ZZZZ318 – Validation of the method SOUS_POINT order PROJ_CHAMP

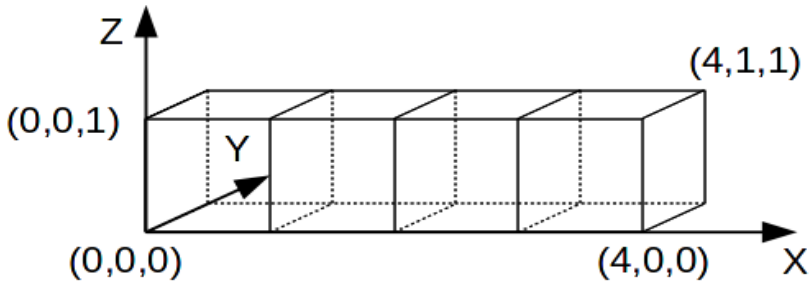
Summary:
The objective is to validate the method SOUS_POINT order PROJ_CHAMP . For that it should be checked that:
• coordinates of the under-points on the families of the list MATER calculated by PROJ_CHAMP are exact for the elements POU_D_EM , POU_D_TGM and DKT and GRILLE_EXCENTREE (TRIA3 and QUAD4).
• the projection of the thermal fields (TEMP, HYDR_ELNO) on a model 3D is correct on mechanical model under-points corresponding.
• projection functions for a field isolated and a result from type EVOL_THER.

Note: the fields at exit of this order are of the fields of the type ELGA .

1 Problem of reference

1.1 Geometry

A parallelepiped length is considered $4\,m$ and on side $1\,m$, constituted by 4 cubes.



1.2 Modeling

Thermal modeling is affected 3D with each of the four meshs HEXA8 grid.

1.3 Thermal fields

Thermal fields TEMP and HYDR_ELNO are created on this model starting from the following formulas:

TEMP : $t=2X+3Y+4Z+5T$

HYDR_ELNO : $h=-2X-3Y-4Z-5T$

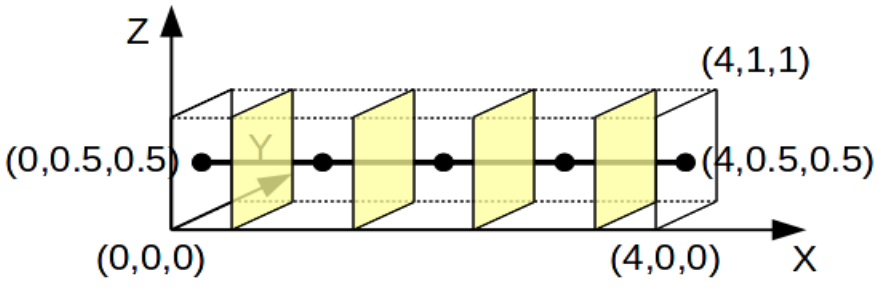
where X,Y,Z are the coordinates of space and T time. These fields are created at the same time in the form of fields isolated and result from type EVOL_THER.

1.4 Projection

These fields are projected on the under-points of the mechanical models of multifibre beams and multi-layer hulls representing same “physical space”, although the grids of beam are 1D and the grids of hulls 2D.

1.4.1 Multifibre beam

Each element of beam is length $1\mathrm{m}$ and a square section on side has $1\mathrm{m}$. The figure below illustrates well that the model of beam represents of the same space than the model 3D.

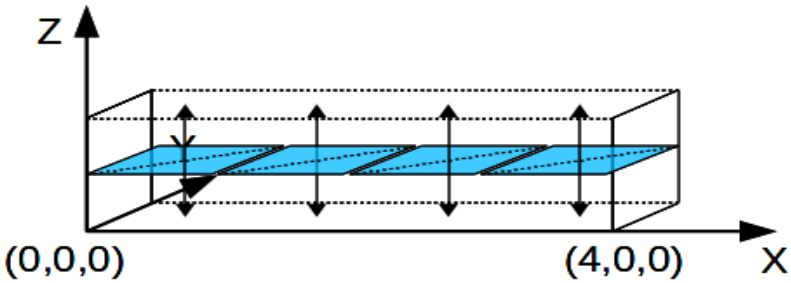


The multifibre section is made up of 4 fibres of which coordinates **compared to the axis of the beam** are the following ones:

	y	z
Fibre or under-point 1	$-0,25$	$-0,25$
Fibre or under-point 2	$-0,25$	$0,25$
Fibre or under-point 3	$0,25$	$0,25$
Fibre or under-point 4	$0,25$	$-0,25$

1.4.2 Multi-layer hull

Each element of hull has a thickness of $1\mathrm{m}$. The elements of hulls (in blue) are in a case of the squares of $1\mathrm{m}$ on side, in the other case of the isosceles right-angled triangles of $1\mathrm{m}$ on side. The figure below illustrates well that the model of hull represents same space as the MODit 3D.

