SSNL135 – Determination of the loads of failure of cantilever MEKELEC

Summarized

In this test, one seeks to validate in the nonlinear field geometrical and material the multifibre beam element of Timoshenko, available in *Code_Aster via* modelization `POU_D_TGM`. To illustrate the opportunities given by this element, one proposes to numerically determine the loads of failure of the cantilever of pylon known as MEKELEC and to compare them with test results.

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

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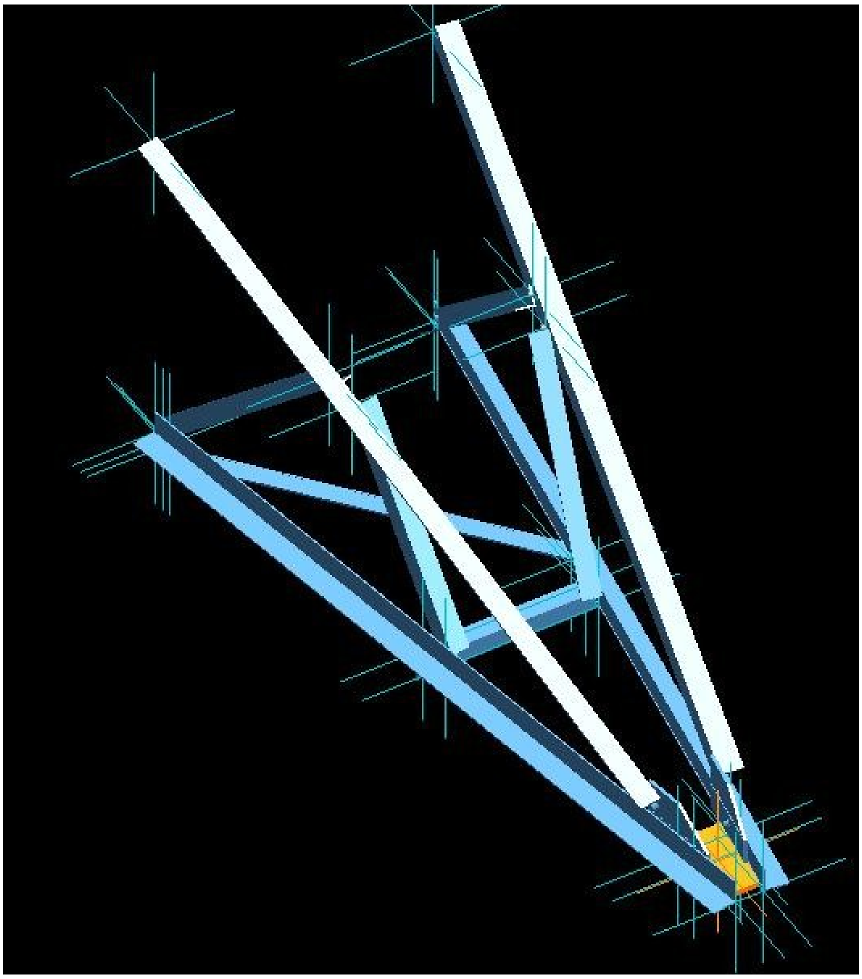
1 Problem of reference

1.1 Geometry of structure

One studies cantilever MEKELEC. It is about a cantilever of pylon P4T, whose dimensions were reduced to facilitate the instrumentation of the tests while preserving a structure whose modes of failure can be varied and cover those met in a pylon real truss.

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



1.2 Characteristics of the angles used

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

Beams	$AE45\times3$	$AE40\times4$	$AE35\times3.5$
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

the quantities EZ and $IZR2$ are null for all the beams.

