SSNP303 - Element in plane constraint and traction - Perfect plasticity

Summary:

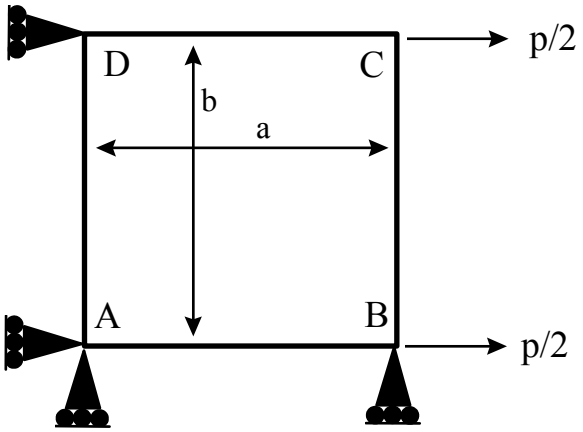
This test of nonlinear quasi-static mechanics $2D$ consist in charging three superimposed elements of plate (standard with element MECPQU4). The 4 nodes are common to the 3 elements. The elements have different properties (perfect plasticity) to obtain a suitable traction diagram. This test is drawn from guide NAFEMS.

The goal is to compare the various methods of the Newton-Raphson type making it possible to solve the system of nonlinear equations (NEWTON: ('ELASTIC' MATRIX) and NEWTON: ('TANGENT' MATRIX) with REAC_INCR and REAC_ITER). The selected convergence criteria correspond to 0.01% residual force (RESI_GLOB_RELA).

Modeling is carried out with elements plans of the type MECPQU4.

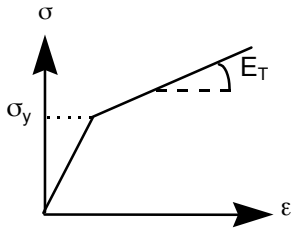
1 Problem of reference

1.1 Geometry



a = b = 1.0

1.2 Material properties



Matériau 1	Matériau 2	Matériau 3
E = 100000 MPa	E = 60000 MPa	E = 40000 MPa
ν = 0.25	ν = 0.25	ν = 0.25
σ_y = 3 MPa	σ_y = 6 MPa	σ_y = 8 MPa
E_T = 0.0	E_T = 0.0	E_T = 0.0

1.3 Boundary conditions and loadings

Not A : $u_x = 0.$
$u_y = 0.$
Not B : $u_y = 0.$
Not D : $u_x = 0.$

Loading by a force $P/2$ on the point B and C. The force P is increased in 6 stages in the following way:

Force P	3.00	6.00	9.00	12.95	15.00	16.93

2 Reference solution

2.1 Method of calculating used for the reference solution

The results considered as reference were got by the SAMCEF software by using 60 increments for each stage of loading. The characteristics of the various methods of resolution are the following ones:

With
- Use of the elastic matrix.

B
- Use of the tangent matrix; this one is revalued only with the first iteration of each increment (REAC_INCR = 1 and REAC_ITER = 0). It is the method of Newton modified.

C
- Use of the tangent matrix; this one is revalued with each iteration of each increment (REAC_INCR = 1 and REAC_ITER = 1). It is the method of Newton classical.

2.2 Results of reference

Results got with 60 increments for each stage of loading

	Element 1		Element 2		Element 3	
Force	σ^{xx}	σ^{yy}	σ^{xx}	σ^{yy}	σ^{xx}	σ^{yy}
3.00	1.500000D+00	6.938894D-18	9.000000D-01	– 1.040834D-17	6.000000D-01	– 6.938894D-18
6.00	3.000000D+00	4.861944D-13	1.800000D+00	– 2.081668D-17	1.200000D+00	– 3.469447D-18
9.00	3.147155D+00	3.199571D-01	3.511707D+00	– 1.900098D-01	2.341138D+00	– 1.279828D-01
12.95	3.252919D+00	5.950074D-01	5.814267D+00	– 3.523377D-01	3.878832D+00	– 2.380030D-01
15.00	3.213822D+00	4.873069D-01	6.017834D+00	3.174572D-02	5.768340D+00	– 5.231355D-01
16.93	3.2092970D+00	4.753345D-01	6.149462D+00	3.048490D-01	7.571241D+00	– 7.863557D-01

2.3 Uncertainty on the solution

Uncertainty lower than $1\ \%$.

