SSNL501 - Beam fixed at the two ends subjected to a uniform pressure

Abstract:

This test represents a quasi-static computation of a clamped beam subjected to a uniform pressure, made up of a perfectly plastic elastic material. This test makes it possible to validate the following modelizations finite elements:

- `COQUE_C_PLAN (SEG3)`,
- `DKT (TRIA3, QUAD4)`,
- `COQUE_3D (TRIA7, QUAD9)`,
- `POU_D_TGM (SEG2)`.

The limiting pressure is compared with an analytical reference solution.

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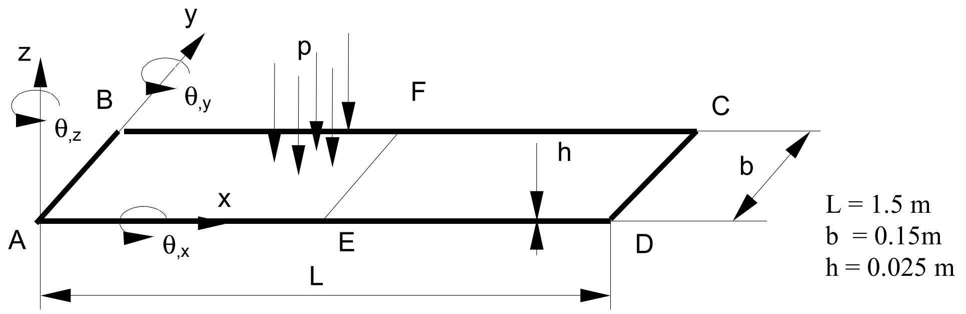
1 Problem of reference

1.1 Geometry



1.2 Properties of the material

the properties of the material constituting the beam are:

$E=2.10^{11}\ Pa$ Young's modulus
$\nu=0.3$ Poisson's ratio

the material follows a perfectly plastic elastic constitutive law:

$\sigma_e=2.35\,10^8\ Pa$ Yield stress
$\varepsilon_e=1.175\,10^{-3}$ Elastic strain limits

1.3 Boundary conditions and loadings

- Boundary conditions: Dimensioned AB and CD embedded
- following Displacement imposed Z in E ($x=L/2$):

$$DZ_e=6.609 10^{-3}\ m\ \left(DZ_e=\frac{q_e L^4}{384 EI}\right)$$

$DZ(E)$ from with 0 Initial conditions $30\,DZ_e$

1.4 Without

Reference solution object

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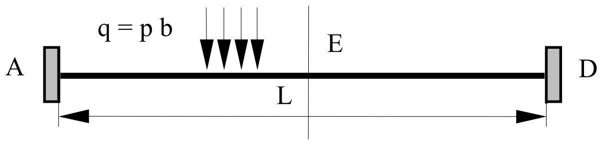
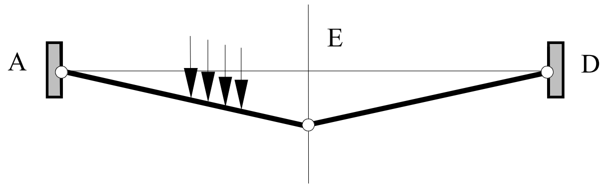
2 Method of calculating

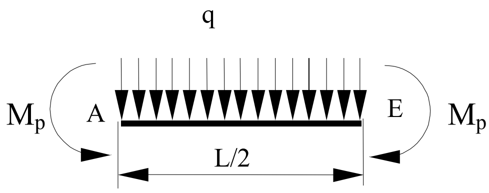
2.1 used for the reference solution



(a)



(b)



(c)

failure of the beam varies appears when there are plastic hinges at the points A , D and E (figure b). The static equilibrium of the left half of the beam, makes it possible to determine the pressure limits (figure c)

$$\sum M_A = 2M_p - q_L(\frac{L}{2})(\frac{L}{4}) = 0 \qquad \Rightarrow \quad q_L = \frac{16 M_p}{L^2}$$

where:

q_L represent the limiting pressure

M_p represents the plastic moment ($M_p = \sigma_e \frac{bh^2}{4}$)

the appearance of the first plastic point on fiber external of the beam takes place at the points A and D , the other fibers being in elastic mode. The pressure yield stress is of $q_e = 2\sigma_e \frac{bh^2}{L^2}$.