1.3 Properties of the material

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

$$E=210000\ MPa$$
$$\nu=0.3$$
$$\sigma_e=300\ Mpa$$
$$E_t=1000\ Mpa$$

1.4 Boundary conditions and loading

1) Boundary conditions are imposed on the points $A\quad B\quad C\quad D$:

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

To simulate the compliance of the folded gussets 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):

$C1$: $FZ=1.0\times t$ in P
$C2$: $FZ=-1.0\times t$ in P
$C3$: $FY=1.0\times t$ in Q

Note:: the goal of the benchmark is here to determine pseudo-TEMPS t corresponding to failure, i.e. the acceptable maximum force by structure. It is a horizontal tangent in the response of the structure (curve force-displacement at the point of application of the force).

2 Reference solution

2.1 Method used for computation of the reference solution

the reference solution was obtained by instrumentation during tests on a reproduction of cantilever MEKELEC [1]. The load of failure 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 equilibrium (nonquasi-static evolution of structure).

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

2.2 Results of reference

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

Loading case	Charges with failure (kN)	Mode associated
$C1$	49.9	Plasticization in nose with cantilever
$C2$	32.4	Buckling with the top booms
$C3$	16.2	Plasticization in nose with cantilever

2.3 Uncertainty on the solution

experimental Results.

2.4 Bibliographical references

[1] PENSERINI P.: "Results of the tests of cantilever MEKELEC of 1991 to 1993", EDF DER, HM-77/93/262, 1993 Notes.

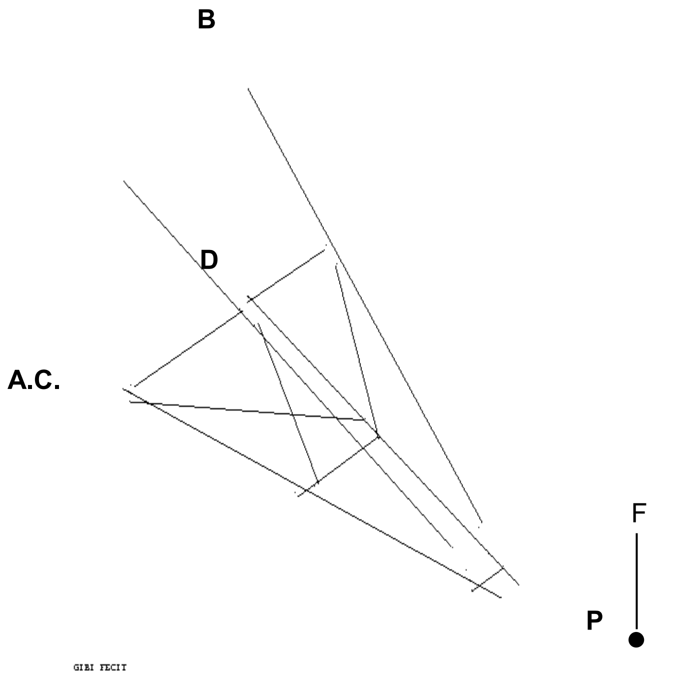
[2] PENSERINI P.: "Simulation of the behavior of cantilever MEKELEC by *the Code_Aster"*, EDF DER, HM-77/94/407, 1994 Notes.

[3] PENSERINI P.: "Tests of investigation of the behavior of the Mékélec structure-test of the type comforts pylon P4T", Document Technical EDF DER, HM-72/5917, 1991.

3 Modelization A

3.1 Characteristic of the modelization

Modelization POU_D_TGM (140 elements)/ DIS_TR (22 elements)



The modelization of the bolted assemblies is ensured by the discrete ones whose stiffness is fixed in a contractual way. The eccentrings 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 ($C1$).

