

## SSNL135 – Determination of the loads of ruin of console MEKELEC

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### Summary

In this test, one seeks to validate in the non-linear field geometrical and material the element of multifibre beam of Timoshenko, available in *Code\_Aster* via modeling `POU_D_TGM`. To illustrate the opportunities given by this element, one proposes to numerically determine the loads of ruin of the console of pylon known as MEKELEC and to compare them with test results.

Console MEKELEC is subjected to various loading cases and for each case, one compares the load of ruin and the mode of ruin predicted with those observed during the tests. The results show a very good prediction of the modes of ruin with, however, a disparity on the loads which is explained more by the simplified modeling adopted for the console than by gaps of the finite element used.

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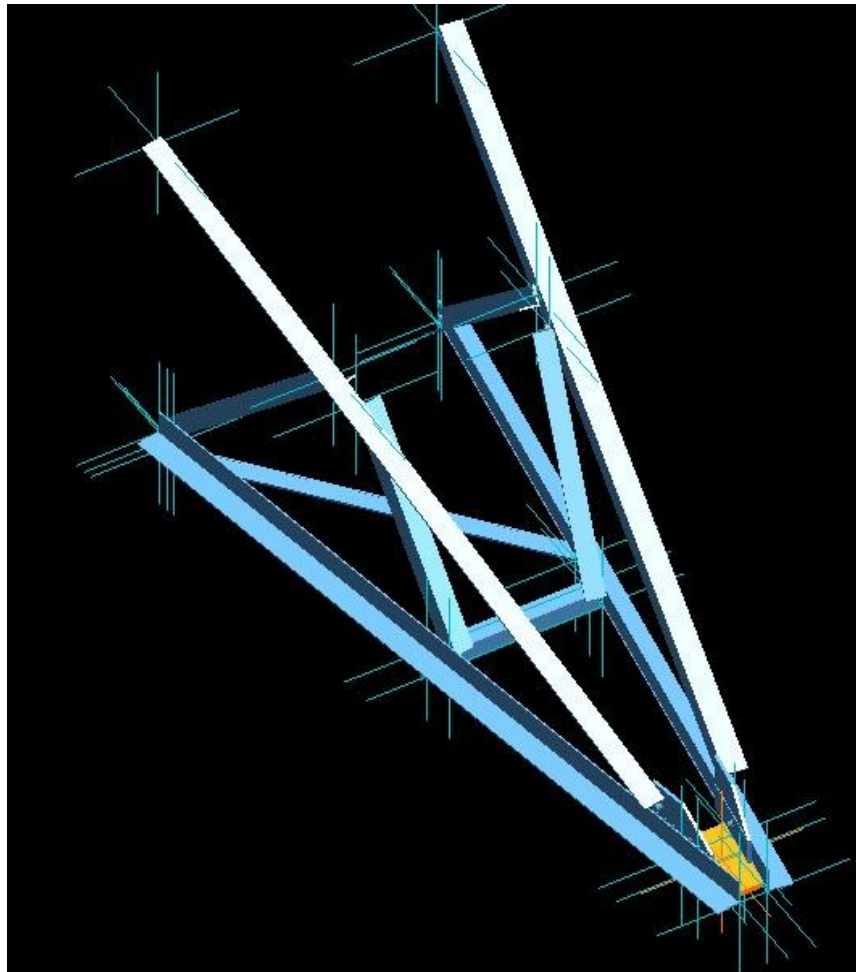
## 1 Problem of reference

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### 1.1 Geometry of the structure

Console MEKELEC is studied. It is about a console of pylon P4T, whose dimensions were reduced to facilitate the instrumentation of the tests while preserving a structure whose modes of ruin can be varied and cover those met in a pylon real lattice.

The structure is made up of 10 angles assembled on their wings with bolts, or via brackets. One will be able to refer to [3] for detailed plans of the console.



### 1.2 Characteristics of the angles used

The angles used in console MEKELEC are standard sections of the metal structure. The basic unit for the sizes below is the meter.