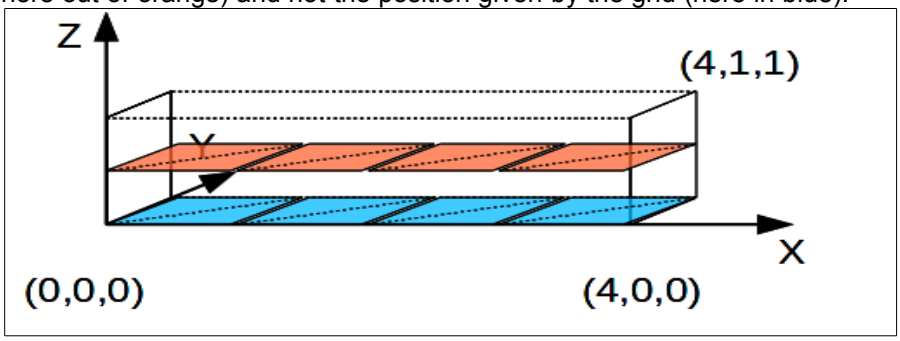


The hulls consist of 2 layers, each layer is made up of three levels. The table below gives the position of the under-points **compared to the median layer of the hull**.

	Z
Under-point 1	$-0,5$
Under-point 2	$-0,25$
Under-point 3	0
Under-point 4	0
Under-point 5	$0,25$
Under-point 6	$0,5$

1.4.3 Offset grids

The offset grids do not have under-points. But as their name indicates it, they can be offset. This method then makes it possible to assign to the elements of grids the temperature the “real” position of the grid (here out of orange) and not the position given by the grid (here in blue).



2 Reference solution

2.1 Method of calculating

The projection carried out by PROJ_CHAMP is linear in space and time. Functions t and h being linear, it is enough to them to apply the coordinates of the under-points (and time) to determine the values of reference.

2.2 Sizes and results of reference

To get the results of references, it is thus necessary to have following information:
- families present in the list MATER of each type of element (see catalogue of elements).
- positions of the points of Gauss of the various families (see R3.01.01).
- positions of the under-points (see § 1.4).

2.3 Uncertainties on the solution

None.

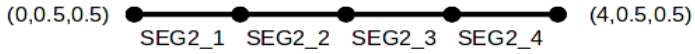
3 Modeling A

3.1 Characteristics of modeling

A modeling is used POU_D_EM for the model under-points.

3.2 Characteristics of the grid

The grid contains 4 elements of the type SEG2.



3.3 Coordinates of the points of Gauss

The list MATER elements POU_D_EM the family contains RIGI , NOEU and FPG1.
The family RIGI consists of 2 points. On an element length 1 , the positions according to the axis of the element are:

P rubs with oil 1	$\frac{1}{2}+\frac{1}{(2\sqrt{(3)})}$
P rubs with oil 2	$\frac{1}{2}-\frac{1}{(2\sqrt{(3)})}$

Coordinates of the points of the family NOEU are the coordinates of Nœuds. The family FPG1 have a point which is the center of the element.

On the whole there are thus 5 points, numbered from 1 to 5 (the second point of the family NOEU the number has 4).

3.4 Sizes tested and results

One tests the values of temperature and hydration in several meshs, points, under-points and moments. The tests are on the isolated fields and the result.

The following table gives the coordinates of the points tested:

Mesh	Not	Under-point	X	Y	Z
SEG2_1	1	3	0.788675134	0.75	0.75
SEG2_2	2	1	1.211324865	0.25	0.25
SEG2_3	3	4	2.000000000	0.75	0.25
SEG2_4	5	2	3.500000000	0.25	0.75

3.4.1 Isolated field TEMP

The moment considered is 0 . The concept is TEMP_SP. The values of reference are calculated with the function t .