3.2 Characteristics of the mesh

Many nodes: 191
Number of meshes and types: 162 SEG2 (including 22 of null length for discrete the)

3.3 Characteristic ones of the cross-sectional area (fibers)

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

3.4 Quantities tested and Values

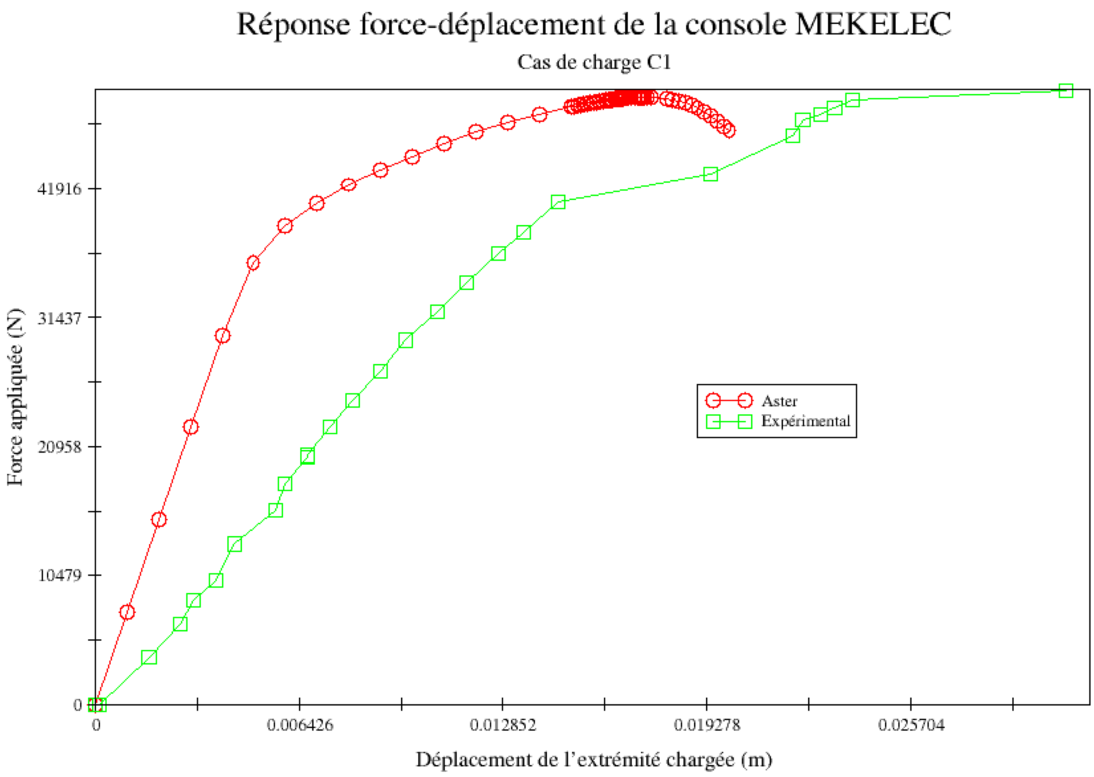
3.4.1 results tested

the value tested is the load of failure estimated for structure. As the results of reference are experimental, one matches the comparisons of tests of NON-regression. The load of failure for computation is defined as being the maximum value taken by the force applied to structure.

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

Reference	Standard	loading case of reference	Tolerance
C1	49.9	"SOURCE_EXTERNE"	10 %

3.4.2 graphic Results of the modelization A



3.4.3 Remarks

the numerical response of structure is obtained by a control in displacement of the charged node, that makes it possible to observe softening due to failure and thus to be able to test the maximum value of the state of control (parameter ETA_PILOTAGE).