Beams	AE45×3	AE40×4	AE35×3.5
A	2.638081e-04	3.077706e-04	2.344277e-04
IY	8.013486e-08	7.077171e-08	4.210543e-08
IZ	2.087844e-08	1.855685e-08	1.095197e-08
AY	2.419087e+00	2.394947e+00	2.359465e+00
AZ	2.207830e+00	2.118989e+00	2.163107e+00
JX	8.404596e-10	1.784041e-09	9.865361e-10
JG	1.243656e-13	1.871860e-13	8.685007e-14
EY	1.459718e-02	1.233794e-02	1.108092e-02
IYR2	6.307966e-10	4.829759e-10	2.482771e-10

Sizes *EZ* and *IZR2* are worthless for all the beams.

## 1.3 Properties of material

Only one material is used, it is steel *E24*. During preliminary tests to the tests, the real characteristics of steel used could be measured, making it possible to adapt the values of the various parameters materials. Below the characteristics used in calculation appear:

$$\begin{aligned}E &= 210000 \text{ MPa} \\ \nu &= 0.3 \\ \sigma_e &= 300 \text{ Mpa} \\ E_t &= 1000 \text{ Mpa}\end{aligned}$$

## 1.4 Boundary conditions and loading

- 1) Boundary conditions are imposed on the points *A*, *B*, *C*, *D* :

$$DX = DY = DZ = DRX = DRY = 0$$

To simulate the flexibility of the folded brackets used at the anchor points, one leaves rotation around *Z* free.

- 2) Three types of case of loading are possible (cf appears for the points *P* and *Q*):

$$\begin{aligned}C1 &: FZ = 1.0 \times t \text{ in } P \\ C2 &: FZ = -1.0 \times t \text{ in } P \\ C3 &: FY = 1.0 \times t \text{ in } Q\end{aligned}$$

Note: the goal of the CAS-test is here to determine pseudo-time *t* corresponding to the ruin, i.e. the acceptable maximum force by the structure. It is a horizontal tangent in the answer of the structure (curve force-displacement at the point of application of the force).

## 2 Reference solution

### 2.1 Method used for calculation of the reference solution

The reference solution was obtained by instrumentation during tests on a reproduction of console MEKELEC [1]. The load of ruin is that for which it occurs a very important displacement of the point of application of the force without it being possible to arrive in a state of balance (nonquasi-static evolution of the structure).

In all the cases, the structure was discharged entirely to 40% and 80% of the load from design to prevent that the games in the assemblies do not come to disturb the load of ruin.

### 2.2 Results of reference

The loads of ruin determined during the tests are presented for each loading case:

Loading case	Load of ruin ( <i>kN</i> )	Associated mode
<i>C1</i>	49.9	Plasticization in nose of console
<i>C2</i>	32.4	Buckling of the top booms
<i>C3</i>	16.2	Plasticization in nose of console

### 2.3 Uncertainty on the solution

Experimental results.

