point of observation of displacements and stresses σ_x.

7 Modelization E

7.1 Characteristic of the modelization

Shell element DST (modelization of a quarter of plate).
The reference user is confused with orthotropic reference. Compared to the modelization A, the model is characterized here by a directional sense different from meshes surface.



Boundary conditions :

```
DDL_IMPO
(GROUP_NO='     AB',     DZ=0.,
DRY=0.)
(GROUP_NO='     BC',     DX=0.,
DRY=0.)
(GROUP_NO='     CD',     DY=0.,
DRX=0.)
(GROUP_NO='     DA',     DZ=0.,
DRX=0.)
```

Not C mesh: 72

7.2 Characteristics of the mesh

Many nodes: 56

Number of meshes and types: 72 TRIA3

7.3 Values tested

Not C	Identification	Reference	*Aster*	% Difference
Stresses	σ_x on lower layer 3	4.7100E+01	5.2430E+01	11.317
	σ_x on higher layer 3	5.8800E+01	6.5537E+01	11.459
	σ_x out of lower layer 2	– 4.7100E+01	– 5.2430E+01	11.317
	σ_x on higher layer 2	4.7100E+01	5.2430E+01	11.317
	σ_x on lower layer 1	– 5.8800E+01	– 6.5537E+01	11.459
	σ_x on layer 1 higher	– 4.7100E+01	– 5.2430E+01	11.317
Displacement	DX	0.0.0.0.0.0		
	DY	0.0.0.0.0.0		
	DZ	4.1920E+01	4.2024E+01	0.248

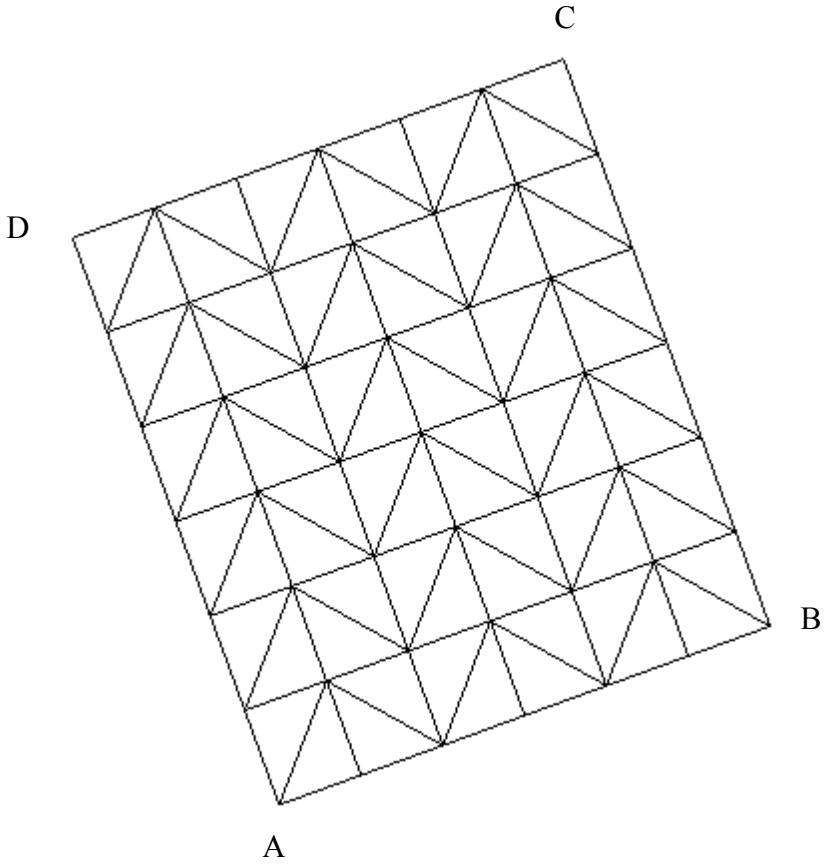
7.4 Contents of the file Values

results than the point of observation of displacements and stresses σ_x.