Mesh	Not	Under-point	Component	**Value of reference**	**Tolerance**
SEG2_1	1	3	TEMP	6.82735026918963	1.E-6
SEG2_2	2	1	TEMP	4.17264973081037	1.E-6
SEG2_3	3	4	TEMP	7.25000000	1.E-6
SEG2_4	5	2	TEMP	10.7500000	1.E-6

3.4.2 Isolated field HYDR_ELNO

The moment considered is 0 . The concept is HYDR_SP. The values of reference are calculated with the function h .

Mesh	Not	Under-point	Component	Value of reference	Tolerance
SEG2_1	1	3	HYDR	- 6.82735026918963	1.E-6
SEG2_2	2	1	HYDR	- 4.17264973081037	1.E-6
SEG2_3	3	4	HYDR	- 7.25000000	1.E-6
SEG2_4	5	2	HYDR	- 10.7500000	1.E-6

3.4.3 Result EVOL_THER

The concept is RESU_SP. The values of reference are calculated with the function t for the field TEMP and with h for the field HYDR_ELNO.

INST	Mesh	Not	Under-point	Field	Comp.	Value of reference	Tolerance
0	SEG2_1	1	3	TEMP	TEMP	6.82735026918963	1.E-6
1	SEG2_2	2	1	TEMP	TEMP	9.17264973081037	1.E-6
2	SEG2_3	3	4	TEMP	TEMP	17.25000000	1.E-6
2	SEG2_4	5	2	TEMP	TEMP	20.7500000	1.E-6

INST	Mesh	Not	Under-point	Field	Comp.	Value of reference	Tolerance
0	SEG2_1	1	3	HYDR_ELNO	HYDR	- 6.82735026918963	1.E-6
1	SEG2_2	2	1	HYDR_ELNO	HYDR	-9.17264973081037	1.E-6
2	SEG2_3	3	4	HYDR_ELNO	HYDR	-17.25000000	1.E-6
2	SEG2_4	5	2	HYDR_ELNO	HYDR	-20.7500000	1.E-6

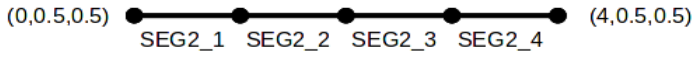
4 Modeling B

4.1 Characteristics of modeling

A modeling is used POU_D_TGM for the model under-points.

4.2 Characteristics of the grid

The grid contains 4 elements of the type SEG2.



4.3 Coordinates of the points of Gauss

The list MATER elements POU_D_ TG M the family contains RIGI and FPG1.
The family RIGI consists of 3 points. On an element length 1 the positions according to the axis of the element are:

Point 1	$\frac{1}{2}-\frac{1}{(2\sqrt{(5/3)})}$
Point 2	0
Point 3	$\frac{1}{2}+\frac{1}{(2\sqrt{(5/3)})}$

The family FPG1 have a point which is the center of the element. On the whole, there are thus 4 points, numbered from 1 to 4 (the first point of the family FPG1 the number has 4).

4.4 Sizes tested and results

One tests the values of temperature and hydration in several meshs, points, under-points and moments. The tests are made on the isolated fields and the result.

The following table gives the coordinates of the points tested:

Mesh	Not	Under-point	X	Y	Z
SEG2_1	1	4	0.112701665	0.75	0. 25
SEG2_2	3	1	1.887298334	0.25	0.25
SEG2_3	4	2	8.750000000	0. 25	0. 75

4.4.1 Isolated field TEMP

The moment considered is 0 . The concept is TEMP_SP. The values of reference are calculated with the function t .

Mesh	Not	Under-point	Component	**Value of reference**	**Tolerance**
SEG2_1	1	4	TEMP	3.47540333075852	1.E-6
SEG2_2	3	1	TEMP	5.52459666924148	1.E-6
SEG2_3	4	2	TEMP	8.75000000	1.E-6

4.4.2 Isolated field HYDR_ELNO

The moment considered is 0 . The concept is HYDR_SP. The values of reference are calculated with the function h .

Mesh	Not	Under-point	Component	Value of reference	Tolerance
SEG2_1	1	4	HYDR	-3.47540333075852	1.E-6
SEG2_2	3	1	HYDR	-5.52459666924148	1.E-6
SEG2_3	4	2	HYDR	-8.75000000	1.E-6

4.4.3 Result EVOL_THER

The concept is RESU_SP. The values of reference are calculated with the function t for the field TEMP and with h for the field HYDR_ELNO.

