SSLS133 - Flexbeam with variable thickness

Abstract:

This test represents a quasi-static computation of a flexbeam with variable thickness. It is embedded at an end, and is subjected to a vertical force at the other end. This test makes it possible to test shell elements voluminal SHB8 and SHB20 to manage the variations of thickness. Four modelizations are tested:

Finite elements SHB8 for a linear variation of the thickness of the plate (modelization A).
Finite elements SHB20 for a linear variation of the thickness of the plate (modelization B).
Finite elements SHB8 for a quadratic variation of the thickness of the plate (modelization C).
Finite elements SHB20 for a quadratic variation of the thickness of the plate (modelization D).

Displacements obtained are compared with the elastic analytical solution of a beam in bending. This test makes it possible to show the capacities and the limiting of elements SHB8 and SHB20 to manage the variations of thickness.

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1 Problem of reference

1.1 Geometry

1.1.1 Plates with thickness varying linearly

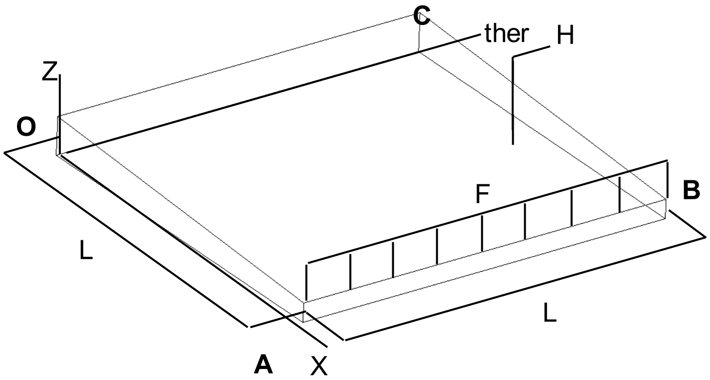

Figure 1.1.1-1 :

Length $L=100m$, width $l=100m$.

The thickness h varies linearly:

$$h(x)=ax+b$$

We pose $h(x=0)=h1=10m$ and $h(x=L)=h2=5m$ what gives us:

$$a=(h_2-h_1)/L \text{ and } b=h_1$$

1.1.2 Plates with thickness varying quadratically

the thickness h varies in a quadratic way:

$$h(x)=ax^2+bx+c$$

We pose $h(x=0)=h1=10m$, $h(x=L)=h2=5m$ and $h(x=L/2)=h_{12}=6,25m$ what gives us

$$a=(2(h_1+h_2)-4h_{12})/L^2,\ b=(4h_{12}-h_2-3h_1)/L \text{ and } c=h_1$$

1.2 Material properties

Modulus Young: $E=2.10^{11}Pa$
Poisson's ratio: $\nu=0.0$

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1.3 Boundary conditions and loadings

Boundary conditions:
Embedded on the side OC : $u=v=w=0$, $\theta_x=\theta_y=\theta_z=0$

Loading:
At the end AB , a load uniformly distributed of resultant:
Force parallel with the axis Z ; $F_z=1N$

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2 Reference solution

2.1 Method of calculating used for the reference solution

the results of reference are got by the theory of the elastic beams.

In the case of a linear variation of the thickness, vertical displacement at the end AB is given by [1]:

$$w(x)=-\frac{FL^2}{2EI_{y_1}c^3}\frac{\left(2Lcx+c^2x^2-c^3x^2+2\mathrm{L}(L+cx)\ln\left(\frac{L}{L+cx}\right)\right)}{(L+cx)}$$

With

$$c=\left(\frac{I_{y_2}}{I_{y_1}}\right)^{\frac{1}{3}}-1 \text{ and } I_{y_i}=\frac{bh_i^3}{12}$$

In the case of a quadratic variation of the thickness, it is possible to find a formula exact of displacement. However its general statement is sufficiently complex not to be able to be written here. We formulated the approximate function of vertical displacement according to x our case:

$$w(x)=3.10^{-8}\frac{2\mathrm{x}-200}{x^2-200x+20000}+6.10^{-10}\arctan(0.01x-1)-3.10^{-12}x+7.71238.10^{-10}m$$

2.2 Quantities and results of reference

Displacement of the points A and B following Z .