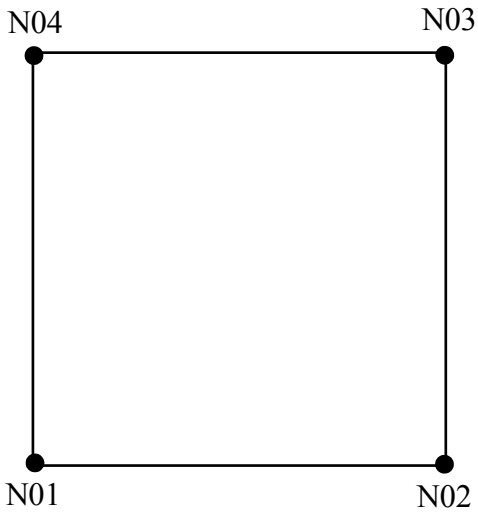
2.4 Bibliographical references

1) Fundamental tests for two and three dimensional, small strain, elastoplastic finite element analysis, 1987, NAFEMS

3 Modeling A

3.1 Characteristics of modeling A

Use of the elements QUAD4



Modeling in plane constraints: C_PLAN

The loading and the boundary conditions are modelled by:

- DDL_IMPO: (Node NO1 DX = 0, DY = 0)
  (Node NO2 DY = 0)
  (Node NO4 DX = 0)
- forces imposed on the nodes $NO2$ and $NO3$.

3.2 Characteristics of the grid

Many nodes: 4
Many meshs and types: 3 MECPQU4

3.3 Sizes tested and results

Identification	Moment	Reference	*Aster*	% difference
SIXX (mesh 1)	1	1,500000E+00	1,500000E+00	0
SIYY (mesh 1)	1	6,938894E-18	1,291047E-14	0
SIXX (mesh 2)	1	9,000000E-01	9,000000E-01	0
SIYY (mesh 2)	1	– 1,040834E-17	– 1,509903E-14	0
SIXX (mesh 3)	1	6,000000E-01	6,000000E-01	0
SIYY (mesh 3)	1	– 6,938894E-18	– 2,107830E-14	0
SIXX (mesh 1)	2	3,000000E+00	3,000000E+00	0
SIYY (mesh 1)	2	4,861944E-13	1,359551E-13	0
SIXX (mesh 2)	2	1,800000E+00	1,800000E+00	0
SIYY (mesh 2)	2	– 2,081668E-17	– 1,093097E-13	0
SIXX (mesh 3)	2	1,200000E+00	1,200000E+00	0
SIYY (mesh 3)	2	– 3,469447E-18	– 1,007126E-13	0
SIXX (mesh 1)	3	3,147155E+00	3,145788E+00	– 0.043
SIYY (mesh 1)	3	3,199571E-01	3,167040E-01	– 1.017
SIXX (mesh 2)	3	3,511707E+00	3,512527E+00	0.023
SIYY (mesh 2)	3	– 1,900098E-01	– 1,900224E-01	0.007
SIXX (mesh 3)	3	2,341138E+00	2,341685E+00	0.023
SIYY (mesh 3)	3	– 1,279828E-01	– 1,266816E-01	– 1.017
SIXX (mesh 1)	4	3,252919E+00	3,250728E+00	– 0.067
SIYY (mesh 1)	4	5,950074E-01	5,887464E-01	– 1.052
SIXX (mesh 2)	4	5,814267E+00	5,816159E+00	0.033
SIYY (mesh 2)	4	– 3,523377E-01	– 3,521695E-01	– 0.048
SIXX (mesh 3)	4	3,878832E+00	3,882391E+00	0.092
SIYY (mesh 3)	4	– 2,380030E-01	– 2,364650E-01	– 0.646
SIXX (mesh 1)	5	3,213822E+00	3,214367E+00	0.017
SIYY (mesh 1)	5	4,873069E-01	4,887527E-01	0.297
SIXX (mesh 2)	5	6,017834E+00	6,015985E+00	– 0.031
SIYY (mesh 2)	5	3,174572E-02	3,209818E-02	1.11
SIXX (mesh 3)	5	5,768340E+00	5,769681E+00	0.023
SIYY (mesh 3)	5	– 5,231355E-01	– 5,207413E-01	– 0.458
SIXX (mesh 1)	6	3,209297E+00	3,210194E+00	0.028
SIYY (mesh 1)	6	4,753345E-01	4,777143E-01	0.501
SIXX (mesh 2)	6	6,149462E+00	6,146791E+00	– 0.043
SIYY (mesh 2)	6	3,048490E-01	3,052330E-01	0.126
SIXX (mesh 3)	6	7,571241E+00	7,572486E+00	0.016
SIYY (mesh 3)	6	– 7,863557E-01	– 7,826545E-01	– 0.471

3.4 Remarks

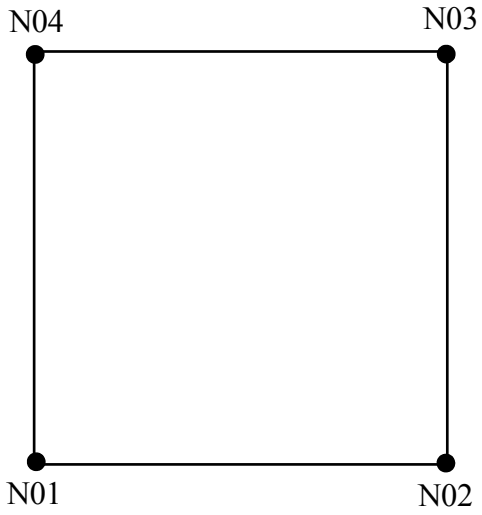
To obtain a correct precision, it is necessary to force a significant number of increments for each stage of loading (60 increments).