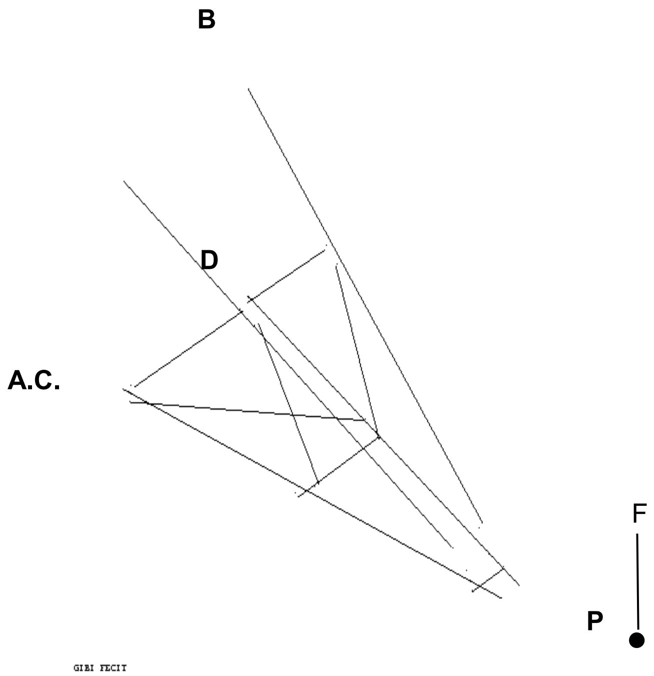
The load of failure for this loading case is correctly estimated, however one notices that the experimental response and the numerical response largely differ, in particular because of an elastic slope largely over-estimated in Aster computation . The stiffness of structure indeed is not well retranscribed in the model: the gussets which make it possible at the head to ensure the assemblies and in foot of cantilever are supposed to have a rigid behavior whereas they are plates.

One can however observe that the total pace of the responses experimental and numerical is the same one with a good description of the break of slope (plasticization at the top of cantilever) then of the Yield-point load (tangent horizontal with curved force-displacement).

4 Modelization B

4.1 Characteristic of the modelization

Modelization `POU_D_TGM` (140 elements)/ `DIS_TR` (22 elements)



The modelization of the bolted assemblies is ensured by the discrete ones whose stiffness is fixed in a contractual way. The eccentrings 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 mesh

Many nodes: 191
Number of meshes and types: 162 `SEG2` (including 22 of null length for discrete the)

