SSNV505 - Contact of 2 beams in great displacements

Summary:

This test represents a calculation of contact without friction between two beams in great displacements, when a specific displacement is imposed with one of it. Initially the beams are not in contact. Once the established contact, the two beams slip one on the other.

The analyzed result is the normal reaction of contact according to displacement. The results got with various modelings are compared.

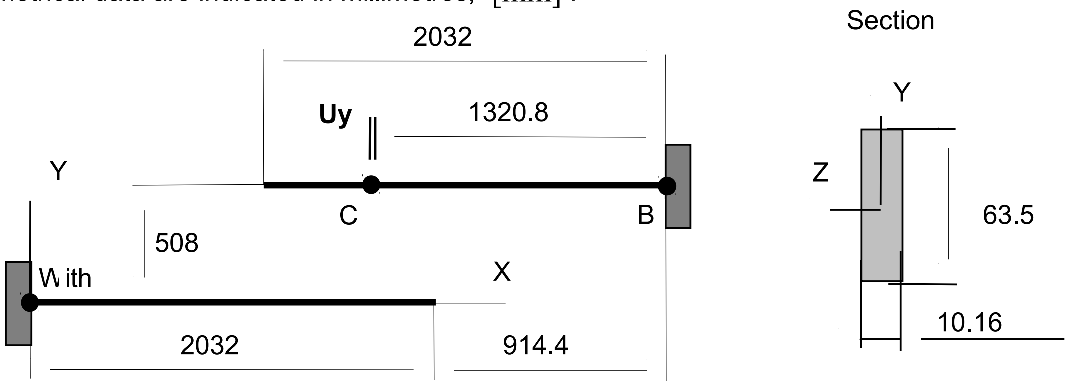
- Modeling A : the structure is modelled with elements of COQUE_3D associated with a mesh QUAD9, with the method CONSTRAINT.
- Modeling B : the structure is modelled in $3\mathrm{D}$ plane deformations using elements HEXA8, with the method CONSTRAINT.
- Modeling C : the structure is modelled in $2\mathrm{D}$ plane deformations using elements QUAD4, with the method CONSTRAINT.
- Modeling D : the structure is modelled in $3\mathrm{D}$ plane deformations using elements HEXA8, with the method CONTINUOUS.
- Modeling E : the structure is modelled in $2\mathrm{D}$ plane deformations using elements QUAD4, with the method CONTINUOUS.
- Modeling F : the structure is modelled in $2\mathrm{D}$ using elements of beam POU_D_E (meshs SEG2), with the methods PENALIZATION (with friction) and CONTINUOUS. This modeling and the following one is distinguished from the preceding ones, in what they are carried out in small transformations.
- Modeling G : the structure is modelled in $2\mathrm{D}$ using elements of beam POU_D_E (meshs SEG2), with Lbe methodS CONSTRAINT, PENALIZATION and CONTINUOUS. This modeling validates the possibility of taking into account the ray of the section of beam like fictitious game.
- Modeling H : the structure is modelled in $2\mathrm{D}$ using elements of beam POU_D_TGM (meshs SEG2), with Lhas method CONTINUOUS. This modeling is carried out in great displacements.
- Modeling I : the structure is modelled in $3D$ using elements of plate DKT (meshs QUAD4), with the method CONTINUOUS . This modeling carried out in small transformations validates the good taking into account of a fictitious game for the elements of structures.

- Modeling J : beam top is modelled in $2D$ with the assistance beams while the beam of bottom is modelled in $3D$ HEXA8 with the method CONTINUOUS and DISCRETE . This modeling carried out in small transformations validates the good taking into account of a fictitious game for the elements of structures.
- Modeling K : the structure is modelled in $3D$ plane deformations using elements HEXA 20 , with the method CONTINUOUS . This modeling validates contact between a face QUAD8 and an edge SEG3 .
- Modeling L : the structure is modelled in $3D$ plane deformations using elements HEXA27 , with the method CONTINUOUS . This modeling validates contact between a face QUAD9 and an edge SEG3 .
- Modeling M : the structure is modelled in $3D$ using elements of beam POU_D_E (meshs SEG2) to test the contact SEG2/SEG2.

1 Problem of reference

1.1 Geometry

The geometrical data are indicated in millimetres, $[\mathrm{mm}]$:



1.2 Properties of material

$E=6.8948\times10^3\,MPa$	Young modulus
$\nu=0.3333$	Poisson's ratio
$\mu=0.$	Coefficient of friction

1.3 Boundary conditions and loadings

- Boundary conditions: Sections at the points A and B embedded
- Loading: vertical displacement of the point C : $d=-790\,mm$

1.4 Initial conditions

Without object.

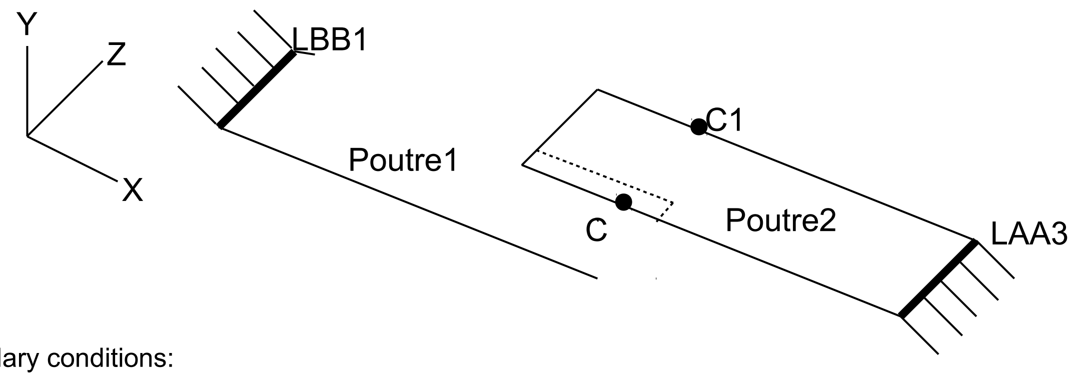
2 Reference solution

2.1 Method of calculating used for the reference solution

One does not have reference solution, one makes only tests of not-regression.