INST	Mesh	Not	Under-point	Field	Comp.	Value of reference	Tolerance
0	SEG2_1	1	4	TEMP	TEMP	3.47540333075852	1.E-6
1	SEG2_2	3	1	TEMP	TEMP	10.52459666924148	1.E-6
2	SEG2_3	4	2	TEMP	TEMP	18.75000000	1.E-6

INST	Mesh	Not	Under-point	Field	Comp.	Value of reference	Tolerance
0	SEG2_1	1	4	HYDR_ELNO	HYDR	-3.47540333075852	1.E-6
1	SEG2_2	3	1	HYDR_ELNO	HYDR	-10.52459666924148	1.E-6
2	SEG2_3	4	2	HYDR_ELNO	HYDR	-18.75000000	1.E-6

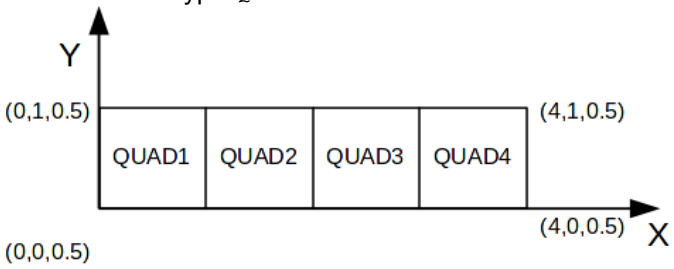
5 Modeling C

5.1 Characteristics of modeling

A modeling is used DKT for the model under-points.

5.2 Characteristics of the grid

The grid contains 4 elements of the type QUAD4.



5.3 Coordinates of the points of Gauss

The list MATER elements DKT quadrangular the family contains RIGI, NOEU and FPG1. The family RIGI consists of 4 points. On a square element $(N1, N2, N3, N4)$ on side 1, of which the axis x east defines by the vector $\overrightarrow{N1N2}$ and centers it y by the vector $\overrightarrow{N1N4}$ positions (x, y) by report with $N1$ are:

	x	y
Point 1	$\frac{1}{2}-\frac{1}{2\sqrt{3}}$	$\frac{1}{2}-\frac{1}{2\sqrt{3}}$
Point 2	$\frac{1}{2}+\frac{1}{2\sqrt{3}}$	$\frac{1}{2}-\frac{1}{2\sqrt{3}}$
Point 3	$\frac{1}{2}+\frac{1}{2\sqrt{3}}$	$\frac{1}{2}+\frac{1}{2\sqrt{3}}$
Point 4	$\frac{1}{2}-\frac{1}{2\sqrt{3}}$	$\frac{1}{2}+\frac{1}{2\sqrt{3}}$

Coordinates of the points of the family NOEU are the coordinates of Nœuds. The family FPG1 have a point which is the center of the element $(0.5, 0.5)$.

On the whole there are thus 9 points, numbered from 1 to 9 (the first point of the family FPG1 number 9 has).

5.4 Sizes tested and results

One tests the values of temperature and hydration in several meshs, points, under-points and moments. The tests are made on the isolated fields and the result.

The following table gives the coordinates of the points tested:

Mesh	Not	Under-point	X	Y	Z
QUAD1	1	4	0.211324865	0.211324865	0.5000000
QUAD2	3	1	1.788675134	0.788675134	0.0000000
QUAD3	6	2	3.000000000	0.0000000	0.2500000
QUAD4	9	5	3.500000000	0.5000000	0.7500000

5.4.1 Isolated field TEMP

The moment considered is 0 . The concept is TEMP_SP. The values of reference are calculated with the function t .

Mesh	Not	Under-point	Component	Value of reference	Tolerance
QUAD1	1	4	TEMP	3.05662432702594	1.E-6
QUAD2	3	1	TEMP	5.94337567297406	1.E-6
QUAD3	6	2	TEMP	7.00000000	1.E-6
QUAD4	9	5	TEMP	11.5000000	1.E-6

5.4.2 Isolated field HYDR_ELNO

The moment considered is 0 . The concept is HYDR_SP. The values of reference are calculated with the function h

Mesh	Not	Under-point	Component	Value of reference	Tolerance
QUAD1	1	4	HYDR	-3.05662432702594	1.E-6
QUAD2	3	1	HYDR	-5.94337567297406	1.E-6
QUAD3	6	2	HYDR	-7.00000000	1.E-6
QUAD4	9	5	HYDR	-11.5000000	1.E-6

5.4.3 Result EVOL_THER

The concept is RESU_SP. The values of reference are calculated with the function t for the field TEMP and with h for the field HYDR_ELNO.