2.2 Results of reference

Pressure limits $q_L = 39\,166.67\, N/m$

2.3 Uncertainties on the analytical

solution Solution

2.4 bibliographical References

1) WILLIAM A. NASH: Theory and problems of Strength of material, Schaum' S outline series, 2/ed, McGRAW-HILL

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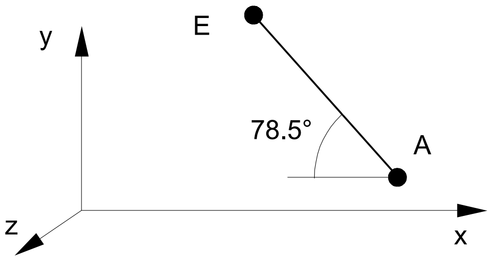
3 Modelization A

3.1 Characteristic of the modelization



Modélisation COQUE_C_PLAN

Point A (2.1 ; 0.7) (nœud n1)

Conditions aux limites : Point A : u = v = θ_z= 0
Conditions de symétrie : Point E : θ_z= 0

la poutre étant inclinée à 78.5°, la valeur du déplacement imposé est alors : DX_e=6.609 10^{-3} m . sin(78.5°)

3.2 Characteristics of the mesh

Many nodes: 21
Number of meshes and type: 10 SEG3

3.3 Values tested

$DX(E)/DX_e$	Identification	Times	Reference	*Aster*	% difference
10	`ETA_PILOTAGE`	10.1.0		1.0699	6.9
12	`ETA_PILOTAGE`	12.1.0		1.0699	6.9

3.4 Remarks

the width for modelization `COQUE_C_PLAN` are imposed on 1 in *Code_Aster*. Consequently, we multiplied by $1/b$ the loading to take account of the real width of the beam.
In this analysis one uses to find the solution, a technique of resolution of type imposed displacement (“`DDL_IMPO`”). This method provides for each value of imposed displacement, a multiplying coefficient of the loading (“`ETA_PILOTAGE`”). The value of the loading imposed in “`AFFE_CHAR_MECA`” is equal to the limiting pressure, consequently the value of reference of parameter “`ETA_PILOTAGE`” is equal to 1.

The reference being taken compared to the solution beam with 20 elements, one observes an improvement of results `COQUE_C_PLAN` when the mesh is refined.

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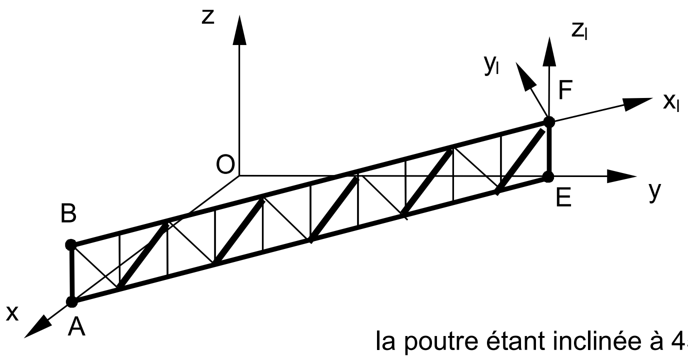
4 Modelization B

4.1 Characteristic of the modelization



Modélisation DKT (TRIA3)
OE = OA = $L/2\sqrt{2}$
AB // EF // axe Z

Conditions aux limites (repère gobal)
- côté AB: $u = v = w = \theta_x = \theta_y = \theta_z = 0$