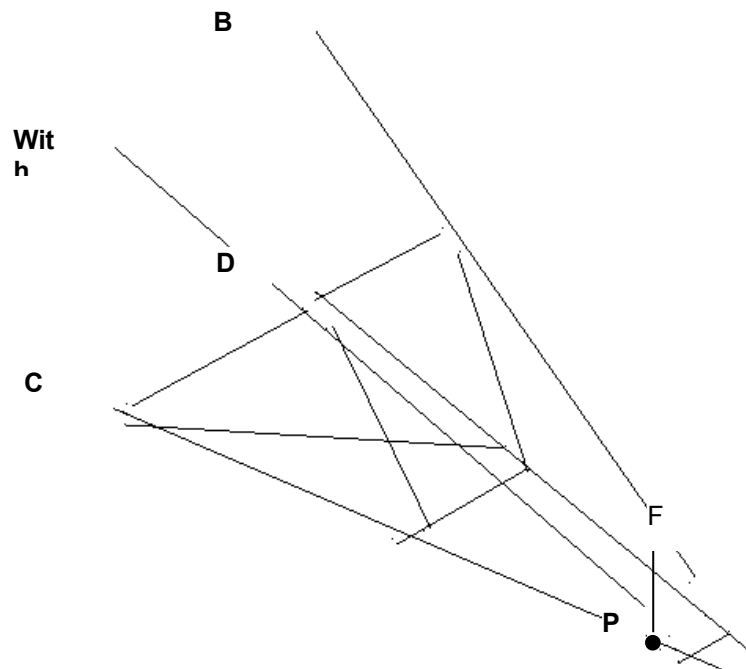
### 2.4 Bibliographical references

- [1] PENSERINI P.: "Results of the tests of console MEKELEC of 1991 to 1993", EDF DER, HM-77/93/262, 1993 Notes.
- [2] PENSERINI P.: "Simulation of the behavior of console MEKELEC by *Code\_Aster* ", EDF DER, HM-77/94/407, 1994 Notes.
- [3] PENSERINI P.: "Tests of investigation of the behaviour of the Mékélec structure-test of the type comforts pylon P4T", Document Technical EDF DER, HM-72/5917, 1991.

## 3 Modeling A

### 3.1 Characteristics of modeling

Modeling POU\_D\_TGM (140 elements)/ DIS\_TR (22 elements)



The modeling of the bolted assemblies is ensured by the discrete ones whose stiffnesses are fixed in a contractual way. Offsettings of the points of fastener are taken into account (what explains why the elements are not convergent). The model is obtained starting from the EVEREST preprocessor.

The loading case is the first ( *CI* ).

### 3.2 Characteristics of the grid

Many nodes: 191

Many meshes and types: 162 SEG2 (including 22 worthless length for the discrete ones)

### 3.3 Characteristics of the transverse section (fibres)

Many fibres: 40 (cutting in 2 in the thickness and 10 in the length of the wings)

### 3.4 Sizes tested and results

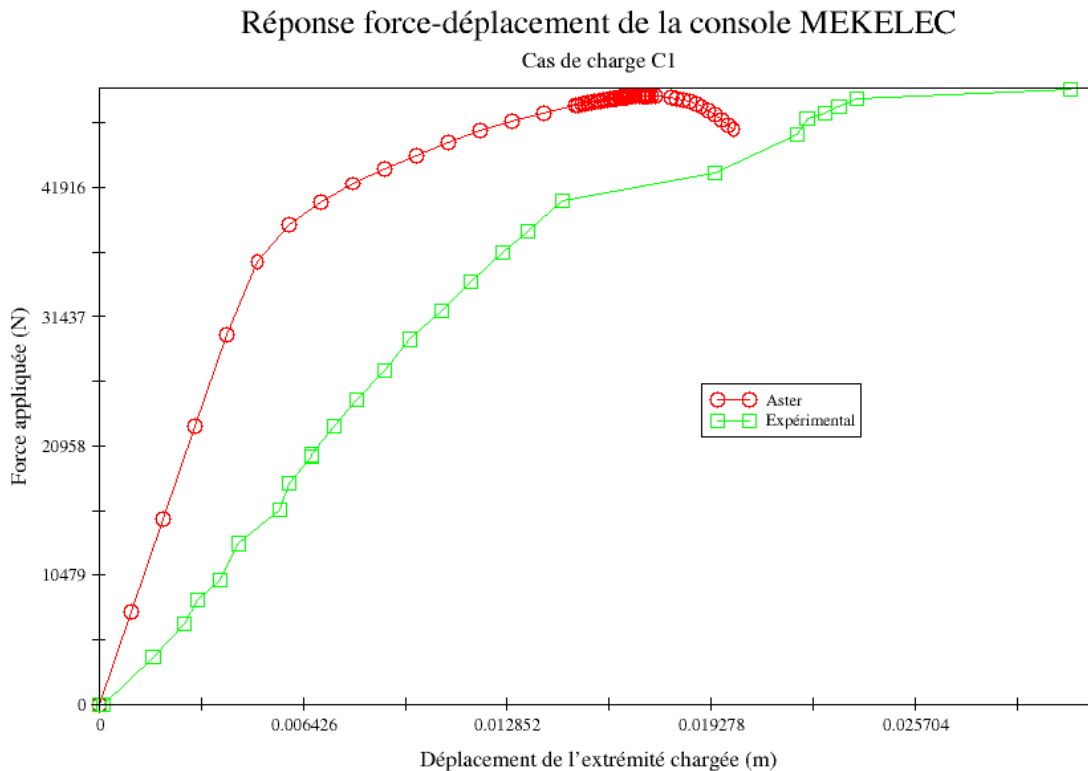
#### 3.4.1 Values tested

The value tested is the load of ruin estimated for the structure. As the results of reference are experimental, one matches the comparisons of tests of not-regression. The load of ruin for calculation is defined as being the maximum value taken by the effort applied to the structure.