The iteration count is equal to 411.

4 Modeling B

4.1 Characteristics of modeling B

Use of the elements QUAD4



4.2 Characteristics of the grid

Many nodes: 4
Many meshs and types: 3 MECPQU4

Modeling in plane constraints: C_PLAN

The loading and the boundary conditions are modelled by:

- DDL_IMPO: (Node NO1 DX = 0, DY = 0)
  (Node NO2 DY = 0)
  (Node NO4 DX = 0)
- forces imposed on the nodes $NO2$ and $NO3$.

4.3 Sizes tested and results

Identification	Moment	Reference	*Aster*	% difference
SIXX (mesh 1)	1	1,500000E+00	1,500000E+00	0,000
SIYY (mesh 1)	1	6,938894E-18	1,351398E-14	0,000
SIXX (mesh 2)	1	9,000000E-01	9,000000E-01	0,000
SIYY (mesh 2)	1	– 1,040834E-17	– 2,142673E-14	0,000
SIXX (mesh 3)	1	6,000000E-01	6,000000E-01	0,000
SIYY (mesh 3)	1	– 6,938894E-18	– 2,924612E-14	0,000
SIXX (mesh 1)	2	3,000000E+00	3,000000E+00	0,000
SIYY (mesh 1)	2	4,861944E-13	9,617834E-14	0,000
SIXX (mesh 2)	2	1,800000E+00	1,800000E+00	0,000
SIYY (mesh 2)	2	– 2,081668E-17	– 8,301280E-14	0,000
SIXX (mesh 3)	2	1,200000E+00	1,200000E+00	0,000
SIYY (mesh 3)	2	– 3,469447E-18	– 9,360717E-14	0,000
SIXX (mesh 1)	3	3,147155E+00	3,145788E+00	– 0,043
SIYY (mesh 1)	3	3,199571E-01	3,167038E-01	– 1,017
SIXX (mesh 2)	3	3,511707E+00	3,512527E+00	0,023
SIYY (mesh 2)	3	– 1,900098E-01	– 1,900225E-01	0,007
SIXX (mesh 3)	3	2,341138E+00	2,341685E+00	0,023
SIYY (mesh 3)	3	– 1,279828E-01	– 1,266817E-01	– 1,017
SIXX (mesh 1)	4	3,252919E+00	3,250686E+00	– 0,069
SIYY (mesh 1)	4	5,950074E-01	5,886265E-01	– 1,072
SIXX (mesh 2)	4	5,814267E+00	5,816233E+00	0,034
SIYY (mesh 2)	4	– 3,523377E-01	– 3,520332E-01	– 0,086
SIXX (mesh 3)	4	3,878832E+00	3,883081E+00	0,110
SIYY (mesh 3)	4	– 2,380030E-01	– 2,365921E-01	– 0,593
SIXX (mesh 1)	5	3,213822E+00	3,214343E+00	0,016
SIYY (mesh 1)	5	4,873069E-01	4,886891E-01	0,284
SIXX (mesh 2)	5	6,017834E+00	6,015971E+00	– 0,031
SIYY (mesh 2)	5	3,174572E-02	3,207056E-02	1,023
SIXX (mesh 3)	5	5,768340E+00	5,769686E+00	0,023
SIYY (mesh 3)	5	– 5,231355E-01	– 5,207599E-01	– 0,454
SIXX (mesh 1)	6	3,209297E+00	3,210140E+00	0,026
SIYY (mesh 1)	6	4,753345E-01	4,775720E-01	0,471
SIXX (mesh 2)	6	6,149462E+00	6,146788E+00	– 0,043
SIYY (mesh 2)	6	3,048490E-01	3,052260E-01	0,124
SIXX (mesh 3)	6	7,571241E+00	7,573072E+00	0,024
SIYY (mesh 3)	6	– 7,863557E-01	– 7,827984E-01	– 0,452

4.4 Remarks

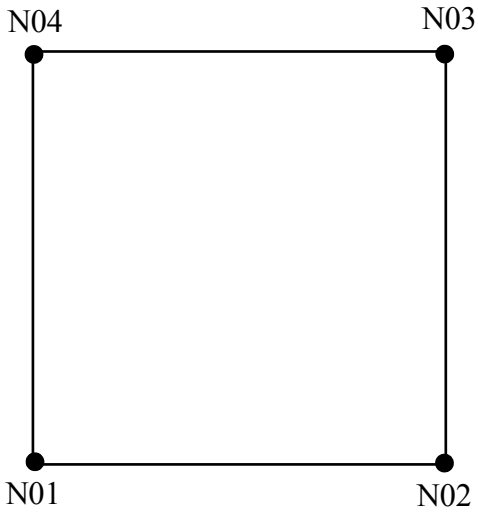
Idem modeling A concerning the number of increments on the precision of the results.