2.3 Bibliographical references

[1] [V3.01.400] SSLL400 – non-prismatic Beam, subjected to forces specific or distributed.

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3 Modelization A

3.1 Characteristic of the modelization

Element SHB8 and thickness varying linearly

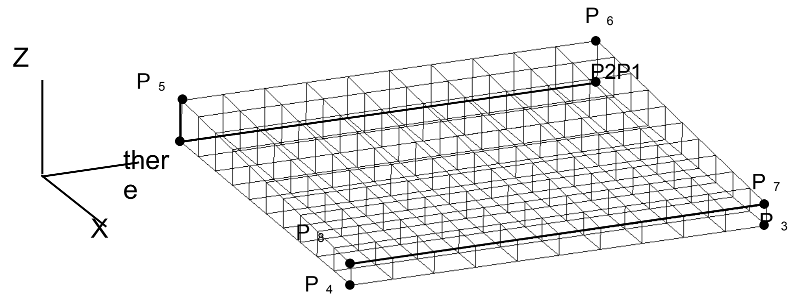

Figure 3.1-1 : Mesh of the modelization A

Cutting: a regular mesh is considered in this modelization.

Regular mesh:

100 meshes SHB8 : 10 according to the width, 10 according to the length, 1 according to the thickness

Boundary conditions:

All nodes inside the side $P_1 P_2 P_6 P_5$: blocked displacement following X
All the nodes on the edge $P_1 P_5$: blocked displacement following Y
All the nodes on the edge $P_2 P_1$: blocked displacement following Z

Loading:
Force linearly distributed on the edge $P_8 P_7$: F = 1

Name of the nodes:

Not P1	N022	Not P5	N020
Not P2	N002	Not P6	N001
Not P3	N102	Not P7	N100
Not P4	N172	Not P8	N171

3.2 Characteristics of the mesh

Many nodes: 242

Number of meshes and types: 100 SHB8

3.3 Quantities tested and regular

Mesh results:

Not	Quantity in unit	Reference	*Aster*	% difference
P7	displacement W (m)	3.2710 10-10	3.2711 10-10	+0.004
P8	displacement W (m)	3.2710 10-10	3.2711 10-10	+0.004

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4 Modelization B

4.1 Characteristic of the modelization

Element `SHB20` and thickness varying linearly

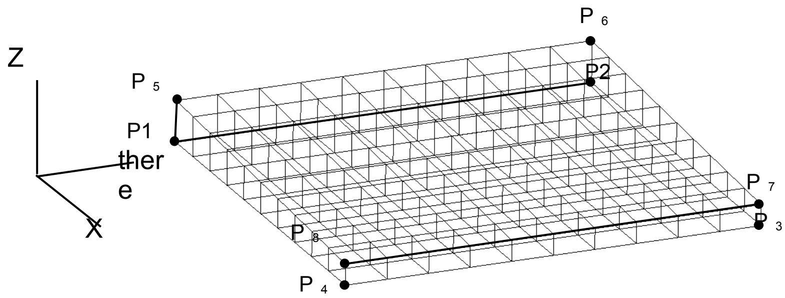

Figure 4.1-1 : Mesh of the modelization B

Cutting: a regular mesh is considered in this modelization.

