SSNL134 - Elastoplastic the purpose of failure of the gantry of Lee

Summarized

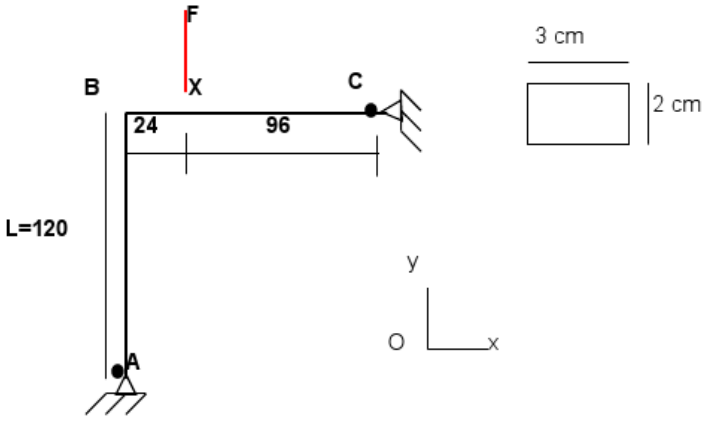
This test is simultaneously validating the nonlinear possibilities material and geometrical of beam element multifibre POU_D_TGM. The element is implemented on a benchmark usually treated in the literature with regard to the elastic behavior because it presents a response complexes with *snap-back* and *snap-through* : it is the gantry of Lee.

One supposes here an elastoplastic behavior of the gantry, which makes it possible to test the good integration of the constitutive law of the multifibre elements but also the correct processing of large displacements. The got results are the object of comparisons to results resulting from the literature as well as tests of NON-regression.

1 Problem of reference

1.1 Geometry

the gantry of Lee is a gantry with 2 arms, articulated at its ends:



Coordinates of the points (in cm):

	A	B	C	X
x	0	0.120		24
y	0.120.120			120

1.2 Characteristics of the section

the arms are with rectangular section from $3\,cm$ $2\,cm$. The section is directed so that the weakest axis of the inertia is perpendicular to the plan of the gantry.

$$A = 6\,cm^2$$
$$I_y = 2.0\,cm^4$$
$$I_z = 4.5\,cm^4$$
$$A_y = 1.2$$
$$A_z = 1.2$$

1.3 Properties of the material

$$E = 720\,N/cm^2$$
$$\nu = 0.3$$
$$E_t = 72\,N/cm^2$$
$$\sigma_e = 10.44\,N/cm^2$$

1.4 Boundary conditions and loading

1) Boundary conditions are imposed on the points A and C (pinned end around Oz):

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

2) One imposes on the point X a top-load F :

$$FY = C \times t$$

The constant C corresponds to the coefficient of given control for example by a method of length of arc. Indeed, this structure presents a complex response under nonmonotonous loading.

2 Reference solution

2.1 Method used for computation of the reference solution

This gantry was studied for the first time in 1968 by Lee [1], who suggested an analytical solution in the elastic case and by neglecting strain energy due to the normal force. Since, several other authors have in their turn studied the structure, in particular in 1984, Cichon [2] was the first to suggest a solution by considering an elastoplastic behavior.

2.2 Results of reference

One is interested in horizontal and vertical displacements in the total reference of the point X for various values of the applied force.

One presents below a summary table of the results got by Cichon like by Waszczyszyn and Janus-Michalska [3]. One chooses like reference the average of these two results illustrated in **fat**.

Displacement (cm)	U (horizontal)			V (vertical)		
$F(N)$	Waszczyszyn	Cichon	Average	Average	Waszczyszyn	Cichon
0,968	1,812	1,734	**1,773**	10,414	10,078	**10,246**
1,242	3,482	3,913	**3,6975**	15,61	16,639	**16,1245**
1,4153	6,281	6,711	**6,496**	22,305	23,344	**22,8245**
1,507	12,516	13,836	**13,176**	38,804	36,501	**37,6525**
1,4605	19,025	18,148	**18,5865**	44,18	42,543	**43,3615**
1,4006	23,104	23,073	**23,0885**	49,262	47,374	**48,318**
1,3151	28,998	28,303	**28,6505**	53,012	51,102	**52,057**
1,1062	39,266	37,765	**38,5155**	58,904	56,181	**57,5425**
0,9275	46,871	44,831	**45,851**	61,775	58,442	**60,1085**

2.3 Uncertainty on the solution

Between 1 and 5% (maximum variation relative to the average of the results).