*Recall: one controls the structure in displacement, one thus observes a softening.*

Loading case	Reference	Type of reference	Tolerance
C1	49.9	'SOURCE_EXTERNE'	10 %

## 3.4.2 Graphic results of modeling A



## 3.4.3 Remarks

The digital answer of the structure is obtained by a piloting in displacement of the charged node, that makes it possible to observe softening due to the ruin and thus to be able to test the maximum value of the state of piloting (parameter `ETA_PILOTAGE`).

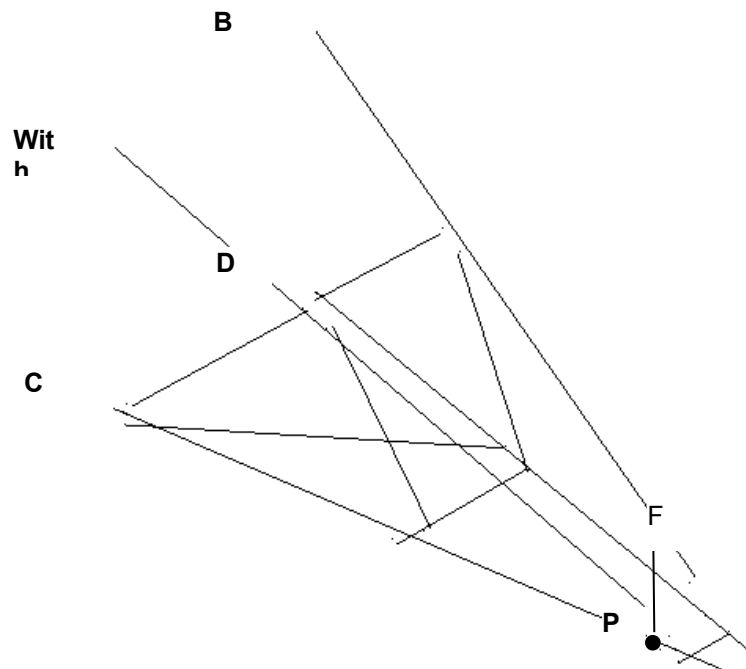
The load of ruin for this loading case is correctly estimated, however one notices that the experimental answer and the digital answer largely differ, in particular because of an elastic slope largely over-estimated in calculation *Aster*. The rigidity of the structure indeed is not well retranscribed in the model: the brackets which make it possible to at the head ensure the assemblies and in foot of console are supposed to have a rigid behavior whereas they are plates.

One can however observe that the total pace of the answers experimental and digital is the same one with a good description of the break of slope (plasticization at the top of console) then limiting load (tangent horizontal with curved force-displacement).

## 4 Modeling B

### 4.1 Characteristics of modeling

Modeling POU\_D\_TGM (140 elements)/ DIS\_TR (22 elements)



The modeling of the bolted assemblies is ensured by the discrete ones whose stiffnesses are fixed in a contractual way. Offsets of the points of fastener are taken into account (what explains why the elements are not convergent). The model is obtained starting from the EVEREST preprocessor.

The loading case is the second ( *C2* ).

### 4.2 Characteristics of the grid

Many nodes: 191

Many meshes and types: 162 SEG2 (including 22 worthless length for the discrete ones)

### 4.3 Characteristics of the transverse section (fibres)

Many fibres: 40 (cutting in 2 in the thickness and 10 in the length of the wings)

### 4.4 Sizes tested and results

#### 4.4.1 Values tested

The value tested is the load of ruin estimated for the structure. As the results of reference are experimental, one matches the comparisons of tests of not-regression. The load of ruin for calculation is defined as being the maximum value taken by the effort applied to the structure.