3 Modeling A

3.1 Characteristics of modeling



Boundary conditions:

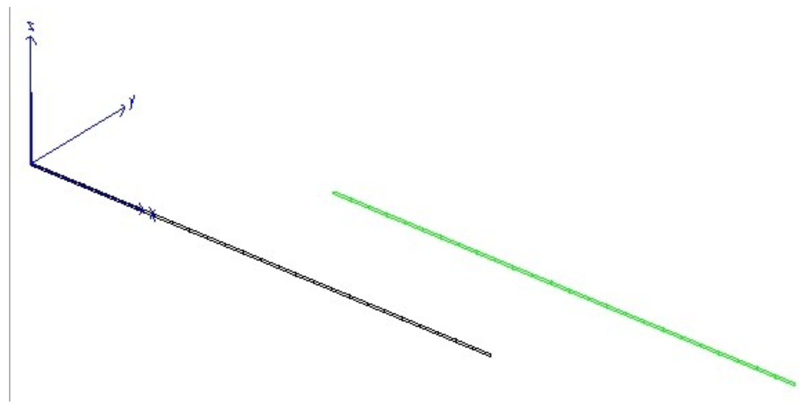
This modeling is carried out in `COQUE_3D`. In fact, the finite elements used are `QUAD9`. The boundary conditions are the following ones:

- sides $LAA3$ and $LBB1$: $DX=DY=DZ=DRX=DRY=DRZ=0$
- Nodes tops C and $C1$: $DY=-790\,mm$
- All the nodes tops of the structure: $DZ=0$, $DRX=0$

Conditions of contact:

- surface Master: group of meshs $POUTRE1$ less the group of meshs whose edge is embedded according to $LBB1$,
- surface slave: group of meshs $POUTRE2$ less the group of meshs whose edge is embedded according to $LAA3$.

3.2 Characteristics of the grid



Many nodes:		261
Many meshs:		158
	`SEG3`	107
	`QUAD8`	51

3.3 Sizes tested and results

One tests the reaction to the displacement imposed on the hull. To obtain it, one calculates the reactions to embeddings in $LBB1$ and $LAA3$.

One only makes 80% loading to limit the time of the CAS-test.

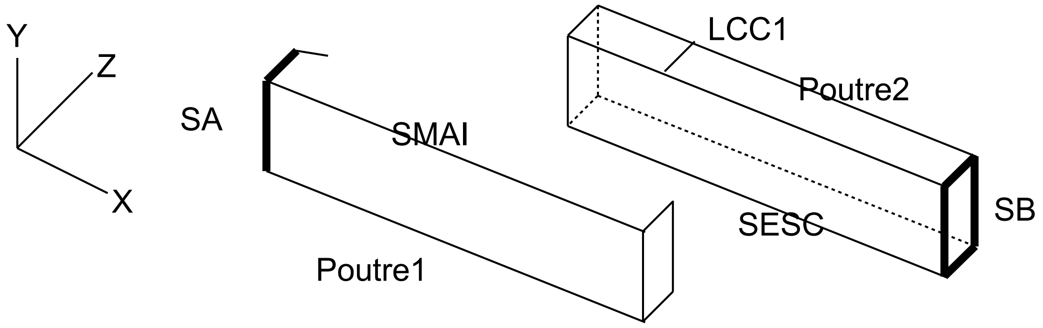
Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.2	313.96515859657	'NON_REGRESSION'	0,10%
Reaction	0.4	1220.6114997884	'NON_REGRESSION'	0,10%
Reaction	0.6	2456.8221137607	'NON_REGRESSION'	0,10%
Reaction	0.8	2067.7188799695	'NON_REGRESSION'	0,10%

3.4 Remarks

This modeling gives results very close to modeling beam (modeling H) but different from modelings $3D$: it is perfectly normal because the contact is specific with the elements of structures.

4 Modeling B

4.1 Characteristics of modeling



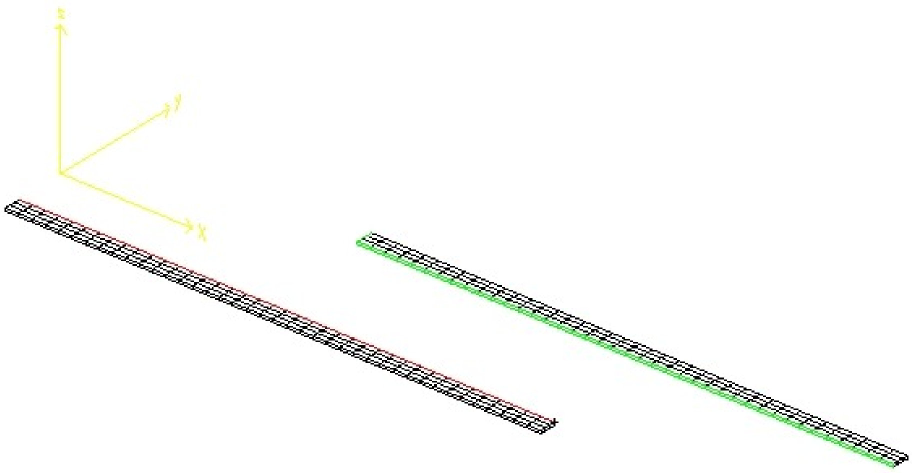
Boundary conditions:

- Surfaces SA and SB : $DX=DY=DZ=0$
- Lines $LCC1$: $DY=-790\,mm$
- All the nodes tops of the structure: $DZ=0$

Conditions of contact:

- surface Master: group of meshs $SMAI$
- surface slave: group of meshs $SESC$

4.2 Characteristics of the grid



Many nodes:	662
Many meshs:	1247
POI1	1
SEG2	351
QUAD4	655
HEXA8	240

4.3 Sizes tested and results

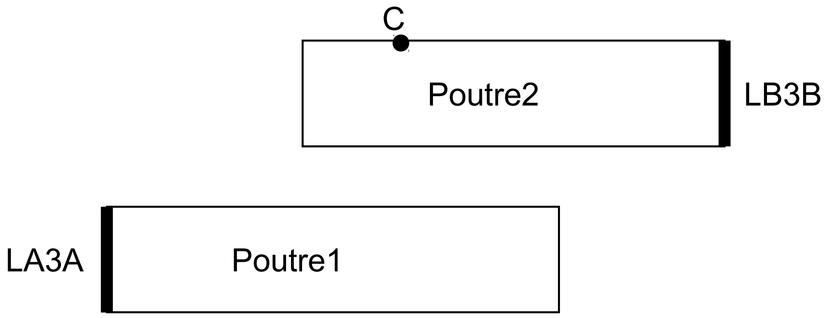
One tests the reaction to the displacement imposed on $POUTRE2$. To obtain it, one calculates the reactions to embeddings in SA and SB .

Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.2	436,995	'NON_REGRESSION'	0,10%
Reaction	0.4	1668.34	'NON_REGRESSION'	0,10%
Reaction	0.6	3258.69	'NON_REGRESSION'	0,10%
Reaction	0.8	2737.16	'NON_REGRESSION'	0.10%
Reaction	1.0	3095.24	'NON_REGRESSION'	0,10%

5 Modeling C

5.1 Characteristics of modeling

Modeling is done in $2D$ plane deformations to find blocking in DZ imposed on the model $3D$.



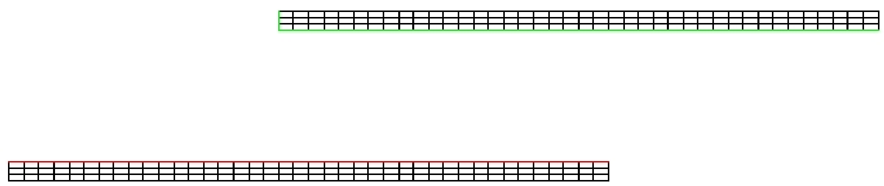
Boundary conditions:

- sides $LA3A$ and $LB3B$: $DX=DY=0$
- Nodes C : $DY=-790\,mm$

Conditions of contact:

- surface Master: group of mesh $SMAI$
- surface slave: group of mesh $SESC$

5.2 Characteristics of the grid



Many meshs:	415
SEG2	175
QUAD4	240

5.3 Sizes tested and results

One tests the reaction to the displacement imposed on the hull. To obtain it, one calculates the reactions to embeddings in $LB3B$ and $LA3A$

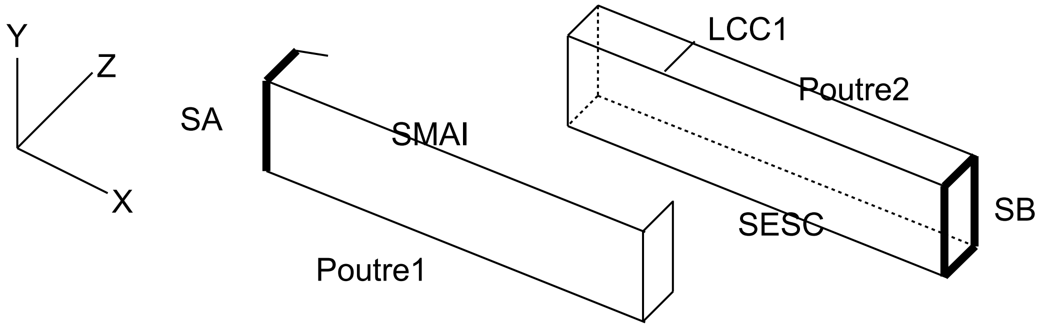
Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.2	43.5668	'NON_REGRESSION'	0,10%
Reaction	0.4	169,598	'NON_REGRESSION'	0,10%
Reaction	0.6	323,491	'NON_REGRESSION'	0.16%
Reaction	0.8	267,162	'NON_REGRESSION'	0.10%
Reaction	1.0	309,623	'NON_REGRESSION'	0,10%

5.4 Notice

To obtain in $2D$ results comparable to the results $3D$, it is necessary to multiply the preceding reactions by the width of the beam, that is to say $10.16\,mm$.