Conditions de symétrie
- côté EF: $u = 0$ (repère local $x_1\ y_1\ z_1$)
- côté EF: $\theta_z = 0$ (repère global)

la poutre étant inclinée à 45°, la valeur du déplacement imposé est alors : DX_e=6.609 10^{-3} m . sin(45°)

4.2 Characteristics of the mesh

Many nodes: 43
Number of meshes and type: 20 TRIA3

4.3 Values tested

$DX(E)/DX_e$	Identification	Times	Reference	*Aster*	% difference
5	`ETA_PILOTAGE`	5.1.0		1.11133	11.11
25	`ETA_PILOTAGE`	15.1.0		1.142	11.42

4.4 Remarks

In this analysis, one use to find the solution, a technique of resolution of type imposed displacement (“`DDL_IMPO`”). This method provides for each value of imposed displacement, a multiplying coefficient of the loading (“`ETA_PILOTAGE`”). The value of the loading imposed in “`AFFE_CHAR_MECA`” is equal to the limiting pressure, consequently the value of reference of parameter “`ETA_PILOTAGE`” is equal to 1.
Computations were stopped when the value of parameter `ETA_PILOTAGE` was stabilized.

The reference being taken compared to the solution beam with 50 elements, one observes an improvement of results `DKT TRIA3` when the mesh is refined.

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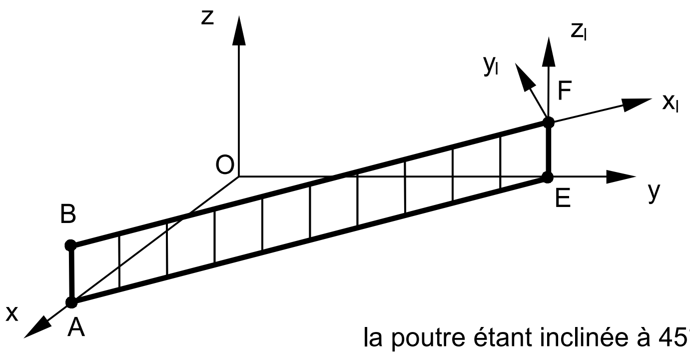
5 Modelization C

5.1 Characteristic of the modelization



Modélisation DKT (QUAD4)
OE = OA = $L/2\sqrt{2}$
AB // EF // axe Z

Conditions aux limites (repère gobal)
- côté AB: u = v =w = $\theta_x = \theta_y = \theta_z = 0$

Conditions de symétrie
- côté EF: u = 0 (repère local x_1 y_1 z_1)
- côté EF: $\theta_z = 0$ (repère global)

la poutre étant inclinée à 45°, la valeur du déplacement imposé est alors : $DX_e = 6.609\ 10^{-3}$ m . sin(45°)

5.2 Characteristics of the mesh

Many nodes: 43
Number of meshes and type: 10 QUAD4

5.3 Values tested

$DX(E)/DX_e$	Identification	Times	Reference	*Aster*	% difference
5	ETA_PILOTAGE	5.1.0		1.0837	8.37
25	ETA_PILOTAGE	25.1.0		1.0998	9.98

5.4 Remarks

In this analysis, one use to find the solution, a technique of resolution of type imposed displacement (“DDL_IMPO”). This method provides for each value of imposed displacement, a multiplying coefficient of the loading (“ETA_PILOTAGE”). The value of the loading imposed in “AFFE_CHAR_MECA” is equal to the limiting pressure, consequently the value of reference of parameter “ETA_PILOTAGE” is equal to 1.
Computations were stopped when the value of parameter ETA_PILOTAGE was stabilized.

The reference being taken compared to the solution beam with 50 elements, one observes an improvement of results DKT QUAD4 when the mesh is refined.