The injective character of curved force-displacement gives us the possibility of testing it in not-regression for the various values of parameter  $\text{ETA\_PILOTAGE}$ .

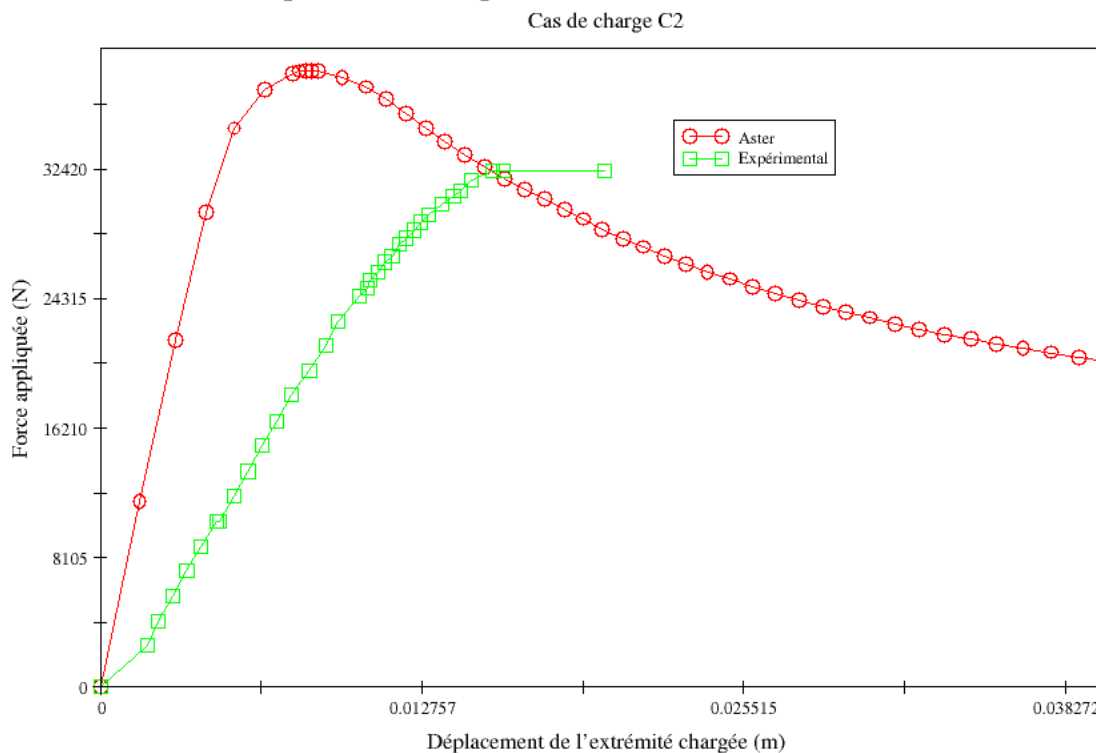
*Recall: one controls the structure in length of arc, one thus observes a softening.*



Loading case	Reference	Type of reference	Tolerance
C2	32.4	'SOURCE_EXTERNE'	30 %

## 4.4.2 Graphic results of modeling B

### Réponse force-déplacement de la console MEKELEC



## 4.4.3 Remarks

The digital answer of the structure is obtained by a piloting in length of arc of all the structure, that makes it possible to observe softening due to the ruin and thus to be able to test the maximum value of the state of piloting (parameter `ETA_PILOTAGE`).

The load of ruin for this loading case is over-estimated to a total value of 20%. The rigidity of the structure is still too important there compared to the real model: the brackets which make it possible to at the head ensure the assemblies and in foot of console are supposed to have a rigid behavior whereas they are plates.

Unlike preceding modeling, that causes to give an erroneous limiting load. Indeed, the tests showed the importance of geometrical non-linearities (ruin by elastoplastic buckling of the angles of the higher panel), it does not have there redistribution of efforts following a plasticization, the ruin is brutal. Softening is concomitant with the end of the elastic slope.