4.3 Characteristic ones of the cross-sectional area (fibers)

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

4.4 Quantities tested and Values

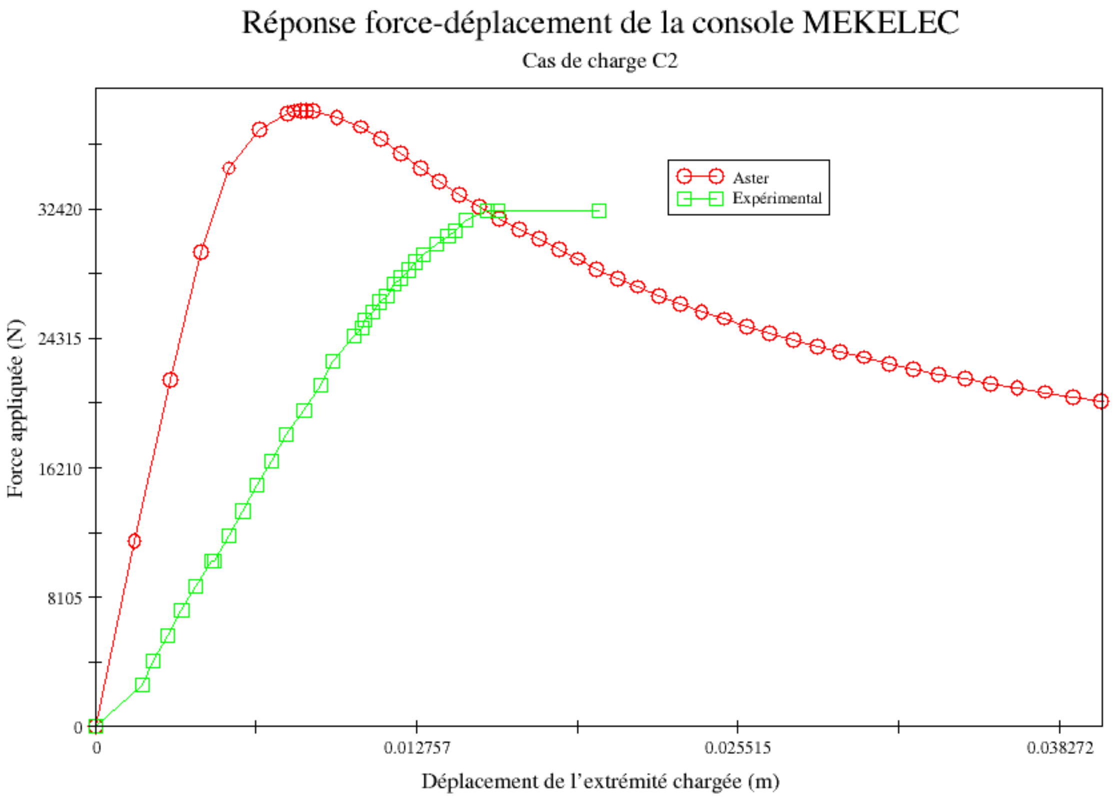
4.4.1 results tested

the value tested is the load of failure estimated for structure. As the results of reference are experimental, one matches the comparisons of tests of NON-regression. The load of failure for computation is defined as being the maximum value taken by the force applied to structure.
Recall: one controls structure in length of arc, one thus observes a softening.

Reference	Standard	loading case of	Tolerance

		reference	
C2	32.4	"SOURCE_EXTERNE"	30 %

4.4.2 graphic Results of the modelization B



4.4.3 Remarks

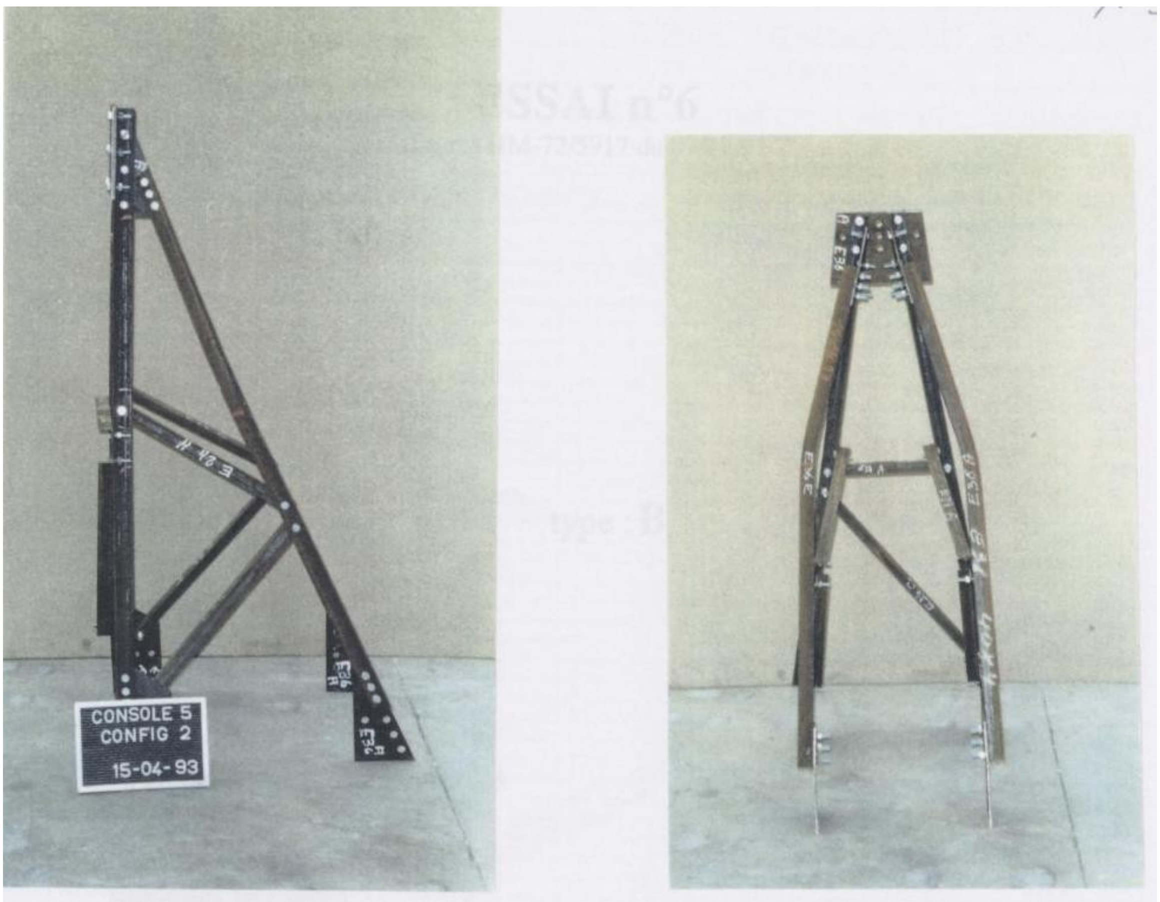
the numerical response of structure is obtained by a control in length of arc of all structure, that makes it possible to observe softening due to failure and thus to be able to test the maximum value of the state of control (parameter ETA_PILOTAGE).

