

SSLX100 - Mixture 3D - Hull - Beam in inflection

Summary:

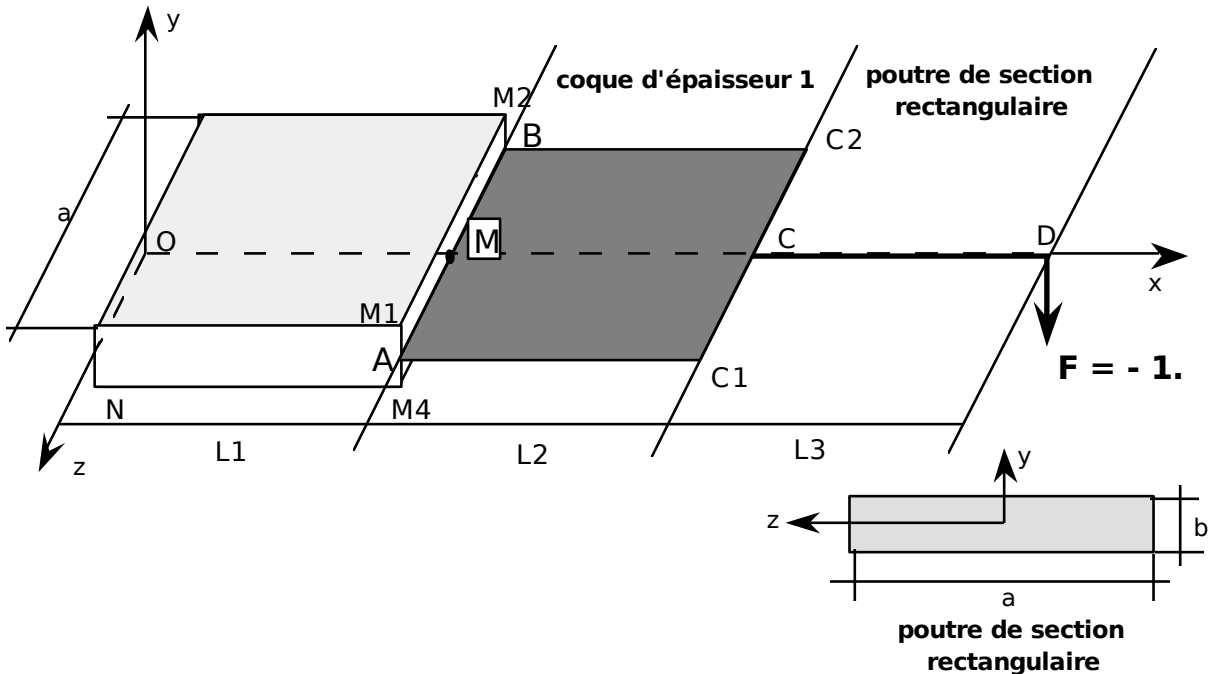
This test makes it possible to validate for a linear elastic design:

- a mixture of various mechanical models: model 3D (element HEXA20), models of hull (elements DKT, or elements COQUE_3D) and model of beam (elements POU_D_E),
- linear relations between degrees of freedom, built in particular with the connections [R3.03.03] and [R3.03.06].

The test is based on the analytical solution **rubber band** of a beam in inflection. The reduced number of elements for the different ones **models** led to a poor solution, which is however improved clearly with employment of boundary conditions appropriate to the theory of the beams.

1 Problem of reference

1.1 Geometry



$$\begin{aligned} L1 &= L2 = L3 = 10 \text{ mm} \\ b &= 1 \text{ mm} \\ a &= 3 \text{ mm} \end{aligned}$$

1.2 Material properties

$$E = 200\,000 \text{ MPa}$$

$$\nu = 0.3$$

$\nu = 0.0$ allows to avoid the variation of orthogonal curve induced by the effect Fish in the plates, which causes a difference between the theories of beams and plates, out of average fibre.

1.3 Boundary conditions and loadings

- force $F_y = -1$ (load 1) or couples $C_z = 1$ (load 2)
- defined or applied to neutral fibre
- embedding of the section $x = 0$
- continuity of displacements of translation on AB
- continuity of displacements of translation in C
- equality of displacements of rotation around z on $C1-C2$
- for the points M section ($M1$ $M2$ $M4$) displacements of translation $u(M)$ depend linearly on the displacement of rotation φ_z points P of AB

$$u(M) = -\varphi_z(P) \cdot y + dx(P)$$

2 Reference solution

2.1 Method of calculating used for the reference solution

Analytical solution, *isostatic structure*.