The iteration count is equal to 361.

5 Modeling C

5.1 Characteristics of modeling C

Use of the elements QUAD4



5.2 Characteristics of the grid

Many nodes: 4
Many meshs and types: 3 MECPQU4

Modeling in plane constraints: C_PLAN

The loading and the boundary conditions are modelled by:

- DDL_IMPO: (Node NO1 DX = 0, DY = 0)
  (Node NO2 DY = 0)
  (Node NO4 DX = 0)
- forces imposed on the nodes $NO2$ and $NO3$.

5.3 Sizes tested and results

Identification	Moment	Reference	*Aster*	% difference
$SIXX$ (mesh 1)	1	1,500000E+00	1,500000E+00	0
$SIYY$ (mesh 1)	1	6,938894E-18	1,351398E-14	0
$SIXX$ (mesh 2)	1	9,000000E-01	9,000000E-01	0
$SIYY$ (mesh 2)	1	– 1,040834E-17	– 2,142673E-14	0
$SIXX$ (mesh 3)	1	6,000000E-01	6,000000E-01	0
$SIYY$ (mesh 3)	1	– 6,938894E-18	– 2,924612E-14	0
$SIXX$ (mesh 1)	2	3,000000E+00	3,000000E+00	0
$SIYY$ (mesh 1)	2	4,861944E-13	9,617834E-14	0
$SIXX$ (mesh 2)	2	1,800000E+00	1,800000E+00	0
$SIYY$ (mesh 2)	2	– 2,081668E-17	– 8,301280E-14	0
$SIXX$ (mesh 3)	2	1,200000E+00	1,200000E+00	0
$SIYY$ (mesh 3)	2	– 3,469447E-18	– 9,360717E-14	0
$SIXX$ (mesh 1)	3	3,147155E+00	3,145788E+00	– 0.043
$SIYY$ (mesh 1)	3	3,199571E-01	3,167040E-01	– 1.017
$SIXX$ (mesh 2)	3	3,511707E+00	3,512527E+00	0.023
$SIYY$ (mesh 2)	3	– 1,900098E-01	– 1,900224E-01	0.007
$SIXX$ (mesh 3)	3	2,341138E+00	2,341685E+00	0.023
$SIYY$ (mesh 3)	3	– 1,279828E-01	– 1,266816E-01	– 1.017
$SIXX$ (mesh 1)	4	3,252919E+00	3,250686E+00	– 0.069
$SIYY$ (mesh 1)	4	5,950074E-01	5,886268E-01	– 1.072
$SIXX$ (mesh 2)	4	5,814267E+00	5,816233E+00	0.034
$SIYY$ (mesh 2)	4	– 3,523377E-01	– 3,520328E-01	– 0.087
$SIXX$ (mesh 3)	4	3,878832E+00	3,883081E+00	0.11
$SIYY$ (mesh 3)	4	– 2,380030E-01	– 2,365919E-01	– 0.593
$SIXX$ (mesh 1)	5	3,213822E+00	3,214343E+00	0.016
$SIYY$ (mesh 1)	5	4,873069E-01	4,886892E-01	0.284
$SIXX$ (mesh 2)	5	6,017834E+00	6,015971E+00	– 0.031
$SIYY$ (mesh 2)	5	3,174572E-02	3,207066E-02	1.024
$SIXX$ (mesh 3)	5	5,768340E+00	5,769686E+00	0.023
$SIYY$ (mesh 3)	5	– 5,231355E-01	– 5,207598E-01	– 0.454
$SIXX$ (mesh 1)	6	3,209297E+00	3,210140E+00	0.026
$SIYY$ (mesh 1)	6	4,753345E-01	4,775721E-01	0.471
$SIXX$ (mesh 2)	6	6,149462E+00	6,146788E+00	– 0.043
$SIYY$ (mesh 2)	6	3,048490E-01	3,052262E-01	0.124
$SIXX$ (mesh 3)	6	7,571241E+00	7,573072E+00	0.024
$SIYY$ (mesh 3)	6	– 7,863557E-01	– 7,827982E-01	– 0.452

5.4 Remarks

Idem modeling A concerning the number of increments on the precision of the results.

The iteration count is equal to 360.

6 Summary of the results

A significant number of increments is necessary to obtain a correct precision: for information, ten increments per stage of loading are not sufficient.