## 4.4.4 Comparison of the modes of ruin

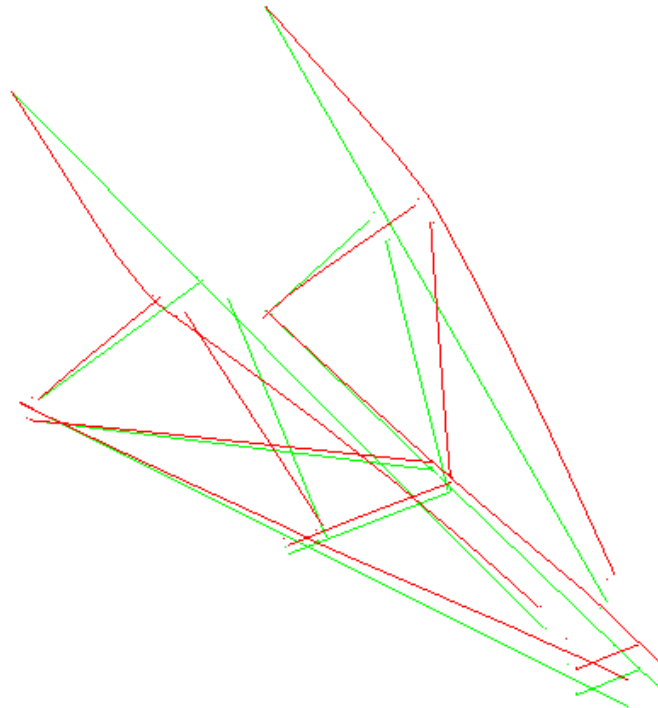


Figure 4.4.4-a : Mode of ruin predicted by calculation in configuration C2 (amplitude 1)