The elastic arrow, elastic constraints and axial deformations and bending moment in any point of X-coordinate x are given by:

- Load n°1: force $F_y = -1$

$$\begin{aligned}M_y(x) &= F_y \cdot L(1 - x/L) && (= E \cdot I_z \cdot u_y''(x) \text{ in elasticity}) \\u_y(x) &= F_y \cdot L \cdot x^2 \cdot (3 - x/L) / (6 \cdot E \cdot I_z) && (\text{in elasticity}) \\\varepsilon_{xx}(x, y) &= -F_y \cdot L(1 - x/L) \cdot y / (E \cdot I_z) && (\text{in elasticity}) \\\sigma_{xx}(x, y) &= -F_y \cdot L(1 - x/L) \cdot y / I_z && (\text{in elasticity})\end{aligned}$$

- Load n°2: couples $C_z = 1$ or rotation $dr_z = C_{z,L} / (E \cdot I_z)$

$$\begin{aligned}M_y(x) &= C_z && (= E \cdot I_z \cdot u_y''(x) \text{ in elasticity}) \\u_y(x) &= C_z \cdot x^2 / (2 \cdot E \cdot I_z) && (\text{in elasticity}) \\\sigma_{xx}(x, y) &= -C_z \cdot y / I_z && (\text{in elasticity}) \\\varepsilon_{xx}(x, y) &= -C_z \cdot y / (E \cdot I_z) && (\text{in elasticity})\end{aligned}$$

with:

$$\begin{aligned}L &= L1 + L2 + L3 = 30 \text{ mm} \\I_z &= a \cdot h^3 / 12 = 0.25 \text{ mm}^4 \\dr_z &= 0.0006\end{aligned}$$

2.2 Results of reference

Mark with arrows, axial constraints and deformations and bending moments in 4 points of the axis of the beam.

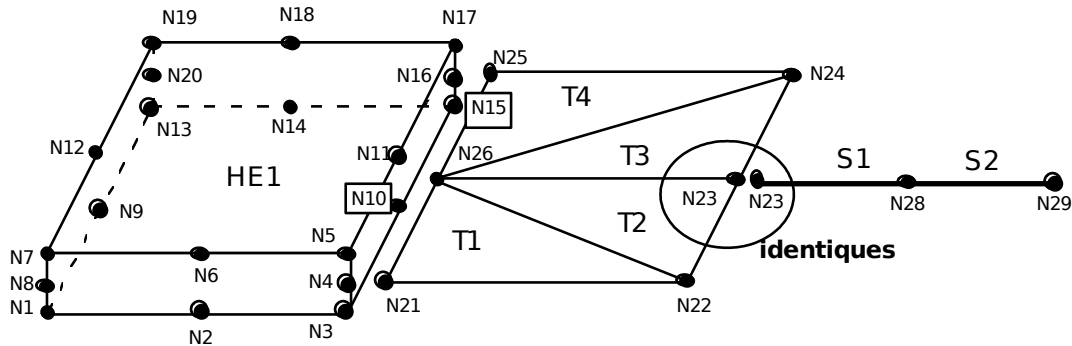
2.3 Uncertainty on the solution

Analytical solution.

3 Modeling A

3.1 Characteristics of modeling

Modeling mixed: 3D, DKT and POU_D_E



Point N --> N1
Point A --> N4
Point C --> N23
Point D --> N29

Load n°1: force F_y
Total embedding on the section in O

3.2 Characteristics of the grid

Number of nodes : 28
Many meshes and types: 1 HEXA20 , 4 TRIA3 / DKT , 2 SEG2/ POU_D_E