2.4 Bibliographical references

1 Lee S., Handbook F.S., and Broad Rossow E.C. “deflections and stability of elastic frames.” *J. Engrg. Mech. Div., ASCE*, 1968; EM2, 521-547.

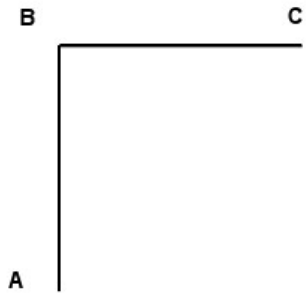
2 Cichon Cz. “Broad displacements IN-plane analysis of elasto-plastic frames”. *Comp Struct* 1984; 19,737-45.

3 IN-plane Waszczyszyn Z., Janus-Michalska Mr. “Numerical approach to the “exact ” finite element analysis of finite displacements of framed structures”. *Comput. Struct*. 1998; 69, 525-535.

3 Modelization A

3.1 Characteristic of the modelization

Modelization POU_D_TGM



Cutting: 10 elements in the column and the beam

3.2 Characteristics of the mesh

Many nodes: 21
Number of meshes and types: 20 SEG2

3.3 Characteristics of the mesh of the cross-sectional area

Many fibers: 100 (cutting in 10 on each side)
Number of meshes and types: 100 QUAD4

3.4 Quantities tested and results

the results are got by an automatic cutting of time step and with control by length of arc of the total response in displacement of structure.