Regular mesh:

100 meshes `SHB20` : 10 according to the width, 10 according to the length, 1 according to the thickness

Boundary conditions:

All nodes inside the side $P_1 P_2 P_6 P_5$: blocked displacement following `X`
All the nodes on the edge $P_1 P_5$: blocked displacement following `Y`
All the nodes on the edge $P_2 P_1$: blocked displacement following `Z`

Loading:
Force linearly distributed on the edge $P_8 P_7$: $F=1$

Name of the nodes:

Not P1	N347	Not P5	N340
Not P2	N579	Not P6	N572
Not P3	N006	Not P7	N002
Not P4	N074	Not P8	N067

4.2 Characteristics of the mesh

Many nodes: 803

Number of meshes and types: 100 `SHB20`

4.3 Quantities tested and regular

Mesh results:

Not	Quantity in unit	Reference	*Aster*	% difference
P7	displacement W (m)	3.2710 10-10	3.2866 10-10	+0.476
P8	displacement W (m)	3.2710 10-10	3.2866 10-10	+0.476

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5 Modelization C

5.1 Characteristic of the modelization

Element SHB8 and thickness varying quadratically

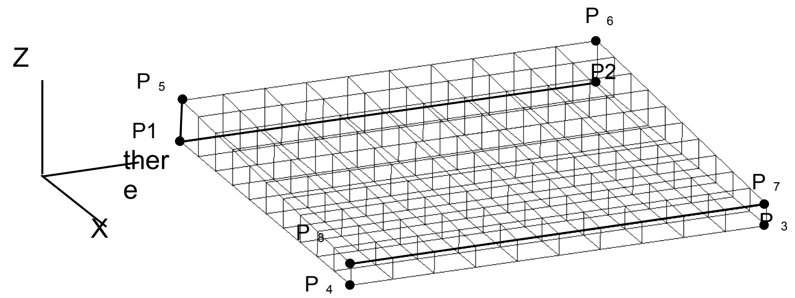

Figure 5.1-1 : Mesh of the modelization C

the characteristics are the same ones as for the modelization A

Name of the nodes:

Not P1	N005	Not P5	N003
Not P2	N006	Not P6	N004
Not P3	N008	Not P7	N002
Not P4	N007	Not P8	N001

5.2 Characteristics of the mesh

The mesh is the same one as the modelization A except for the thickness which varies here in a quadratic way.

5.3 Quantities tested and regular

Mesh results:

Not	Quantity in unit	Reference	*Aster*	% difference
P7	displacement W (m)	4.7124 10-10	5.1212 10-10	+8.67
P8	displacement W (m)	4.7124 10-10	5.1212 10-10	+8.67

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6 Modelization D

6.1 Characteristic of the modelization

Element SHB20 and thickness varying quadratically

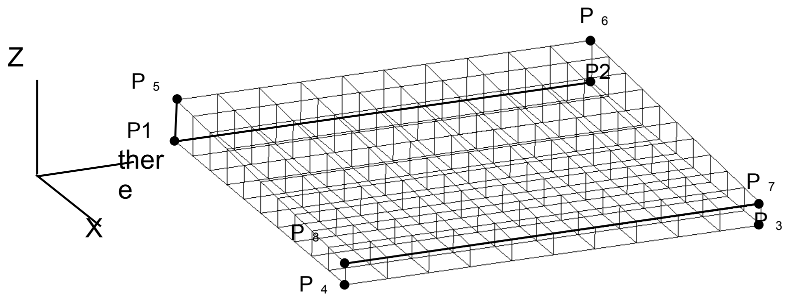

Figure 6.1-1 : Mesh of the modelization D

the characteristics are the same ones as for the modelization B

Name of the nodes:

Not P1	N005	Not P5	N003
Not P2	N006	Not P6	N004
Not P3	N008	Not P7	N002
Not P4	N007	Not P8	N001

6.2 Characteristics of the mesh

The mesh is the same one as the modelization B except for the thickness which varies here in a quadratic way.

6.3 Quantities tested and regular

Mesh results:

Not	Quantity in unit	Reference	*Aster*	% difference
P7	displacement W (m)	4.7124 10-10	4.6754 10-10	-0.784
P8	displacement W (m)	4.7124 10-10	4.6754 10-10	-0.784

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7 Summary of the results

In the case in a variation linaire of the thickness of the plate, good solutions are obtained some is the finite element used (SHB8 or SHB20).

When the geometrical variation is of a quadratic nature, elements SHB20 provide more precise results (error $<1\%$) that elements SHB8 (error $<9\%$).

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