6 Modeling D

6.1 Characteristics of modeling



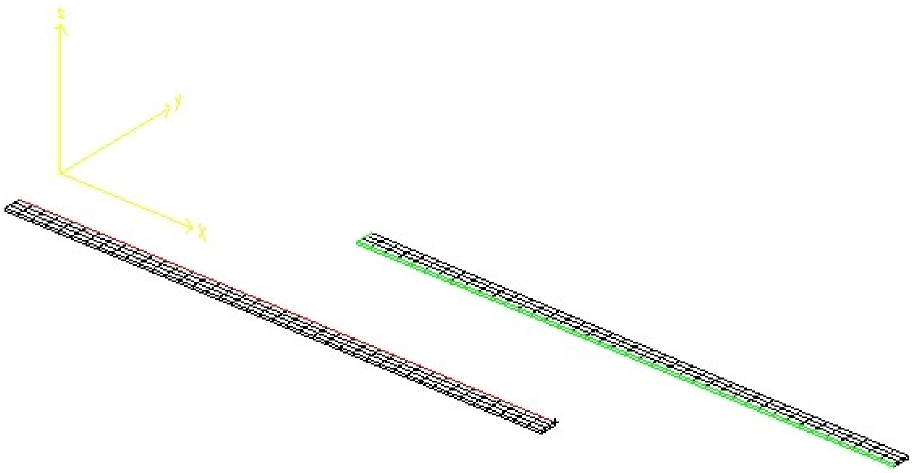
Boundary conditions:

- Surfaces SA and SB : $DX=DY=DZ=0$
- Line $LCC1$: $DY=-790\,mm$
- All the nodes tops of the structure: $DZ=0$

Conditions of contact:

- surface Master: group of meshs $SMAI$
- surface slave: group of meshs $SESC$

6.2 Characteristics of the grid



Many nodes:		662
Many meshs:		1247
	POI1	1
	SEG2	351
	QUAD4	655
	HEXA8	240

6.3 Sizes tested and results

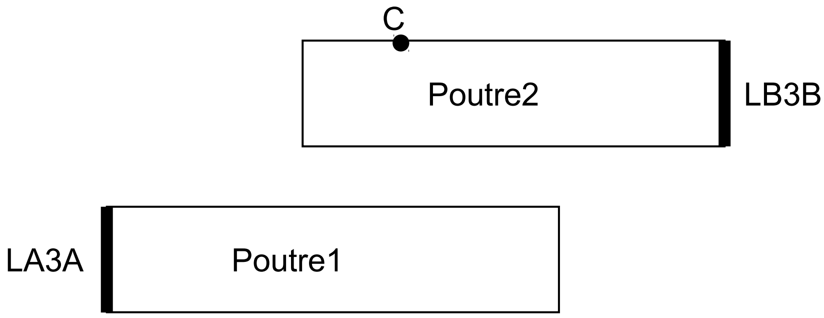
One tests the reaction to the displacement imposed on $POUTRE2$. To obtain it, one calculates the reactions to embeddings in SA and SB . The percentage of difference indicates the difference between this modeling and equivalent modeling with the method CONSTRAINT.

Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.2	436,995	'NON_REGRESSION'	0,10%
Reaction	0.4	1668.34	'NON_REGRESSION'	0,10%
Reaction	0.6	3264.54	'NON_REGRESSION'	0.15%
Reaction	0.8	2737.16	'NON_REGRESSION'	0.20%
Reaction	1.0	3095.24	'NON_REGRESSION'	0,10%

7 Modeling E

7.1 Characteristics of modeling

Modeling is done in 2D plane deformations to find blocking in DZ imposed on the model 3D .



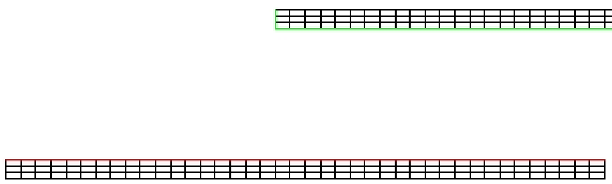
Boundary conditions:

- sides $LA3A$ and $LB3B$: $DX=DY=0$
- Nodes C : $DY=-790\,mm$

Conditions of contact:

- surface Master: group of mesh $SMAI$
- surface slave: group of mesh $SESC$

7.2 Characteristics of the grid



Many meshs:	415
SEG2	175
QUAD4	240

7.3 Sizes tested and results

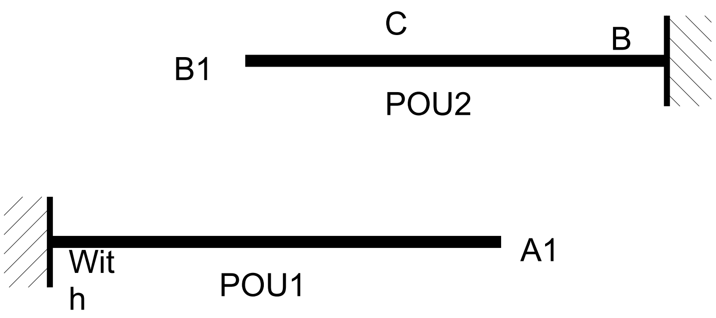
One tests the reaction to the displacement imposed on the hull. To obtain it, one calculates the reactions to embeddings in $LB3B$ and $LA3A$. The percentage of difference indicates the difference between this modeling and equivalent modeling with the method CONSTRAINT.

Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.2	43.5668	'NON_REGRESSION'	0,10%
Reaction	0.4	169,598	'NON_REGRESSION'	0,10%
Reaction	0.6	323,491	'NON_REGRESSION'	0.16%
Reaction	0.8	267,162	'NON_REGRESSION'	0.20%
Reaction	1.0	309,623	'NON_REGRESSION'	0,10%

8 Modeling F

8.1 Characteristics of modeling

One carries out here a modeling using elements beam in $3D$. Deformations being plane in the plan (DX, DY), one imposes $DZ=0$ with the model $3D$. The goal of this CAS-test is to compare the deformation of the beams with a formulation in small rotations with that obtained with great rotations. The first model is of course abusive (forgery) compared to the second (true), but makes it possible to illustrate the difference of the results got in one or the other case. The true motivation of this CAS-test is however to display an example of validation of the contact between beams with taking into account of fictitious games.