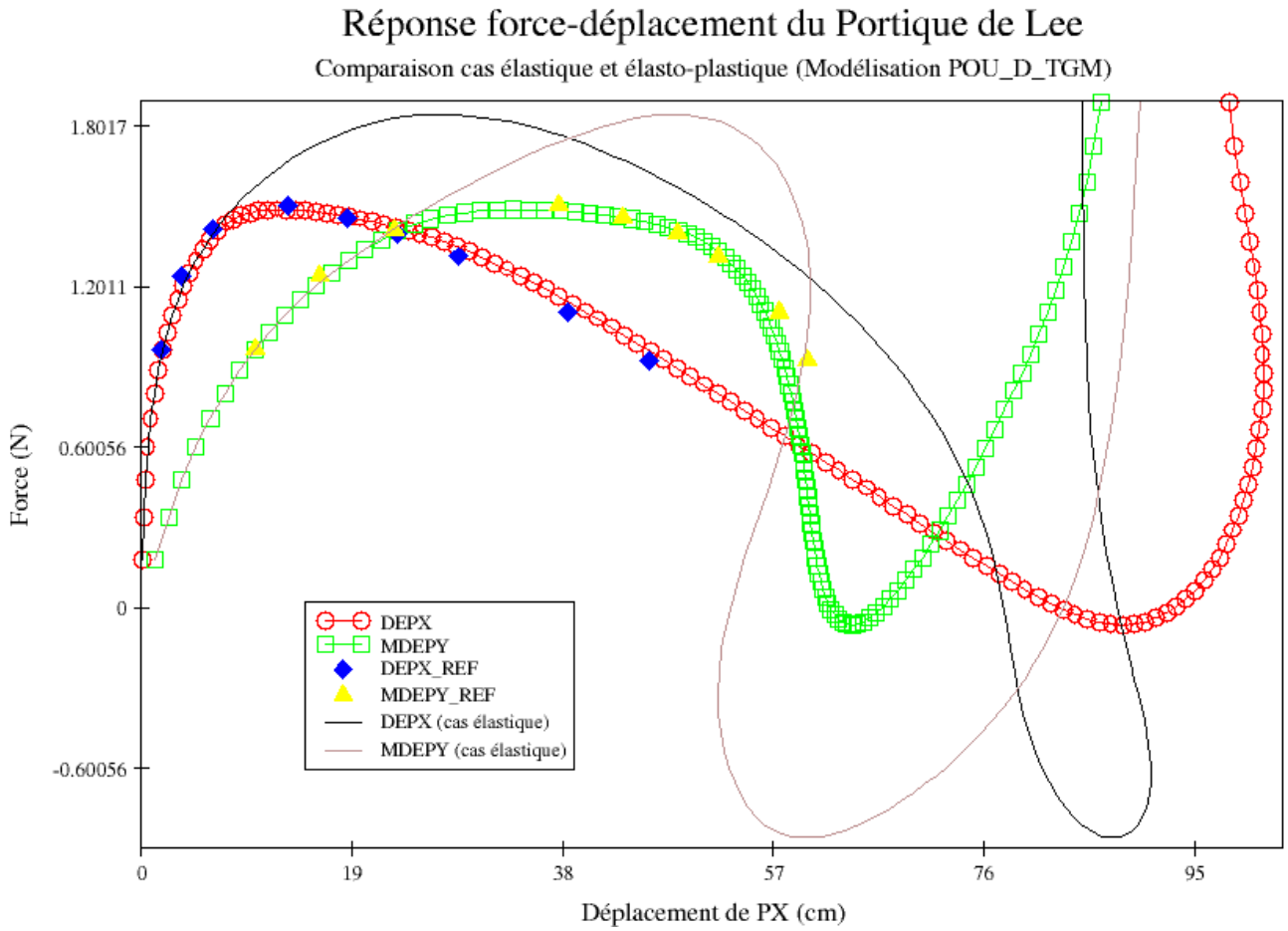
Displacement	Standard	Identification	Reference of reference	Tolerance
1,773	DX	0,968	"SOURCE_EXTERNE"	5%
10,246	DY	0,968	"SOURCE_EXTERNE"	5%
3,6975	DX	1,242	"SOURCE_EXTERNE"	5%
16,1245	DY	1,242	"SOURCE_EXTERNE"	5%
6,496	DX	1,4153	"SOURCE_EXTERNE"	5%
22,8245	DY	1,4153	"SOURCE_EXTERNE"	5%
13,176	DX	1,507	"SOURCE_EXTERNE"	5%
37,6525	DY	1,507	"SOURCE_EXTERNE"	5%
18,5865	DX	1,4605	"SOURCE_EXTERNE"	5%
43,3615	DY	1,4605	"SOURCE_EXTERNE"	5%
23,0885	DX	1,4006	"SOURCE_EXTERNE"	5%
48,318	DY	1,4006	"SOURCE_EXTERNE"	5%
28,6505	DX	1,3151	"SOURCE_EXTERNE"	5%
52,057	DY	1,3151	"SOURCE_EXTERNE"	5%
38,5155	DX	1,1062	"SOURCE_EXTERNE"	5%
57,5425	DY	1,1062	"SOURCE_EXTERNE"	15%
45,851	DX	0,9275	"SOURCE_EXTERNE"	5%
60,1085	DY	0,9275	"SOURCE_EXTERNE"	55%

3.5 Remarks

the use of the technique of length of arc makes difficult the definition of the value of reference to be introduced into command TEST_RESU, since these values cannot be imposed. The tests were thus made with back by choosing like parameter the values of displacements and value tested the value of force (i.e. ETA_PILOTAGE).
It is this way test which explains the high differences noted in DY at the last moments whereas the curves are superimposed perfectly.

4 Summary of the Comparison

4.1 results with the elastic case



One presents above a chart of the response force-displacement of the gantry of Lee where one made appear the response in the case of an elastic structure (obtained with the same modelization in *Code_Aster*).

It is interesting to notice as the addition of the elastoplastic behavior completely modifies the response of structure as of the first plasticization.

4.2 Synthesis

Overall the mistake made on displacements never exceeds 5% that it is necessary to compare with uncertainty on the solution which is approximately 5%. Moreover as one explained, to carry out tests on values is difficult in the presence of control.

If one observes the figure above, one notices a good correlation between the response of reference and that obtained by *Code_Aster*. One describes in particular well the change of pace due to the first plasticization.