INST	Mesh	Not	Under-point	Field	Comp.	Value of reference	Tolerance
0	QUAD1	1	4	TEMP	TEMP	3.05662432702594	1.E-6
1	QUAD2	3	1	TEMP	TEMP	10.94337567297406	1.E-6
2	QUAD3	6	2	TEMP	TEMP	17.00000000	1.E-6
2	QUAD4	9	5	TEMP	TEMP	21.5000000	1.E-6

INST	Mesh	Not	Under-point	Field	Comp.	Value of reference	Tolerance
0	QUAD1	1	4	HYDR_ELNO	HYDR	-3.05662432702594	1.E-6
1	QUAD2	3	1	HYDR_ELNO	HYDR	-10.94337567297406	1.E-6
2	QUAD3	6	2	HYDR_ELNO	HYDR	-17.00000000	1.E-6
2	QUAD4	9	5	HYDR_ELNO	HYDR	-21.5000000	1.E-6

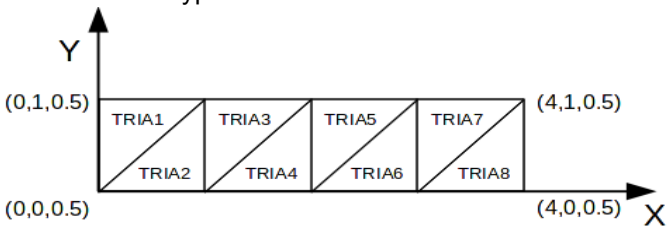
6 Modeling D

6.1 Characteristics of modeling

A modeling is used DKT for the model under-points.

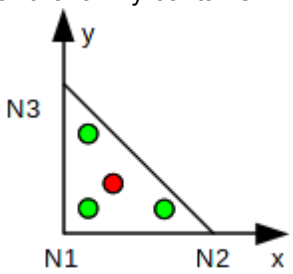
6.2 Characteristics of the grid

The grid contains 8 elements of the type TRIA3.



6.3 Coordinates of the points of Gauss

The list MATER elements DKT triangular the family contains RIGI, NOEU and FPG1.



The family RIGI consists of 3 points (green points on the figure). Positions (x, y) are:

	x	y
Point 1	$1/6$	$1/6$
Point 2	$2/3$	$1/6$
Point 3	$1/6$	$2/3$

Coordinates of the points of the family NOEU are the coordinates of NœUDS. The family FPG1 have a point (not red) coordinates $(1/3,1/3)$.

On the whole there are thus 7 points, numbered from 1 to 7 (the first point of the family FPG1 number 7 has).

6.4 Sizes tested and results

One tests the values of temperature and hydration in several meshs, points and under-points and moments. The tests are made on the isolated fields and the result.

The following table gives the coordinates of the points tested:

Mesh	Not	Under-point	X	Y	Z
SORTED 1	1	4	0.166666666	0.833333333	0.5000000
TRIA4	3	1	1.333333333	0.166666667	0.0000000
TRIA6	5	2	3.000000000	1.0000000	0.2500000
TRIA7	7	5	3.333333333	0.666666667	0.7500000

6.4.1 Isolated field TEMP

The moment considered is 0 . The concept is TEMP_SP. The values of reference are calculated with the function t .

Mesh	Not	Under-point	Component	Value of reference	Tolerance
SORTED 1	1	4	TEMP	4.83333333333333	1.E-6
TRIA4	3	1	TEMP	3.16666666666667	1.E-6
TRIA6	5	2	TEMP	10.00000000	1.E-6
TRIA7	7	5	TEMP	11.6666666666667	1.E-6

6.4.2 Isolated field HYDR_ELNO

The moment considered is 0 . The concept is HYDR_SP. The values of reference are calculated with the function h .

Mesh	Not	Under-point	Component	Value of reference	Tolerance
SORTED 1	1	4	HYDR	-4.83333333333333	1.E-6
TRIA4	3	1	HYDR	-3.16666666666667	1.E-6
TRIA6	5	2	HYDR	-10.00000000	1.E-6
TRIA7	7	5	HYDR	-11.6666666666667	1.E-6

6.4.3 Result EVOL_THER

The concept is RESU_SP . The values of reference are calculated with the function t for the field TEMP and with h for the field HYDR_ELNO.