Boundary conditions:

- Nodes A and B : $DX=DY=0$
- Nodes C : $DY=-790\,mm$

Conditions of contact:

- surface Master: group of mesh $POU1$
- surface slave: group of mesh $POU2$

8.2 Characteristics of the grid

Many meshs:	80
SEG2	80

8.3 Sizes tested and results

One tests the reaction to the displacement imposed on the beam. To obtain it, one calculates the reactions to embeddings in A and B. The percentage of difference indicates the difference between this modeling and equivalent modeling with the method PENALIZATION.

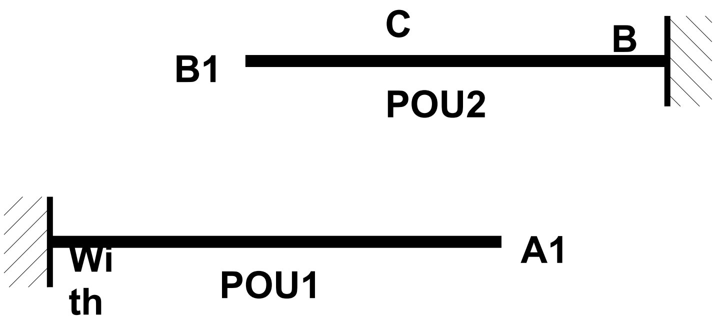
On the curve of bottom, one represented the force at the point B (embedding of the higher beam) according to the evolution of the loading. The methods are compared penalized and continues with the solution obtained in great displacements. It appears that the two methods give almost identical results, but that the latter differ notably from those obtained in great displacements. This point is rather logical, since within the framework of the small disturbances in which calculations were carried out, one neglects the terms of deformation of the second order, which as one notes it are not negligible in great transformations.

Calculation with penalized method in discrete method and the method continues standard. One tests values in NON_REGRESSION.

9 Modeling G

9.1 Characteristics of modeling

One carries out here a modeling using elements beam in $3D$. Deformations being plane in the plan (DX, DY), one imposes $DZ=0$ with the model $3D$. The goal of this CAS-test is to validate the taking into account of the real section of the beam, that the user informed by the keyword 'BEAM' in AFFE_CARA_ELEM.



Boundary conditions:

- Nodes A and B : $DX=DY=0$
- Nodes C : $DY=-790\,mm$

Conditions of contact:

- surface Master: group of mesh $POU1$
- surface slave: group of mesh $POU2$

Characteristics of the beam:

1) tubular section of ray $31.75\,mm$ and thickness $1\,mm$

9.2 Characteristics of the grid

Many meshs:	80
SEG2	80

9.3 Sizes tested and results

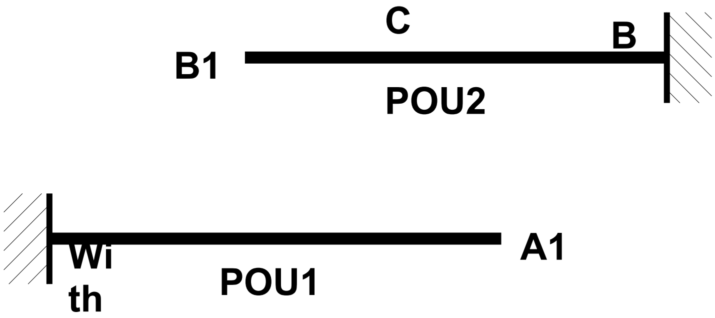
One tests the reaction to the displacement imposed on the beam. One compares the case where the section of the beam entered via a constant game DIST_ESCL and the case where one takes into account the real section via the keyword DIST_POUTRE.
Finally one also compares the formulation continues with the discrete formulation if the real section is taken into account via the keyword DIST_POUTRE.

Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.16	245,987	'AUTRE_ASTER'	0,10%
Reaction	0.4	1251.49	'AUTRE_ASTER'	0,10%

10 Modeling H

10.1 Characteristics of modeling

One carries out here a modeling using elements beam in $3\mathrm{D}$. Deformations being plane in the plan (DX, DY), one imposes $DZ=0$ with the model $3\mathrm{D}$. Contrary to preceding modelings of beam, one uses here an element able to take into account great displacements (multifibre elements, [R3.08.09]).



Boundary conditions:

- Nodes A and B : $DX=DY=0$
- Nodes C : $DY=-790\,mm$

Conditions of contact:

- surface Master: group of mesh $POU1$
- surface slave: group of mesh $POU2$

10.2 Characteristics of the grid

Many meshs:	80
SEG2	80

10.3 Sizes tested and results

One tests the reaction to the displacement imposed on the beam. To obtain it, one calculates the reactions to embeddings in A and B. Is calculated with the method CONTINUOUS. The sizes tested are it only by tests of not-regression.

Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.2	311,885	'NON_REGRESSION'	-
Reaction	0.4	1210.43	'NON_REGRESSION'	-
Reaction	0.6	2432.31	'NON_REGRESSION'	-
Reaction	0.8	2085.15	'NON_REGRESSION'	-
Reaction	1.0	2342.33	'NON_REGRESSION'	-

One also tests in this modeling the use of the normal slave for the writing of the conditions of contact.

Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.2	311,885	'NON_REGRESSION'	-
Reaction	0.4	1273.768	'NON_REGRESSION'	-
Reaction	0.6	3036.885	'NON_REGRESSION'	-
Reaction	0.8	4817.154	'NON_REGRESSION'	-
Reaction	0.94	6256.072	'NON_REGRESSION'	-

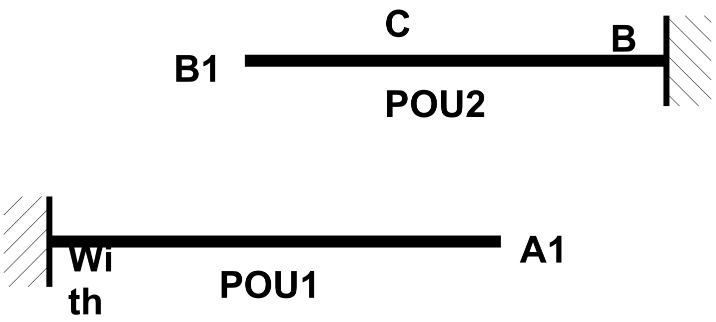
10.4 Remarks

One notes the very good agreement between the results got in great displacements by a model hull (modeling A) and a model beam (this modeling).
It will be noticed on the other hand that these two modelings give results different from a modeling $3D$, that is with the description of the contact at the end of beam which is specific in modelings of structures.
One in addition notes in this modeling that certain tests are the object of not-regression: it is because the answer of the structure when the normal slave is used differs from the case where the normal Master is used (same manner as if one inverts surfaces Masters and slaves).

11 Modeling I

11.1 Characteristics of modeling

One carries out here a modeling using elements of plate in $3D$. Deformations being plane in the plan (DX, DY) , one imposes $DZ=0$ with the model $3D$. The goal of this CAS-test is to compare the deformation of the plates with a formulation in small rotations with that obtained with great rotations. The first model is of course abusive (forgery) compared to the second (true), but makes it possible to illustrate the difference of the results got in one or the other case. The true motivation of this CAS-test is however to display an example of validation of the contact between beams with taking into account of fictitious games.



Boundary conditions:

- Nodes A and B : $DX=DY=0$
- Nodes C : $DY=-790\,mm$

Conditions of contact:

- surface Master: group of mesh $POU1$
- surface slave: group of mesh $POU2$

11.2 Characteristics of the grid

Many meshs:	90
QUAD4	90

11.3 Sizes tested and results

One tests the reaction to the displacement imposed on the beam. To obtain it, one calculates the reactions to embeddings in A and B . The tests are of not-regression.

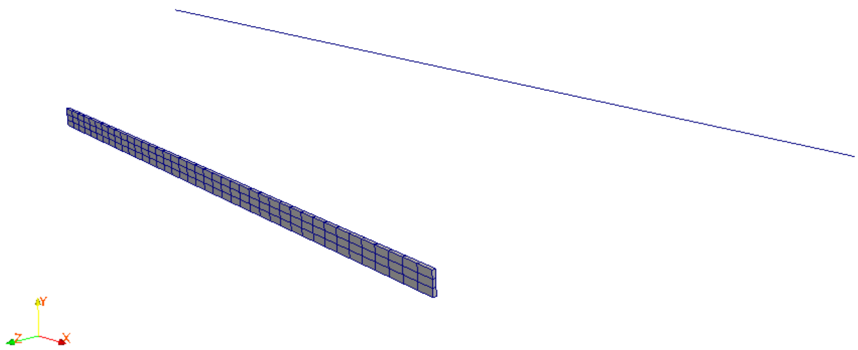
Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.2	345.91080450711	'NON_REGRESSION'	0,10%
Reaction	0.4	1407.8768333509	'NON_REGRESSION'	0,10%
Reaction	0.6	3401.7749540056	'NON_REGRESSION'	0.10%
Reaction	0.8	5432.9851518568	'NON_REGRESSION'	0.10%
Reaction	1.0	7487.5203886243	'NON_REGRESSION'	0,10%

It is noted first of all that the results of the model plates under Assumption of the Small Disturbances (HPP) are very distant from those of the models in great displacements: as explained in the conclusions of modeling F (model of beam in small disturbances), it is normal.
It is noted that the results plates and beam (modeling F) differ rather largely in spite of an identical tendency. There still that can be explained by the following reason: the model plates fate of its framework of use because the thickness of the plates (of $63{,}5\,mm$ not modelled) is not small in particular in front in front of two other dimensions ($10{,}16\,mm$).

12 Modeling J

12.1 Characteristics of modeling

One carries out here a modeling using elements beam and solid masses. Deformations being plane in the plan (DX, DY), one imposes $DZ=0$ with the model. One uses here an element of beam able to take into account great displacements (multifibre elements, [R3.08.09]).



12.2 Characteristics of the grid

Many nodes: 369.
Many meshs: 40 SEG2, 120 HEXA8.

12.3 Sizes tested and results

One tests the reaction to the displacement imposed on the beam. To obtain it, one calculates the reactions to embeddings in A and B. Two modelings with respectively method CONSTRAINT and method CONTINUOUS are the object of tests of not-regression. Moreover modeling CONTINUOUS is compared with modeling CONSTRAINT.

The first calculation (method CONSTRAINT)

Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.2	311.88	'NON_REGRESSION'	0,10%
Reaction	0.4	1498.48	'NON_REGRESSION'	0,10%
Reaction	0.6	3042.17	'NON_REGRESSION'	0,10%
Reaction	0.8	2172	'NON_REGRESSION'	0,10%
Reaction	1.0	2159.73	'NON_REGRESSION'	0,10%

The second calculation (formulation CONTINUOUS)

Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.2	311.88	'AUTRE_ASTER'	0,10%
Reaction	0.4	1498.48	'AUTRE_ASTER'	0,10%
Reaction	0.6	3042.17	'AUTRE_ASTER'	0,10%
Reaction	0.8	2172	'AUTRE_ASTER'	1.0%
Reaction	1.0	2159.73	'AUTRE_ASTER'	2.0%

Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.2	311.88	'NON_REGRESSION'	0,10%
Reaction	0.4	1498.49	'NON_REGRESSION'	0,10%
Reaction	0.6	3042.27	'NON_REGRESSION'	0,10%
Reaction	0.8	2191.47	'NON_REGRESSION'	0,10%
Reaction	0.94	2183.24	'NON_REGRESSION'	0,10%