3.3 Sizes tested and results

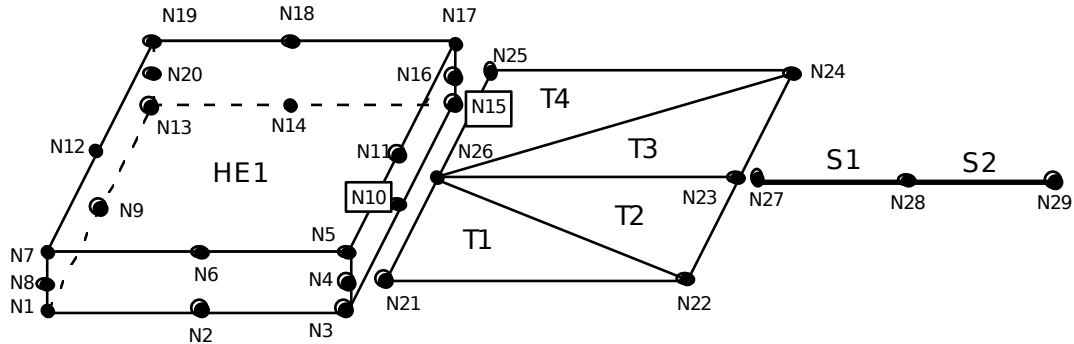
- Load n°1: force F_y

Identification	Type of Reference	Reference	Tolerance (%)
uN (node $N1$)	ANALYTICAL	0.	1,00E-006
uM (node $N26$)	ANALYTICAL	-0.0267	14.0
uA (node $N4$)	ANALYTICAL	-0.0267	14.0
uC_I (node $N22$)	ANALYTICAL	-0.0933	8.40
uC (node $N23$)	ANALYTICAL	-0.0933	8.30
uD (node $N29$)	ANALYTICAL	-0.18	6.40

4 Modeling B

4.1 Characteristics of modeling

Mixed modeling: 3D, DKT, POU_D_E and DIS_TR



Point N --> N1
Point A --> N4
Point C --> N23
Point D --> N29

Load n°1: force F_y

Embedding on the section in O realized by a connection 3D_POUTRE between the face $NI\ N13\ N19\ N7$ and a discrete element located on the origin.

Additional relation, compared to modeling A , enters C_1 C_2 and C , introduced by LIAISON_ELEM: 'COQ_POU'.

4.2 Characteristics of the grid

Number of nodes : 29

Many meshes and types: 1 HEXA20 , 4 TRIA3 / DKT , 2 SEG2/ POU_D_E , 1 POI1/DIS_TR , 1 QUAD8 , 2 SEG2/BORD_DKT

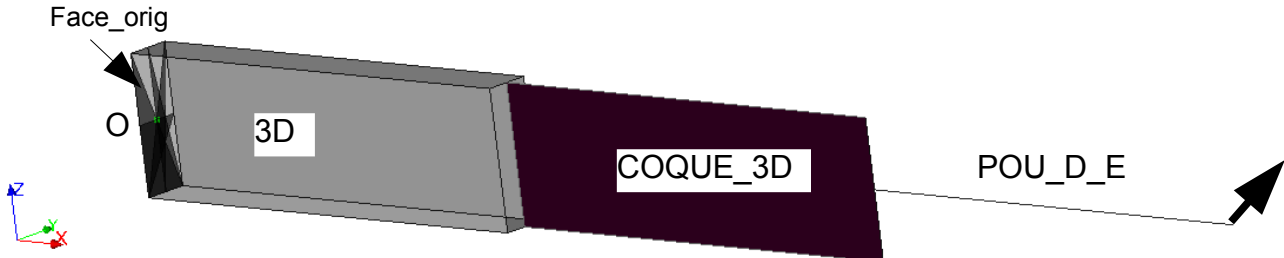
4.3 Sizes tested and results

- Load n°1: force F_y

Identification	Type of Reference	Reference	Tolerance (%)
uN (node $N1$)	ANALYTICAL	0.	
uM (node $N26$)	ANALYTICAL	- 0.0267	3.0
uA (node $N4$)	ANALYTICAL	- 0.0267	3.0
$uC1$ (node $N22$)	ANALYTICAL	- 0.0933	1.0
uC (node $N23$)	ANALYTICAL	- 0.0933	1.0
uD (node $N29$)	ANALYTICAL	- 0.18	1.0
M_z (node $N27$)	ANALYTICAL	- 10.	1.0
M_z (node $N29$)	ANALYTICAL	0.	1.0

5 Modeling C

Mixed modeling: 3D , COQUE_3D , DIS_TR , POU_D_E .



- Force F_y
- Embedding on the section in O realized by a connection 3D_POUTRE between the face and an element Discrete "Face_orig" located on the origin O .
- Additional relation between COQUE_3D and the beam by LIAISON_ELEM: 'COQ_POU'.
- This modeling validates also the not-regression of CALC_FERRAILLAGE (density of reinforcement in the plates and hull) on COQUE_3D.