Inst	Mesh	Not	Under-point	Field	Comp.	Value of reference	Tolerance
0	SORTED 1	1	4	TEMP	TEMP	4.83333333333333	1.E-6
1	TRIA4	3	1	TEMP	TEMP	8.16666666666667	1.E-6
2	TRIA6	5	2	TEMP	TEMP	20.00000000	1.E-6
2	TRIA7	7	5	TEMP	TEMP	21.6666666666667	1.E-6

Inst	Mesh	Not	Under-point	Field	Comp.	Value of reference	Tolerance
0	SORTED 1	1	4	HYDR_ELNO	HYDR	-4.83333333333333	1.E-6
1	TRIA4	3	1	HYDR_ELNO	HYDR	-8.16666666666667	1.E-6
2	TRIA6	5	2	HYDR_ELNO	HYDR	-20.00000000	1.E-6
2	TRIA7	7	5	HYDR_ELNO	HYDR	-21.6666666666667	1.E-6

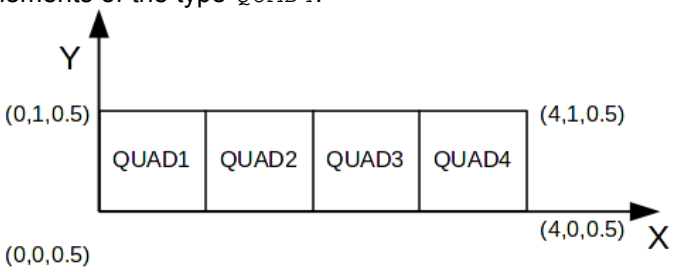
7 Modeling E

7.1 Characteristics of modeling

A modeling is used GRILLE_EXCENTREE.

7.2 Characteristics of the grid

The grid contains 4 elements of the type QUAD4.



7.3 Coordinates of the points of Gauss

The list MATER elements GRILLE_EXCENTREE quadrangular contains the families RIGI and FARMHOUSE. These two families correspond to the family FPG4 . The family RIGI consists of 4 points. On a square element $(N1, N2, N3, N4)$ on side 1 , of which the axis x is defined by the vector $\overrightarrow{N1N2}$ and centers it y by the vector $\overrightarrow{N1N4}$ positions (x, y) by report with $N1$ are:

	x	y
Point 1	$\frac{1}{2}-\frac{1}{2\sqrt{3}}$	$\frac{1}{2}-\frac{1}{2\sqrt{3}}$
Point 2	$\frac{1}{2}+\frac{1}{2\sqrt{3}}$	$\frac{1}{2}-\frac{1}{2\sqrt{3}}$
Point 3	$\frac{1}{2}+\frac{1}{2\sqrt{3}}$	$\frac{1}{2}+\frac{1}{2\sqrt{3}}$
Point 4	$\frac{1}{2}-\frac{1}{2\sqrt{3}}$	$\frac{1}{2}+\frac{1}{2\sqrt{3}}$

On the whole there are thus 8 numbered points from 1 to 8.

7.4 Sizes tested and results

One tests the values of temperature and hydration in several meshs, points, under-points and moments. The tests are made on the isolated fields and the result.

The following table gives the coordinates of the points tested:

Mesh	Not	Under-point	X	Y	Z
QUAD1	1	1	2.11324865E-1	2.11324865E-1	0.5
QUAD2	2	1	1.78867514E0	2.11324865E-1	0.5

7.4.1 Isolated field TEMP

The moment considered is 0 . The concept is TEMP_SP. The values of reference are calculated with the function t .

Mesh	Not	Under-point	Component	Value of reference	Tolerance
QUAD1	1	1	TEMP	3.0566234E0	1.E-6
QUAD2	2	1	TEMP	6.2113249E0	1.E-6

7.4.2 Isolated field HYDR_ELNO

The moment considered is 0 . The concept is HYDR_SP. The values of reference are calculated with the function h .

Mesh	Not	Under-point	Component	Value of reference	Tolerance
QUAD1	1	1	HYDR	-3.0566234E0	1.E-6
QUAD2	2	1	HYDR	-6.2113249E0	1.E-6

7.4.3 Result EVOL_THER

The concept is RESU_SP. The values of reference are calculated with the function t for the field TEMP and with h for the field HYDR_ELNO.