12.4 Remarks

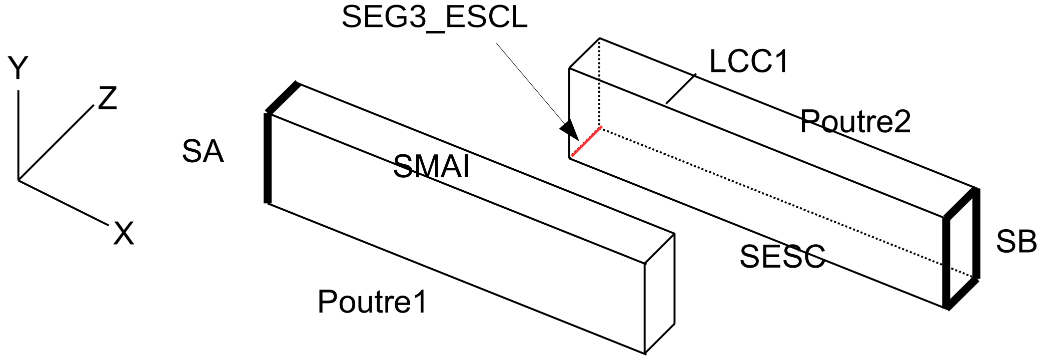
The results got between the two formulations of contact are close although they differ from a few percent at the end of the loading: these differences can be explained by the modeling of beam used (POU_D_TGM in great displacements) which is sensitive to the iteration count of Newton (approximate formulation of great displacements). A refinement of the step of time must correct this variation.
This modeling validates the contact between an edge and a facet for the two formulations of contact.

It is noted that the got results are different from the contact beam-beam and contact 3D-3D. The particular geometrical configuration of this test explains that (the zone of contact is different in each case).

13 Modeling K

13.1 Characteristics of modeling

In this modeling, one wishes to validate the contact of a face `QUAD8` and of an edge `SEG3`. The grid is in this entirely quadratic case. Calculation in contact `QUAD8/SEG3` is compared to same calculation with contact `QUAD8/QUAD8` (calculation of reference).



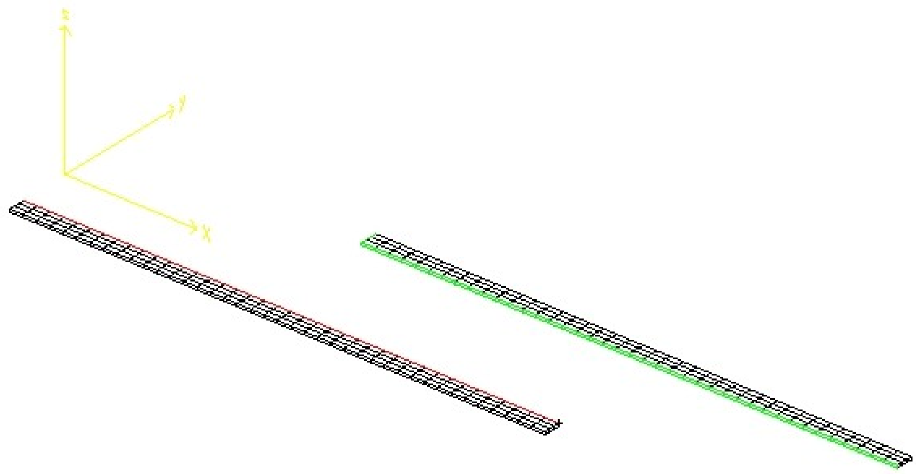
Boundary conditions:

- Surfaces SA and SB : $DX=DY=DZ=0$
- Line $LCC1$: $DY=-790\,mm$
- All the nodes tops of the structure: $DZ=0$

Conditions of contact:

- surface Master: group of meshs $SMAI$
- surface slave:
  - mesh SEG3_ESCL for the calculation of validation
  - group of meshs SESC for the calculation of reference

13.2 Characteristics of the grid



Many nodes:		2116
Many meshs:		1247
	SEG3	351
	QUAD8	655
	HEXA20	240

13.3 Sizes tested and results

One tests the reaction to the displacement imposed on $POUTRE2$. To obtain it, one calculates the reactions to embeddings in SA and SB .

Calculation of reference (contact face/face):

Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.2	-	'NON_REGRESSION'	-
Reaction	0.4	-	'NON_REGRESSION'	-
Reaction	0.6	-	'NON_REGRESSION'	-
Reaction	0.8	-	'NON_REGRESSION'	-
Reaction	1.0	-	'NON_REGRESSION'	-

Calculation of validation (contact face/edge):

Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.2	348.708752921	'AUTRE_ASTER'	0,10%
Reaction	0.4	1330.02714552	'AUTRE_ASTER'	0,10%
Reaction	0.6	2604.89459614	'AUTRE_ASTER'	0.10%
Reaction	0.8	2191.78984705	'AUTRE_ASTER'	0.10%
Reaction	1.0	2468.55600727	'AUTRE_ASTER'	3,00%