5.1 Characteristics of the grid

Number of nodes : 33.

Many meshes and types: 3D/1 HEXA20 , 1 QUAD8 , COQUE_3D/ 1 QUAD9 , 1 SEG3 / DIS_TR/1 POI1/ POU_D_E 2 SEG2

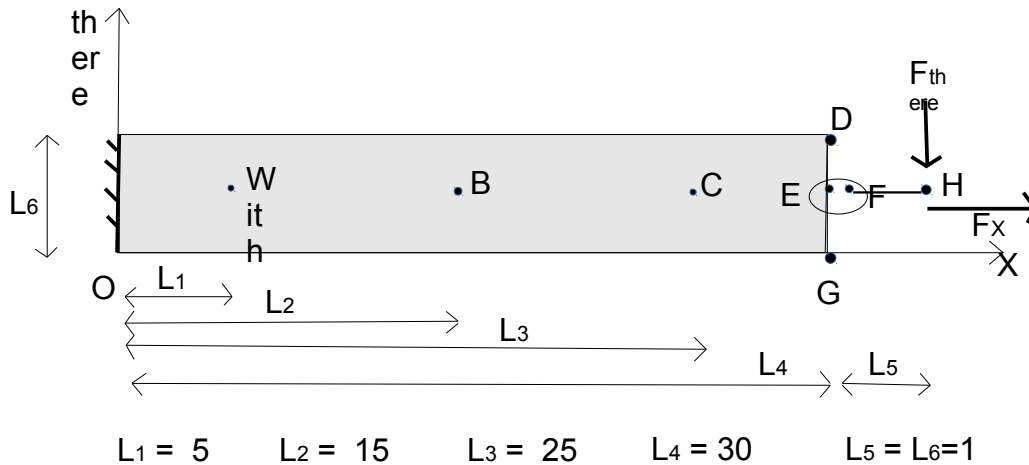
5.2 Sizes tested and results

Identification	Type of Reference	Reference	Tolerance (%)
DY (node $N26$)	ANALYTICAL	- 0.0267	3.0
DY (node $N4$)	ANALYTICAL	- 0.0267	3.0
DY (node $N22$)	ANALYTICAL	- 0.0933	1.0
DY (node $N23$)	ANALYTICAL	- 0.0933	1.0
DY (node $N29$)	ANALYTICAL	- 0.18	1.0
Moment			
M_{FZ} (node $N27$)	ANALYTICAL	- 10.	1.0
M_{FZ} (node $N29$)	ANALYTICAL	0.	1.0
Reinforcement			
$DNSXS$ (mesh CI)	NON-RÉGRESSION	2.30587085238E-06	1.0E-6
$DNSYI$ (mesh CI)	NON-RÉGRESSION	2.29077876872E-06	1.0E-6
$SIGMBE$ (mesh CI)	NON-RÉGRESSION	130714.081463	1.0E-6

6 Modeling D

6.1 Characteristics of modeling

Mixed modeling: C_PLAN , 2D_DIS_TR



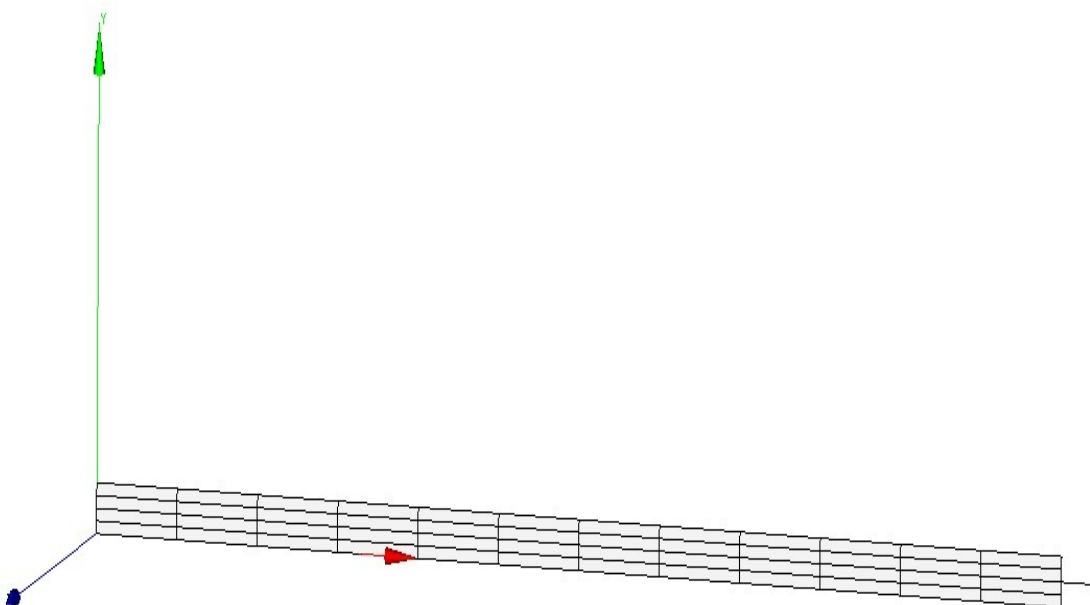
In H : load n°1: force F_x , load n°2: F_y