INST	Mesh	Not	Under-point	Field	Comp.	Value of reference	Tolerance
0	QUAD1	1	1	TEMP	TEMP	3.0566234E0	1.E-6
2	QUAD2	2	1	TEMP	TEMP	1.6211325E1	1.E-6

INST	Mesh	Not	Under-point	Field	Comp.	Value of reference	Tolerance
0	QUAD1	1	1	HYDR_ELNO	HYDR	-3.0566234E0	1.E-6
2	QUAD2	2	1	HYDR_ELNO	HYDR	-1.6211325E1	1.E-6

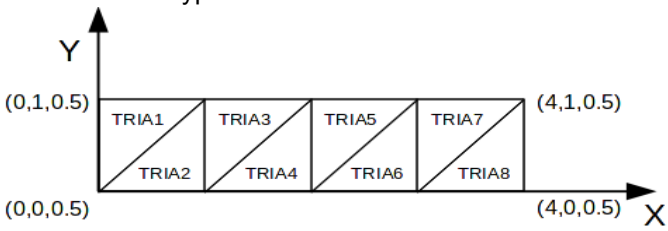
8 Modeling F

8.1 Characteristics of modeling

A modeling is used GRILLE_EXCENTREE.

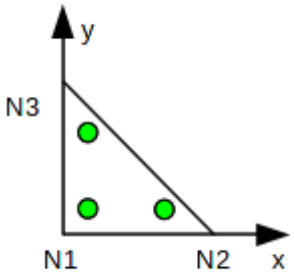
8.2 Characteristics of the grid

The grid contains 8 elements of the type TRIA3.



8.3 Coordinates of the points of Gauss

The list MATER elements GRILLE_EXCENTREE triangular contains the families RIGI and FARMHOUSE. These two families correspond in fact to the family FPG3.



The family RIGI consists of 3 points (green points on the figure). Positions (x, y) are:

	x	y
Point 1	$1/6$	$1/6$
Point 2	$2/3$	$1/6$
Point 3	$1/6$	$2/3$

On the whole there are thus 6 points, numbered from 1 to 6.

8.4 Sizes tested and results

One tests the values of temperature and hydration in several meshs, points, under-points and moments. The tests are made on the isolated fields and the result.

The following table gives the coordinates of the points tested:

Mesh	Not	Under-point	X	Y	Z
TRIA1	1	2	1.66666667E-1	8.33333333E-1	0.5
TRIA2	2	1	8.33333333E-1	6.66666667E-1	0.5

8.4.1 Isolated field TEMP

The moment considered is 0 . The concept is TEMP_SP. The values of reference are calculated with the function t .

Mesh	Not	Under-point	Component	Value of reference	Tolerance
TRIA1	1	1	TEMP	4.83333333333	1.E-6
TRIA2	2	1	TEMP	5.66666666667	1.E-6

8.4.2 Isolated field HYDR_ELNO

The moment considered is 0 . The concept is HYDR_SP. The values of reference are calculated with the function h .

Mesh	Not	Under-point	Component	Value of reference	Tolerance
TRIA1	1	1	HYDR	-4.83333333333	1.E-6
TRIA2	2	1	HYDR	-5.66666666667	1.E-6

8.4.3 Result EVOL_THER

The concept is RESU_SP. The values of reference are calculated with the function t for the field TEMP and with h for the field HYDR_ELNO.

INST	Mesh	Not	Under-point	Field	Comp.	Value of reference	Tolerance
0	TRIA1	1	1	TEMP	TEMP	4.83333333333	1.E-6
2	TRIA2	2	1	TEMP	TEMP	15.6666666667	1.E-6

INST	Mesh	Not	Under-point	Field	Comp.	Value of reference	Tolerance
0	TRIA1	1	1	HYDR_ELNO	HYDR	-4.83333333333	1.E-6
2	TRIA2	2	1	HYDR_ELNO	HYDR	-15.6666666667	1.E-6

9 Summary of the results

Thanks to formulas giving the fields of temperature and hydration according to the coordinates of the points, one can check simply that coordinates of the under-points is well calculated for all the types of elements concerned and that the projection made with the method SOUS_POINT order PROJ_CHAMP give the expected results. This projection functions for fields isolated from type NOEU or ELNO and for results of the type EVOL_THER.