8 Modelization F

8.1 Characteristic of the modelization

Shell element DST (modelization of a quarter of plate).
The model of plate associated with the modelization E is turned of 20 degrees according to the nautical angle alpha and of 30 degrees according to beta. Compared to the modelization C, the model is characterized here by a directional sense different from meshes.



Boundary conditions :

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LIAISON_OBLIQUE
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DRY=0.)
(GROUP_NO=' BC', ANGL_NAUT= (20. , 30. , 0.), DX=0.,
DRY=0.)
(GROUP_NO=' CD', ANGL_NAUT= (20. , 30. , 0.), DY=0.,
DRX=0.)
(GROUP_NO=' DA', ANGL_NAUT= (20. , 30. , 0.), DZ=0.,
DRX=0.)
```

Not C mesh: 72

8.2 Characteristics of the mesh

Many nodes: 56

Number of meshes and types: 72 TRIA3

8.3 Values tested

Not C	Identification	Reference	*Aster*	% Difference
Stresses	σ_x on lower layer 3	4.7100E+01	5.2430E+01	11.317
	σ_x on higher layer 3	5.8800E+01	6.5537E+01	11.459
	σ_x out of lower layer 2	– 4.7100E+01	– 5.2430E+01	11.317
	σ_x on higher layer 2	4.7100E+01	5.2430E+01	11.317
	σ_x on lower layer 1	– 5.8800E+01	– 6.5537E+01	11.459
	σ_x on layer 1 higher	– 4.7100E+01	– 5.2430E+01	11.317
Displacement	DX	1.9696E+01	1.9744E+01	0.248
	DY	7.1687E+00	7.1865E+00	0.249
	DZ	3.6304E+01	3.6393E+01	0.248

8.4 Remarks

the values of reference of displacement than the point C are obtained by projecting the theoretical displacement established for a plate not turned in the new reference user (displacement for a not turned plate being vertical, new displacement is function of the projection of the axis Z). In the local coordinate system, the projection of the axis Z is the following one:

$$\begin{pmatrix} \sin\beta\cos\alpha \\ \sin\beta\sin\alpha \\ \cos\beta \end{pmatrix}, \text{ with } \alpha = 20. \text{ and } \beta = 30.$$

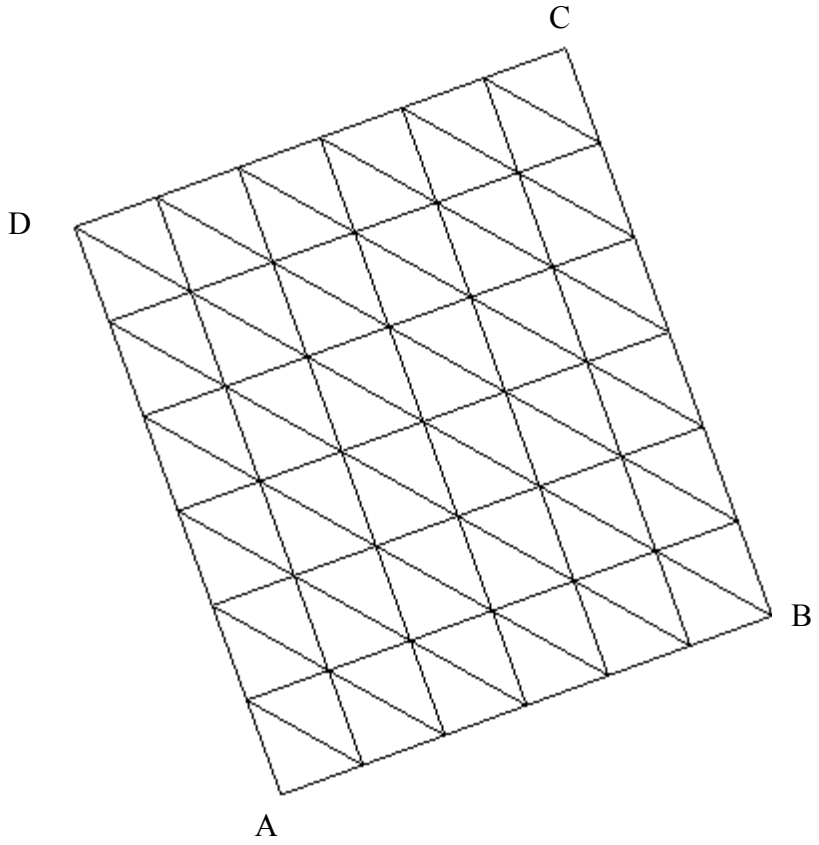
8.5 Contained file Values

results at the point of observation of displacements and stresses σ_x.

9 Modelization G

9.1 Characteristic of the modelization

Shell element DST (modelization of a quarter of plate).
The model of plate is turned of 20 degrees according to the nautical angle alpha and of 30 degrees according to beta, without reference to a model not turned.
The directional sense of meshes is here identical to that of the reference [bib1].



Limiting conditions:

```
LIAISON_OBLIQUE
(GROUP_NO='  AB',  ANGL_NAUT=  (20.  ,  30.  ,  0.),  DZ=0.,
DRY=0.)
(GROUP_NO='  BC',  ANGL_NAUT=  (20.  ,  30.  ,  0.),  DX=0.,
DRY=0.)
(GROUP_NO='  CD',  ANGL_NAUT=  (20.  ,  30.  ,  0.),  DY=0.,
DRX=0.)
(GROUP_NO='  DA',  ANGL_NAUT=  (20.  ,  30.  ,  0.),  DZ=0.,
DRX=0.)
```

Not C mesh: 72

9.2 Characteristics of the mesh

Many nodes: 56

Number of meshes and types: 72 TRIA3

9.3 Values tested

Not C	Identification	Reference	*Aster*	% Difference
Stresses	σ_x on lower layer 3	4.7100E+01	4.7920E+01	1.742
	σ_x on higher layer 3	5.8800E+01	5.9900E+01	1.872
	σ_x out of lower layer 2	– 4.7100E+01	– 4.7920E+01	1.742
	σ_x on higher layer 2	4.7100E+01	4.7920E+01	1.742
	σ_x on lower layer 1	– 5.8800E+01	– 5.9900E+01	1.872
	σ_x on layer 1 higher	– 4.7100E+01	– 4.7920E+01	1.742
Displacement	DX	1.9696E+01	1.9882E+01	0.946
	DY	7.1687E+00	7.2365E+00	0.947
	DZ	3.6304E+01	3.6647E+01	0.946

9.4 Remarks

the values of reference of displacement than the point C are obtained by projecting the theoretical displacement established for a plate not turned in the new reference user (displacement