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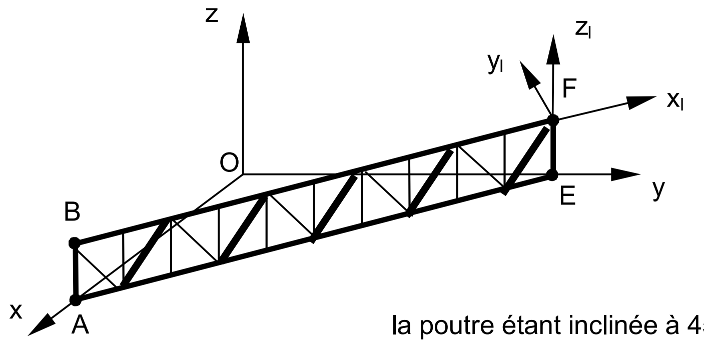
6 Modelization D

6.1 Characteristic of the modelization



Modélisation COQUE_3D (TRIA7)
OE = OA = $L/2\sqrt{2}$
AB // EF // axe Z

Conditions aux limites (repère gobal)
- côté AB: $u = v = w = \theta_x = \theta_y = \theta_z = 0$

Conditions de symétrie
- côté EF: $u = 0$ (repère local $x_1\ y_1 z_1$)
- côté EF: $\theta_z = 0$ (repère global)

la poutre étant inclinée à 45°, la valeur du déplacement imposé est alors : $DX_e = 6.609\ 10^{-3}$ m . sin(45°)

6.2 Characteristics of the mesh

Many nodes: 83
Number of meshes and type: 20 TRIA7

6.3 Values tested

$DX(E)/DX_e$	**Identification**	**Times**	**Reference**	***Aster***	**% difference**
5	`ETA_PILOTAGE`	5.1.0		1.1143	11.43
15	`ETA_PILOTAGE`	15.1.0		1.1682	16.82

6.4 Remarks

In this analysis, one use to find the solution, a technique of resolution of type imposed displacement (“`DDL_IMPO`”). This method provides for each value of imposed displacement, a multiplying coefficient of the loading (“`ETA_PILOTAGE`”). The value of the loading imposed in “`AFFE_CHAR_MECA`” is equal to the limiting pressure, consequently the value of reference of parameter “`ETA_PILOTAGE`” is equal to 1.
Computations were stopped when the value of parameter `ETA_PILOTAGE` was stabilized.

The reference being taken compared to the solution beam with 50 elements, one observes 3D an improvement of the results `shells TRIA7` when the mesh is refined.

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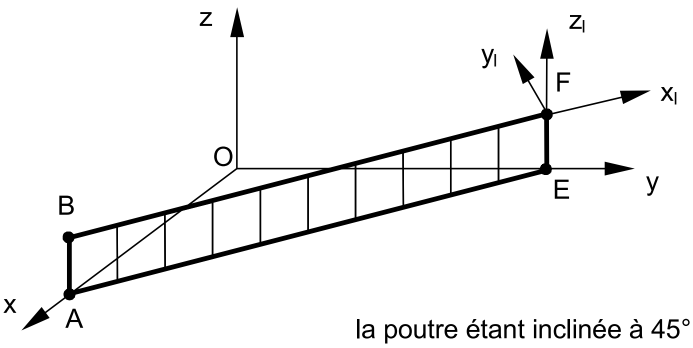
7 Modelization E

7.1 Characteristic of the modelization



Modélisation COQUE_3D (QUAD9)
OE = OA = $L/2\sqrt{2}$
AB // EF // axe Z

Conditions aux limites (repère gobal)
- côté AB: u = v =w = $\theta_x = \theta_y = \theta_z = 0$

Conditions de symétrie
- côté EF: u = 0 (repère local x_1 y_1 z_1)
- côté EF: $\theta_z = 0$ (repère global)

la poutre étant inclinée à 45°, la valeur du déplacement imposé est alors : DX_e=6.609 10^{-3} m . sin(45°)

7.2 Characteristics of the mesh

Many nodes: 54
Number of meshes and type: 10 QUAD9

7.3 Values tested

$DX(E)/DX_e$	Identification	Times	Reference	*Aster*	% difference
5	ETA_PILOTAGE	5.1.0		1.0978	9.78
25	ETA_PILOTAGE	25.1.0		1.1085	10.85

7.4 Remarks

In this analysis, one use to find the solution, a technique of resolution of type imposed displacement ("DDL_IMPO"). This method provides for each value of imposed displacement, a multiplying coefficient of the loading ("ETA_PILOTAGE"). The value of the loading imposed in "AFFE_CHAR_MECA" is equal to the limiting pressure, consequently the value of reference of parameter "ETA_PILOTAGE" is equal to 1.