Displacements u_x and u_y worthless on the left edge of the 2D part.

6.2 Characteristics of the grid

Many nodes: 179

Many meshes and types : 8 SEG3, 1 SEG2, 48 QUAD8 (=12 X 4)



6.3 Sizes tested and results

Identification	Type of Reference	Reference	Tolerance (%)
Load 1: force F_x			
$u_x(A)$ (node N13)	ANALYTICAL	2,50	1.0e-5
$u_x(B)$ (node N75)	ANALYTICAL	7,50	1.0e-5
$u_x(C)$ (node N131)	ANALYTICAL	12,50	1.0e-5
$u_x(D)$ (node N141)	ANALYTICAL	15,00	1.0e-5
$u_x(E)$ (node N133)	ANALYTICAL	15,00	1.0e-5
$u_x(F)$ (node N178)	ANALYTICAL	15,00	1.0e-5
$u_x(G)$ (node N125)	ANALYTICAL	15,00	1.0e-5
$u_x(H)$ (node N179)	ANALYTICAL	15,25	1.0e-5
Load 2: force F_y			
$u_y(A)$ (node N13)	ANALYTICAL	2.125e-2	1.0e-2
$u_y(B)$ (node N75)	ANALYTICAL	-1.6875e-1	1.0e-2
$u_y(C)$ (node N131)	ANALYTICAL	-4,0625	1.0e-2
$u_y(D)$ (node N141)	ANALYTICAL	-0,54	1.0e-2
$u_y(E)$ (node N133)	ANALYTICAL	-0,54	1.0e-2
$u_y(F)$ (node N178)	ANALYTICAL	-0,54	1.0e-2
$u_y(G)$ (node N125)	ANALYTICAL	-0,54	1.0e-2
$u_y(H)$ (node N179)	ANALYTICAL	-0,54	1.0e-2