for a not turned plate being vertical, new displacement is function of the projection of the axis Z). In the local coordinate system, the projection of the axis Z is the following one:

$$\begin{pmatrix} \sin\beta\cos\alpha \\ \sin\beta\sin\alpha \\ \cos\beta \end{pmatrix}, \text{ with } \alpha = 20. \text{ and } \beta = 30.$$

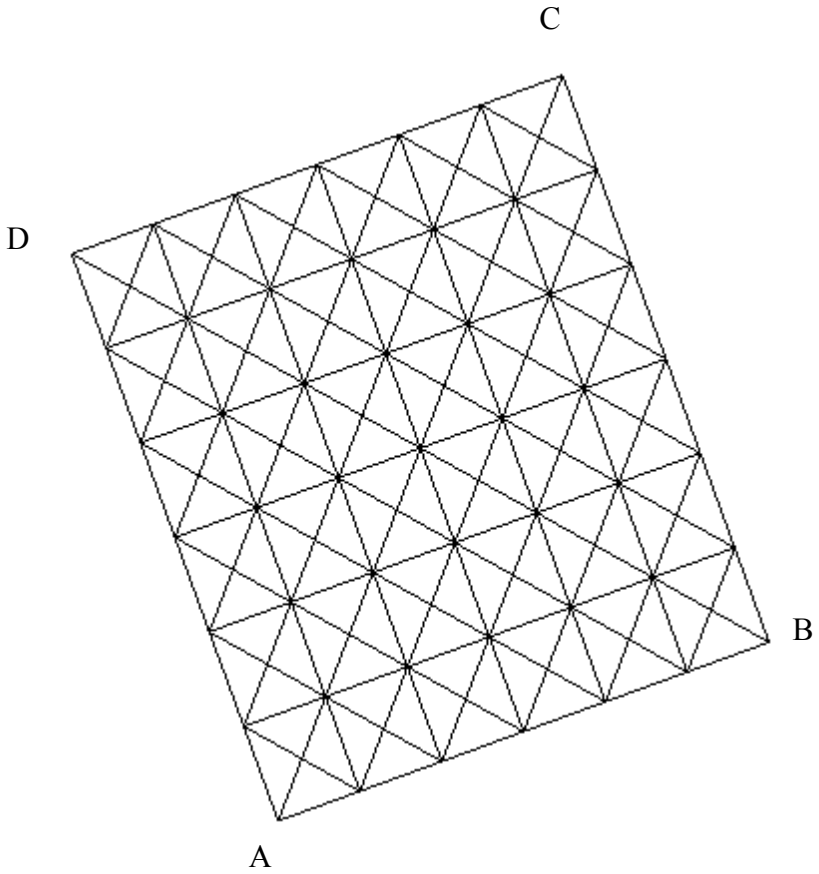
9.5 Contained file Values

results at the point of observation of displacements and stresses σ_x.

10 Modelization H

10.1 Characteristic of the modelization

Shell element DST (modelization of a quarter of plate).
The model of plate is turned of 20 degrees according to the nautical angle alpha and of 30 degrees according to beta, without reference to a model not turned.



Limiting conditions:

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LIAISON_OBLIQUE
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DRY=0.)
(GROUP_NO='  BC',  ANGL_NAUT=  (20.  ,  30.  ,  0.),  DX=0.,
DRY=0.)
(GROUP_NO='  CD',  ANGL_NAUT=  (20.  ,  30.  ,  0.),  DY=0.,
DRX=0.)
(GROUP_NO='  DA',  ANGL_NAUT=  (20.  ,  30.  ,  0.),  DZ=0.,
DRX=0.)
```