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

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

4.4.4 Comparison of the modes of failure

Appears 4.4.4-a : Mode of failure predicted by computation in configuration C2 (amplitude 1)

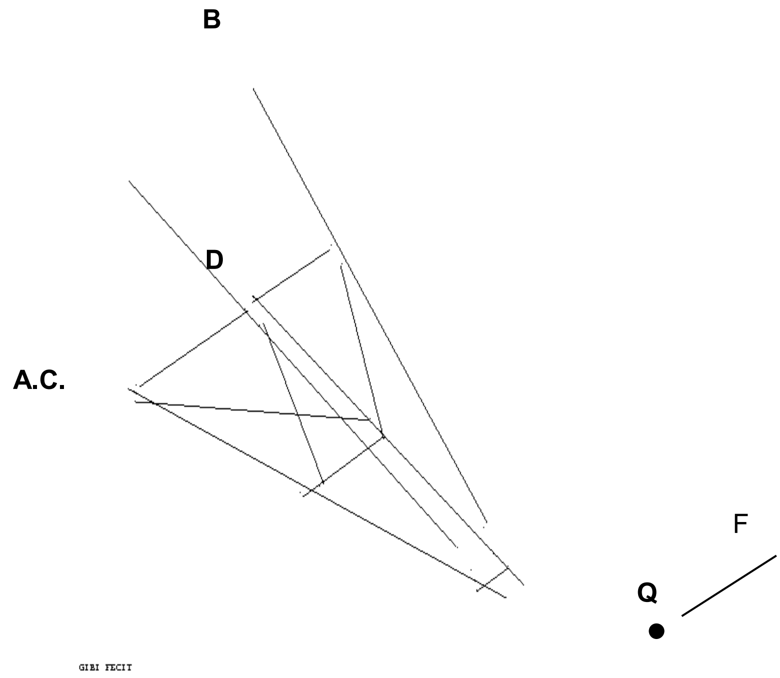


Appears 4.4.4-b : Mode of failure observed during the tests in configuration C2

5 Modelization C

5.1 Characteristic of the modelization

Modelization POU_D_TGM (140 elements)/ DIS_TR (22 elements)



The modelization of the bolted assemblies is ensured by the discrete ones whose stiffness is fixed in a contractual way. The eccentrings 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 mesh

Many nodes: 191
Number of meshes and types: 162 SEG2 (including 22 of null length for discrete the)