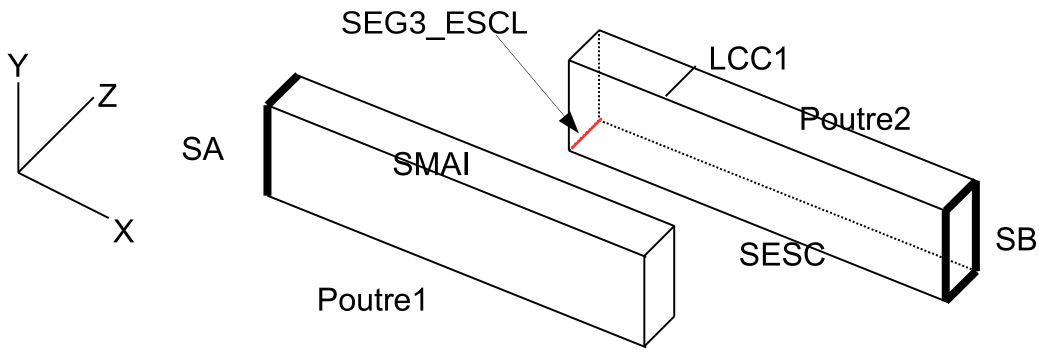
The results tested are exactly the same ones for two calculations until the moment $t=0{,}8$. The difference noted at the moment $t=1$ be explained by the fact that there is no more only the edge SEG3_ESCL which is in contact with $POUTRE1$. However that is not taken into account in calculation in contact face/edge.

The contact QUAD8/SEG3 is thus validated by this modeling.

14 Modeling L

14.1 Characteristics of modeling

In this modeling, one wishes to validate the contact of a face QUAD9 and of an edge SEG3. The grid is in this entirely quadratic case. Calculation in contact QUAD9/SEG3 is compared to same calculation with contact QUAD9/QUAD9 (calculation of reference).



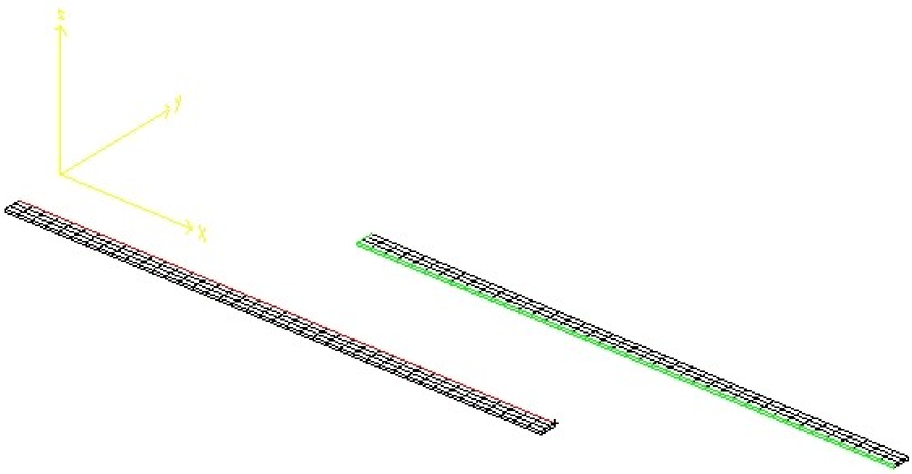
Boundary conditions:

- Surfaces SA and SB : $DX=DY=DZ=0$
- Line $LCC1$: $DY=-790\,mm$
- All the nodes tops of the structure: $DZ=0$

Conditions of contact:

- surface Master: group of meshs $SMAI$
- surface slave:
  - mesh SEG3_ESCL for the calculation of validation
  - group of meshs SESC for the calculation of reference

14.2 Characteristics of the grid



Many nodes:		3796
Many meshs:		1247
	SEG3	351
	QUAD9	655
	HEXA27	240

14.3 Sizes tested and results

One tests the reaction to the displacement imposed on $POUTRE2$. To obtain it, one calculates the reactions to embeddings in SA and SB.

Calculation of reference (contact face/face):

Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.2	-	'NON_REGRESSION'	-
Reaction	0.4	-	'NON_REGRESSION'	-
Reaction	0.6	-	'NON_REGRESSION'	-
Reaction	0.8	-	'NON_REGRESSION'	-
Reaction	1.0	-	'NON_REGRESSION'	-

Calculation of validation (contact face/edge):

Identification	Moments	Reference	Type of reference	Tolerance
Reaction	0.2	325.581162553	'AUTRE_ASTER'	0,10%
Reaction	0.4	1240.46130573	'AUTRE_ASTER'	0,10%
Reaction	0.6	2431.47438935	'AUTRE_ASTER'	0.10%
Reaction	0.8	2051.49459253	'AUTRE_ASTER'	0.10%
Reaction	1.0	2304.9293421	'AUTRE_ASTER'	3,00%

The results tested are exactly the same ones for two calculations until the moment $t=0,8$. The difference noted at the moment $t=1$ be explained by the fact that there is no more only the edge SEG3_ESCL which is in contact with $POUTRE1$. However that is not taken into account in calculation in contact face/edge.

The contact QUAD9/SEG3 is thus validated by this modeling.

15 Modeling M

15.1 Characteristics of modeling

In this modeling, one wishes to validate the contact of a beam POU_D_E SEG2 with a beam SEG 2 . The grid is in this entirely telegraphic case. Calculation in contact SEG2 /SEG 2 is tested in not-regression.

Boundary conditions:

* on the ends $DX=DY=DZ=0$
* $DY=-790\,mm$
* All the nodes tops of the structure: $DZ=0$

Conditions of contact: The contact is treated with the method of discrete penalization.

15.2 Characteristics of the grid

```
MANY NODES                     82
MANY MESHS                    80
             SEG2                   80
```

15.3 Sizes tested and results

Values of non-r are testedégression.

16 Summary of the results

The graph below presents the evolution of the component DY force of reaction to the displacement imposed according to this last.
One notices very a good agreement between various modelings until $500\,mm$ then the curve COQUE_3D (just as modeling POU_D_TGM) separates from $2\mathrm{D}$ and of $3\mathrm{D}$ before meeting with $700\,mm$. This variation is normal: it appears when the end of beam 2 is orthogonal with beam 1 (specific description of the contact *vs.* description $3\mathrm{D}$).