7 Modeling E

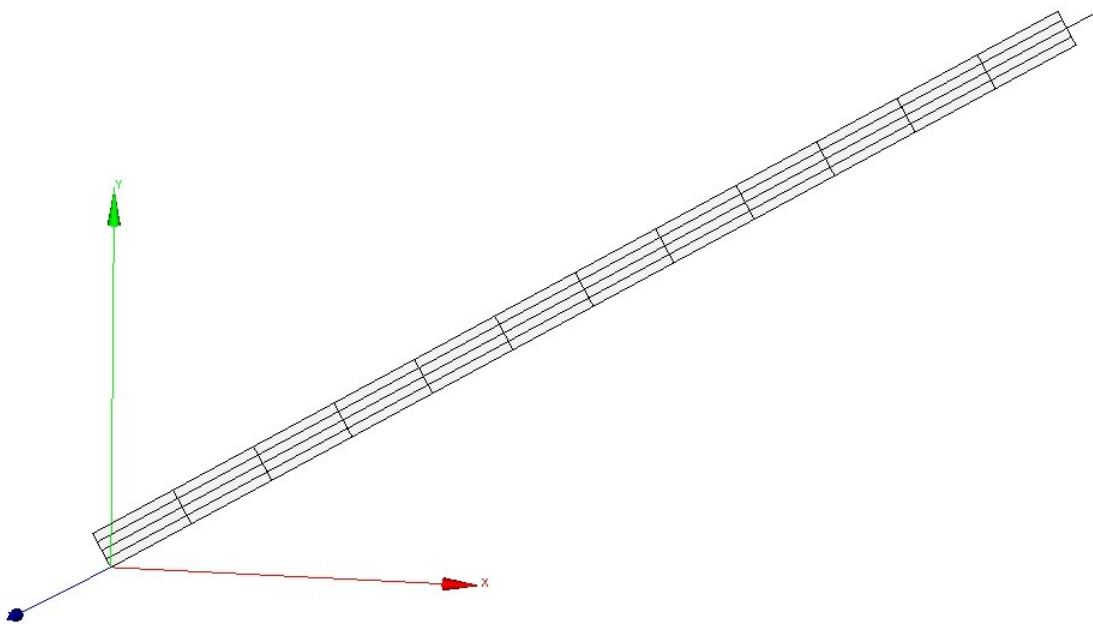
7.1 Characteristics of modeling

Modeling G = Modeling F (C_PLAN , 2D_DIS_TR) + rotation of 30° in the beginning.

7.2 Characteristics of the grid

Many nodes: 179

Many meshes and types : 8 SEG3, 1 SEG2, 48 QUAD8 (=12 X 4)



7.3 Sizes tested and results

Identification	Type of Reference	Reference	Tolerance (%)
Load 1: force F_x			
$u_x(A)$ (node N13)	ANALYTICAL	2,165064	1.0e-6
$u_x(B)$ (node N75)	ANALYTICAL	6,495191	1.0e-6
$u_x(C)$ (node N131)	ANALYTICAL	10,825318	1.0e-6
$u_x(D)$ (node N141)	ANALYTICAL	12,990381	1.0e-6
$u_x(E)$ (node N133)	ANALYTICAL	12,990381	1.0e-6
$u_x(F)$ (node N178)	ANALYTICAL	12,990381	1.0e-6
$u_x(G)$ (node N125)	ANALYTICAL	12,990381	1.0e-6
$u_x(H)$ (node N179)	ANALYTICAL	13,208874	1.0e-6
Load 2: force F_y			
$u_y(A)$ (node N13)	ANALYTICAL	-1.8403e-2	1.0e-2
$u_y(B)$ (node N75)	ANALYTICAL	-0,146142	1.0e-2

$u_y(C)$	(node N131)	ANALYTICAL	-0,351823	1.0e-2
$u_y(D)$	(node N141)	ANALYTICAL	-0,467654	1,5
$u_y(E)$	(node N133)	ANALYTICAL	-0,467654	1.0e-2
$u_y(F)$	(node N178)	ANALYTICAL	-0,467654	1.0e-2
$u_y(G)$	(node N125)	ANALYTICAL	-0,467654	1,5
$u_y(H)$	(node N179)	ANALYTICAL	-0,467654	1.0e-2

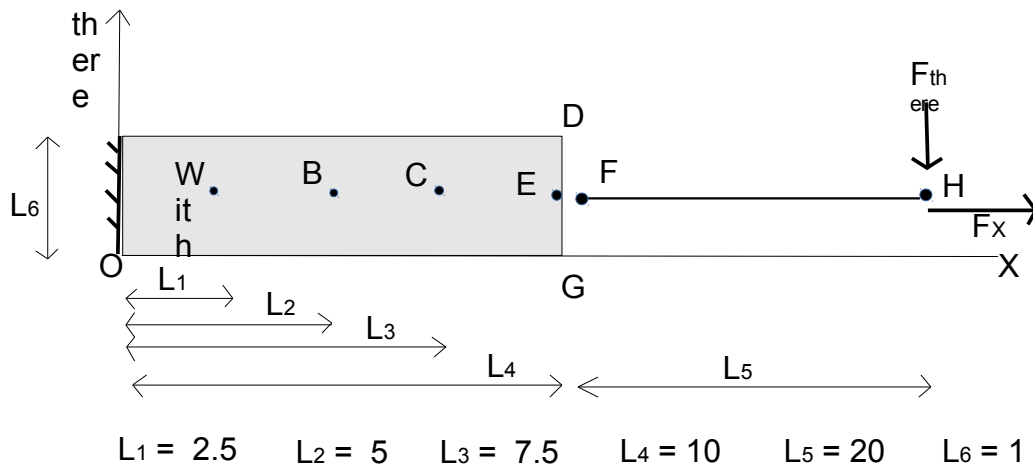
7.4 Remarks

The analytical values of displacement are those of modeling G multiplied by the cosine of 30 degrees.