Not C mesh: 142

10.2 Characteristics of the mesh

Many nodes: 101

Number of meshes and types: 144 TRIA3

10.3 Values tested

Not C	Identification	Reference	*Aster*	% Difference
Stresses	σ_x on lower layer 3	4.7100E+01	5.0957E+01	8.19
	σ_x on higher layer 3	5.8800E+01	6.3691E+01	8.32
	σ_x out of lower layer 2	– 4.7100E+01	– 5.0957E+01	8.19
	σ_x on higher layer 2	4.7100E+01	5.0957+01	8.19
	σ_x out of lower layer 1	– 5.8800E+01	– 6.3696E+01	8.32
	σ_x on layer 1 higher	– 4.7100E+01	– 5.0957E+01	8.19
Displacement	DX	1.9696E+01	1.9735E+01	0.199
	DY	7.1687E+00	7.1830E+00	0.200
	DZ	3.6304E+01	3.6376E+01	0.200

10.4 Remarks

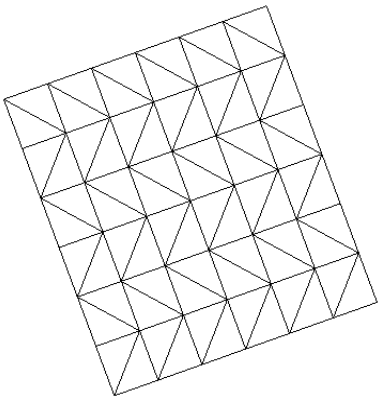
the values of reference of displacement than the point C are obtained by projecting the theoretical displacement established for a plate not turned in the new reference user (displacement for a not turned plate being vertical, new displacement is function of the projection of the axis Z). In the local coordinate system, the projection of the axis Z is the following one:

$$\begin{pmatrix} \sin\beta\cos\alpha \\ \sin\beta\sin\alpha \\ \cos\beta \end{pmatrix}, \text{ with } \alpha = 20. \text{ and } \beta = 30.$$

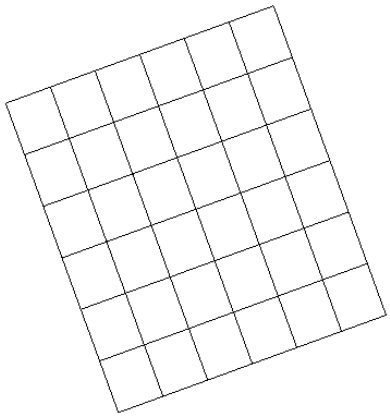
10.5 Contained file Values

results at the point of observation of displacements and stresses σ_x.

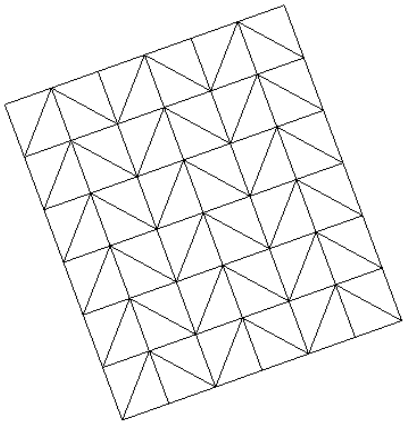
11 Graphic synthesis



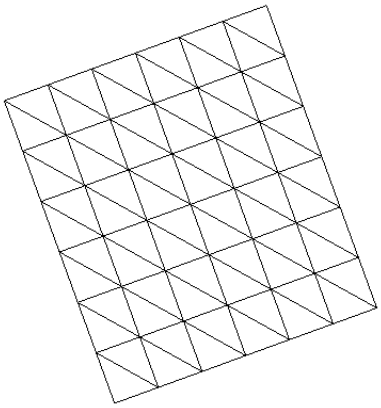
Modelization C



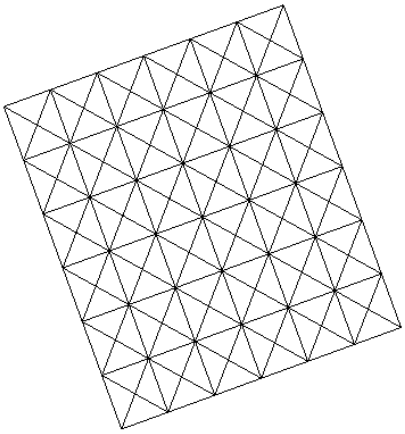
Modelization D



Modelization F



Modelization G



Modelization H

	% Forced	% Displacement
C	1.2	– 0.17
D	8.1	0.23
F	11.4	0.25
G	1.8	0.95

	H	8.2	0.20

12 Summary of the results

the got results show that:

A identical mesh (standard of meshes surface and directional sense of meshes), the change of reference user does not influence the stresses;
Because of orthotropy of the problem, there meshes exists a considerable sensitivity to the directional sense of surface triangular (the accuracy of computations passes from 1 to 11% for the stresses and from 0.17 to 0.95% for displacements). This sensitivity does not disappear by refining the mesh. This point is thus to take into account at the time of the comparison of the performances triangle/quadrangle.