5.3 Characteristic ones of the cross-sectional area (fibers)

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

5.4 Quantities tested and Values

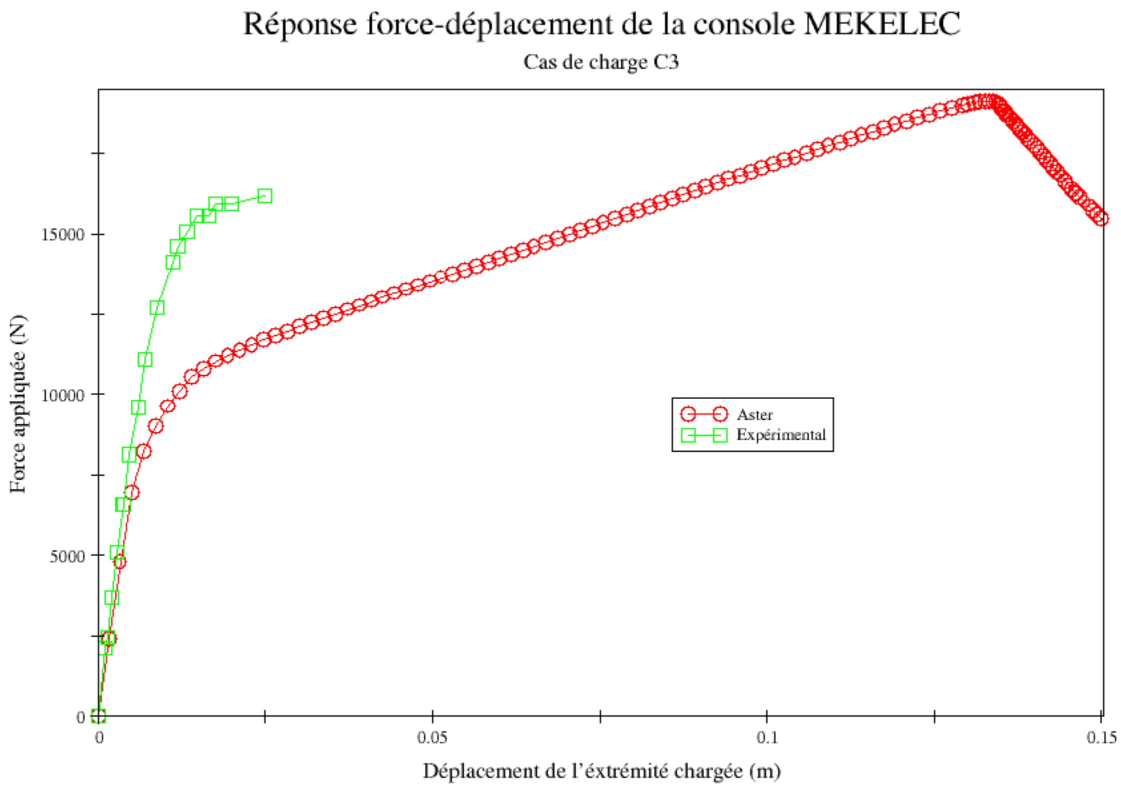
5.4.1 results tested

the value tested is the load of failure estimated for structure. As the results of reference are experimental, one matches the comparisons of tests of NON-regression. The load of failure for computation is defined as being the maximum value taken by the force applied to structure.
Recall: one controls structure in length of arc, one thus observes a softening.

Reference	Standard	loading case of	Tolerance

		reference	
C3	16.2	“SOURCE_EXTERNE”	20 %

5.4.2 graphic Results of the modelization C



5.4.3 Remarks

the numerical response of structure is obtained by a control in length of arc of all structure, that makes it possible to observe softening due to failure and thus to be able to test the maximum value of the state of control (parameter ETA_PILOTAGE).

The load of failure 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 the Yield-point load obtained under tests here: compared to the other loading cases, failure is definitely marked (not of important displacement at the end), and one can think that it would have been possible to draw still on the structure.

6 Summary of the multifibre

results beam element POU_D_TGM usable into nonlinear geometrical and material makes it possible in this benchmark to simulate the behavior of a cantilever of pylon until the first softening and further if one controls structure in displacement (in the case of a failure by plasticization) or by length of arc (in the case of a failure per buckling).

The computation is fast and does not ask any adjustment to conclude it (if it is not the installation of control). 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 the modelization (assemblies in particular).