8 Modeling F

8.1 Characteristics of modeling

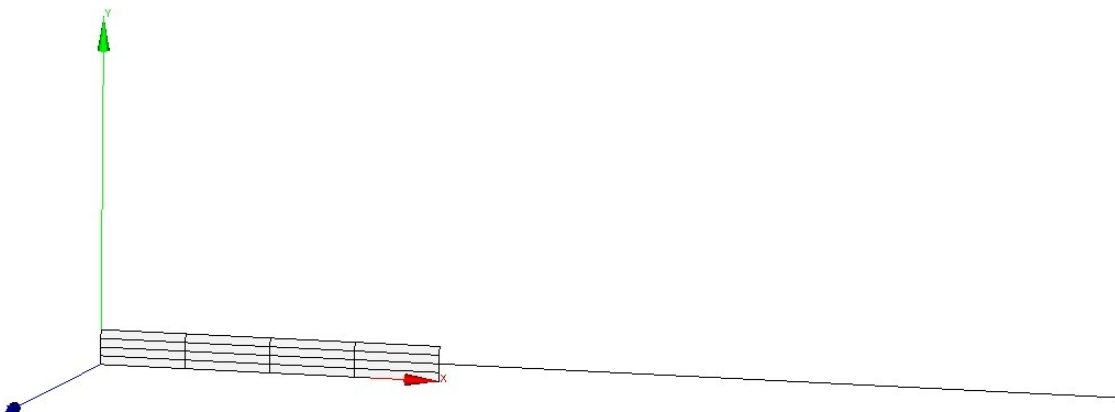
Mixed modeling: C_PLAN , POU_D_E



8.2 Characteristics of the grid

Many nodes: 67

Many meshes and types : 8 SEG3, 1 SEG2, 16 QUAD8 (=4 X 4)



8.3 Sizes tested and results

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

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Identification	Type of Reference	Reference	Tolerance (%)
Load 1: force F_x			
$u_x(A)$ (node N12)	ANALYTICAL	1,25	1.0e-6
$u_x(B)$ (node N13)	ANALYTICAL	2,50	1.0e-6
$u_x(C)$ (node N14)	ANALYTICAL	3,75	1.0e-6
$u_x(D)$ (node N25)	ANALYTICAL	5,00	1.0e-6
$u_x(E)$ (node N15)	ANALYTICAL	5,00	1.0e-6
$u_x(F)$ (node N66)	ANALYTICAL	5,00	1.0e-6
$u_x(G)$ (node N5)	ANALYTICAL	5,00	1.0e-6
$u_x(H)$ (node N67)	ANALYTICAL	15,00	1.0e-6
Load 2: force F_y			
$u_y(A)$ (node N12)	ANALYTICAL	-5.46875e-3	1.0e-2
$u_y(B)$ (node N13)	ANALYTICAL	-2.125e-2	1.0e-2
$u_y(C)$ (node N14)	ANALYTICAL	-4.640625e-2	1.0e-2
$u_y(D)$ (node N25)	ANALYTICAL	-0,08	1.0e-2
$u_y(E)$ (node N15)	ANALYTICAL	-0,08	1.0e-2
$u_y(F)$ (node N66)	ANALYTICAL	-0,08	1.0e-2
$u_y(G)$ (node N5)	ANALYTICAL	-0,08	1.0e-2
$u_y(H)$ (node N67)	ANALYTICAL	-0,54	1.0e-3

9 Summary of the results

The studied cases are:

Modeling	Connections
A: 3D, DKT and POU_D_E	LIAISON_GROUP
B: 3D, DKT, POU_D_E and DIS_TR	LIAISON_GROUP; LIAISON_ELEM: 3D_POU, COQ_POU
C: 3D, COQUE_3D, POU_D_E and DIS_TR	LIAISON_GROUP; LIAISON_ELEM: 3D_POU, COQ_POU
D: C_PLAN , 2D_DIS_TR	LIAISON_ELEM: 2D_POU
E: C_PLAN , 2D_DIS_TR	LIAISON_ELEM: 2D_POU
F: C_PLAN , POU_D_E	LIAISON_ELEM: 2D_POU

- The grid is very coarse in elements 3D and plates. The test deserves a finer modeling, since the results are influenced by the way of describing the conditions of embedding in O . Modeling A conduit with an error of 14% to the maximum,
- however with a good taking into account of these conditions, the solution is definitely better (modeling B conduit with an error of 3% maximum).
- The comparisons of the constraints and efforts give good performances (modeling B). For the element of hull 1D, the results are very good.