Computations were stopped when the value of parameter ETA_PILOTAGE was stabilized.

The reference being taken compared to the solution beam with 50 elements, one observes 3D an improvement of the results shells QUAD9 when the mesh is refined.

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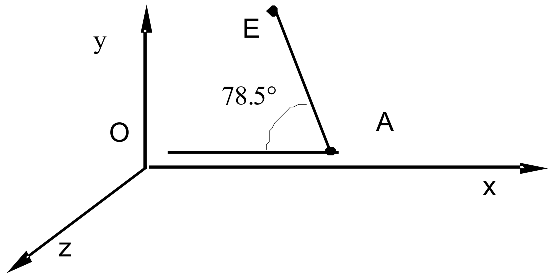
8 Modelization F

8.1 characteristic of the modelization



Modélisation `POU_D_TGM`
A= 2.1 0.7 0.
AE =0.75 m

Conditions aux limites (repère gobal)
- noeud A: $u = v = w = \theta_x = \theta_y = \theta_z = 0$

Conditions de symétrie
- noeud E: $u = 0$, $\theta_z = 0$

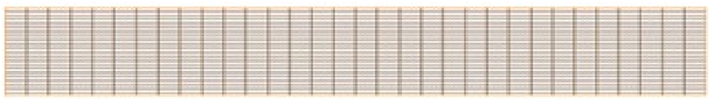
la poutre étant inclinée à 78.5°, la valeur du déplacement imposé est alors : $DX_e = 6.609\ 10^{-3}$ m . sin(78.5°)

8.2 characteristic of the mesh

- mesh of the beam

  Many nodes: 21
  Number of meshes and type: 10 `SEG2`

- mesh of the section



  Many nodes: 355
  Number of meshes and type: 280 `QUAD4`

8.3 Values tested

$DX(E)/DX_e$	Identification	Times	Reference	% Tolerance
5	`ETA_PILOTAGE`	10.1.0		14.
5.24	`ETA_PILOTAGE`	12.1.0		14.

In this analysis, one uses to find the solution, a technique of resolution of type imposed displacement ("`DDL_IMPO`"). This method provides for each value of imposed displacement, a multiplying coefficient of the loading ("`ETA_PILOTAGE`"). The value of the loading imposed in "`AFFE_CHAR_MECA`" is equal to the limiting pressure, consequently the value of reference of parameter "`ETA_PILOTAGE`" is equal to 1.

Computations were stopped when the value of parameter `ETA_PILOTAGE` was stabilized.

The solution beam improves appreciably when the mesh is refined.

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9 Summary of the results

Concerning the evolution of normal displacement in the center of the plate according to the parameter of control, one observes that:

- the modelizations comprising of the quadrangles give better results, compared to meshes the triangles.

Computations were stopped when the value of parameter ETA_PILOTAGE was stabilized, or when computation was not possible any more. Taking into account the meshes used, the got results are satisfactory. The errors observed are for the modelizations:

- COQUE_C_PLAN : 6.9% (A) ,
- DKT : 11.4% for mesh TRIA3 (B) and 9.9% for mesh QUAD4 (C),
- COQUE_3D : 16% for mesh TRIA7 (D) and 10.8% for mesh QUAD9 (E),
- POUT_D_TGM : 9% (F).

But it is noted that with a finer mesh at the ends and the center of the plate, place or plasticization appears, it is possible to minimize the error compared to the reference solution.

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