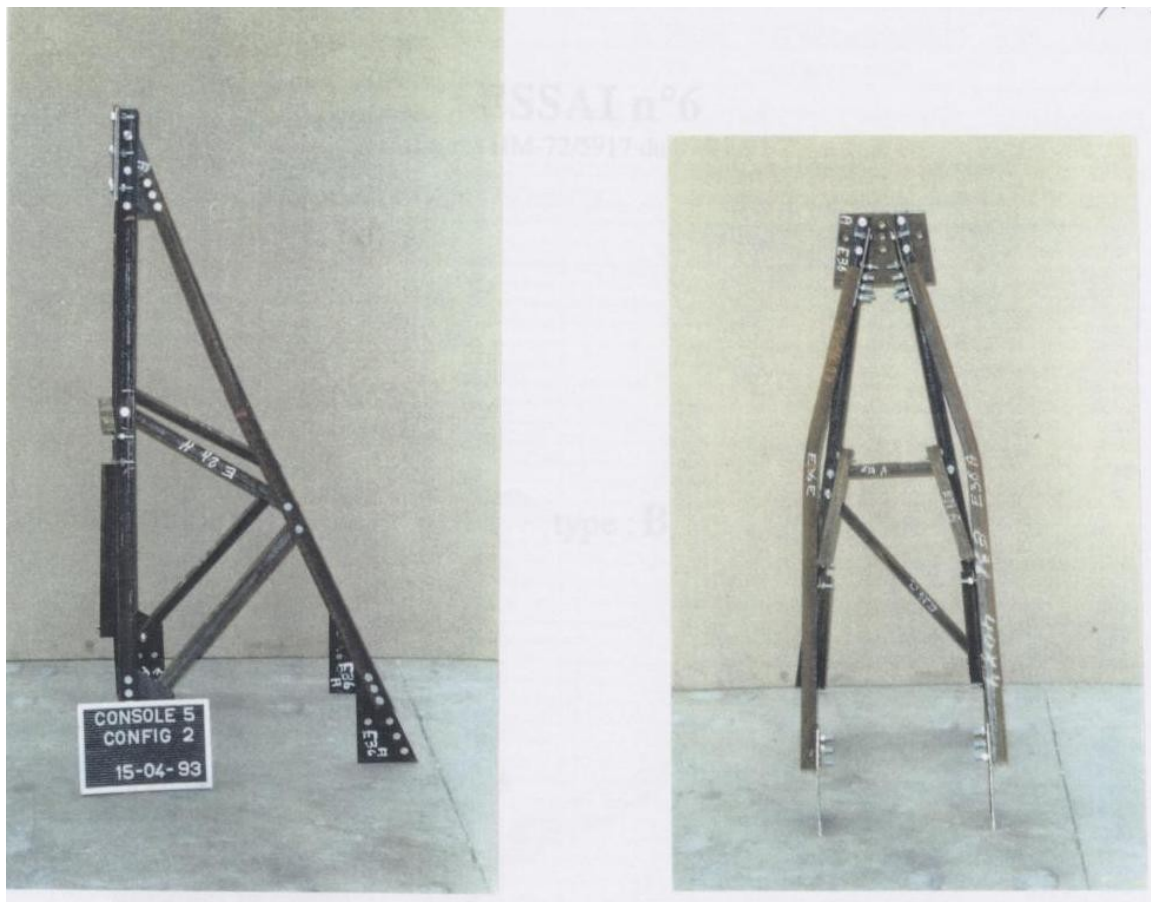
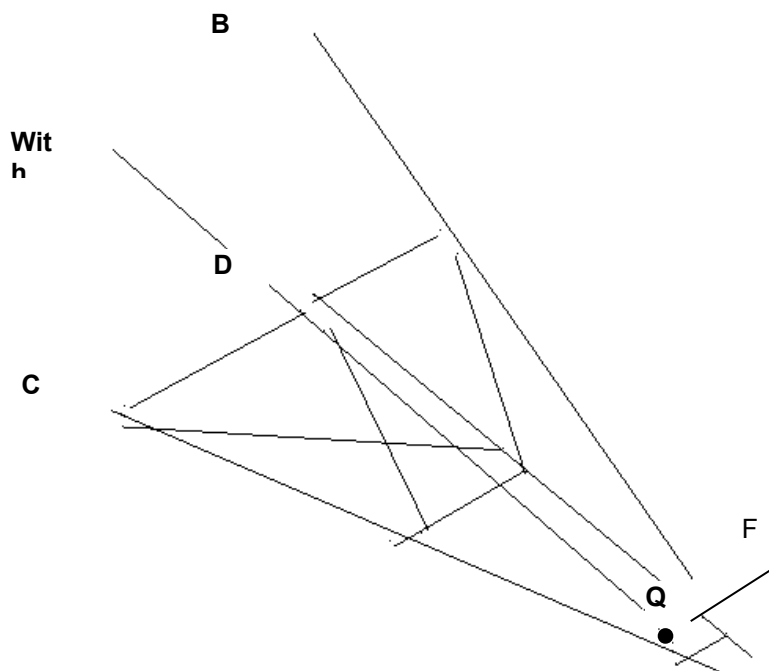


Figure 4.4.4-b : Mode of ruin observed during the tests in C2 configuration

## 5 Modeling C

### 5.1 Characteristics of modeling

Modeling POU\_D\_TGM (140 elements)/ DIS\_TR (22 elements)



The modeling of the bolted assemblies is ensured by the discrete ones whose stiffnesses are fixed in a contractual way. Offsettings of the points of fastener are taken into account (what explains why the elements are not convergent). The model is obtained starting from the EVEREST preprocessor.

The loading case is the third ( C3 ).

### 5.2 Characteristics of the grid

Many nodes: 191

Many meshes and types: 162 SEG2 (including 22 worthless length for the discrete ones)

### 5.3 Characteristics of the transverse section (fibres)

Many fibres: 40 (cutting in 2 in the thickness and 10 in the length of the wings)

### 5.4 Sizes tested and results

#### 5.4.1 Values tested

The value tested is the load of ruin estimated for the structure. As the results of reference are experimental, one matches the comparisons of tests of not-regression. The load of ruin for calculation is defined as being the maximum value taken by the effort applied to the structure.

The injective character of curved force-displacement gives us the possibility of testing it in not-regression for the various values of parameter `ETA_PILOTAGE`.

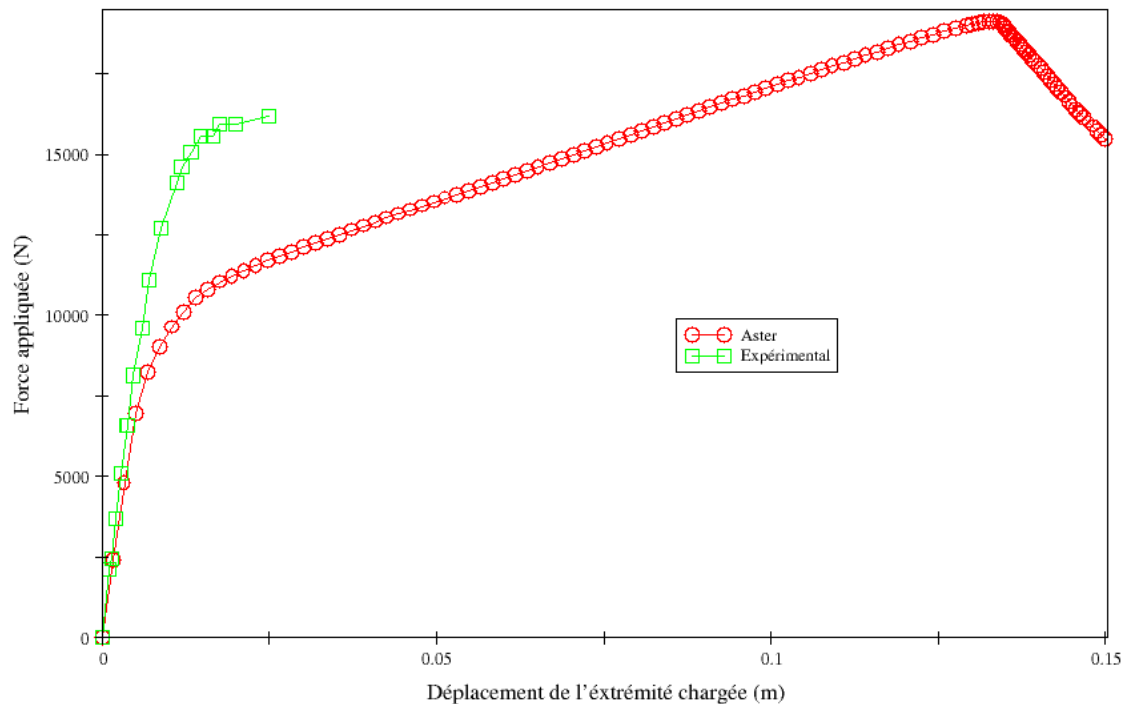
*Recall: one controls the structure in length of arc, one thus observes a softening.*

Loading case	Reference	Type of reference	Tolerance
C3	16.2	'SOURCE_EXTERNE'	20 %

## 5.4.2 Graphic results of modeling C

### Réponse force-déplacement de la console MEKELEC

Cas de charge C3



## 5.4.3 Remarks

The digital answer of the structure is obtained by a piloting in length of arc of all the structure, that makes it possible to observe softening due to the ruin and thus to be able to test the maximum value of the state of piloting (parameter `ETA_PILOTAGE`).

The load of ruin for this loading case is over-estimated to a total value of 20%. This time the elastic slope is however in concord with the experiment. One can doubt here the limiting load obtained under tests: compared to the other loading cases, the ruin is definitely marked (not of important displacement at the end), and one can think that it would have been possible to still draw on the structure.

## 6 Summary of the results

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The element of beam multifibre `POU_D_TGM` usable into non-linear geometrical and material makes it possible in this CAS-test to simulate the behavior of a console of pylon until the first softening and further if one controls the structure in displacement (in the case of a ruin by plasticization) or by length of arc (in the case of a ruin by buckling).

Calculation is fast and does not ask any adjustment to conclude it (if it is not the installation of piloting). The results, if they differ from the experiment, do not call into question the performances of the element. Indeed, the disparities observed are to be put on choice of modeling (assemblies in particular).