SSLS139 – Inflection of a plate with simplified representation of the reinforcements

Summary:

The objective of this test is to validate the representation of tablecloths of reinforcement by a model of grid or membrane homogenized in a reinforced concrete structure. One thus considers a classical problem of inflection of plate, and one compares the solution obtained with a three-dimensional solution of reference.

One also benefits from it to check the good performance of the membrane in great deformation, by comparing his results with the result in small deformations.

1 Problem of reference

1.1 Geometry

One considers a reinforced concrete plate, comprising tablecloths of reinforcement on the faces lower and higher. This plate is embedded at an end, and is subjected to one moment at the other end.

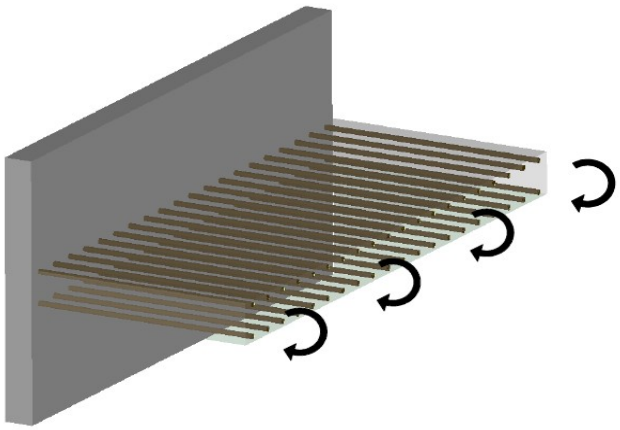

Figure 1: Classical problem of inflection of a reinforced concrete plate.

To limit the cost of calculation, one models only one section of plate, at the edges of which conditions of periodicity are imposed. Dimensions of the plate and the reinforcements are indicated on the Figure 2.

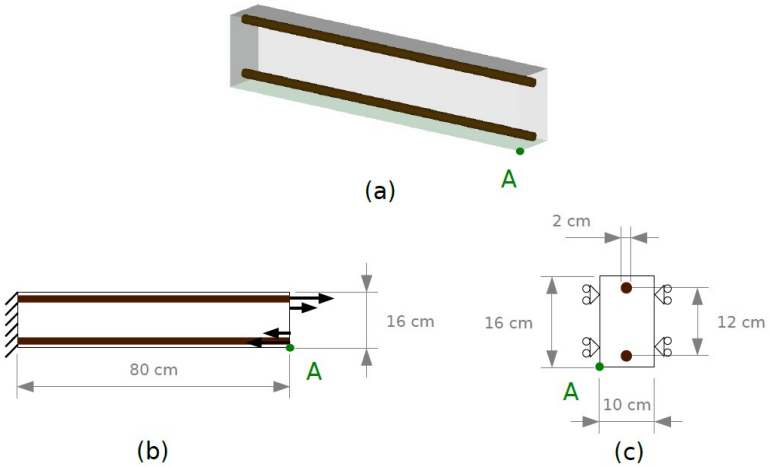

Figure 2: Dimensions of the section of plate modelled. (A) Seen general; (b) seen longitudinal; (c) crosses modelled section.

One represents the tablecloths of reinforcement by a model of grid or equivalent membrane, which makes it possible to limit the cost of calculation much (see Figure 3). Points `POINT_1` and `POINT_2` are used for the postprocessing of the results.

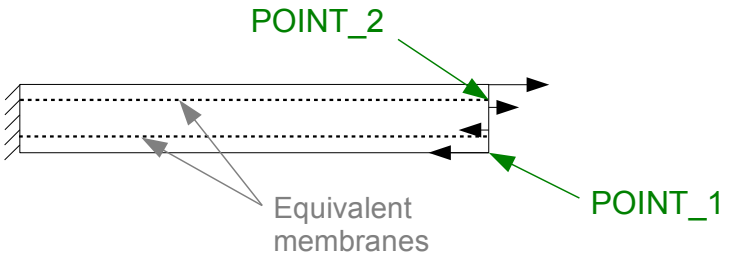

Figure 3: Representation of the tablecloths of reinforcement by a model of grid or equivalent membrane

1.2 Properties of materials

The concrete has an isotropic homogeneous elastic behavior, characterized by Young the modulus and Poisson's ratio indicated below:

$$\begin{cases} E_B = 30 \text{ GPa} \\ \nu_B = 0.22 \end{cases}$$

Steel also presents an isotropic homogeneous elastic behavior, characterized by the coefficients:

$$\begin{cases} E_A = 200 \text{ GPa} \\ \nu_A = 0.3 \end{cases}$$

1.3 Boundary conditions and loadings

The boundary conditions applied to the plate are indicated below, corresponding respectively to the conditions of embedding, the conditions of periodicity and the time exerted at the end of plate:

$$\begin{cases} \boldsymbol{u} = \mathbf{0} \text{ sur ENCAST} \\ u_Y = 0 \text{ sur BORDS} \\ F_X = 937500 \dfrac{Z - 0.08}{0.08} \text{ sur BOUT} \end{cases}$$

2 Reference solution

2.1 Method of calculating

This problem does not admit an exact analytical solution. The reference solution is thus obtained by a fine three-dimensional modeling, detailed in the reference [1].

2.2 Sizes and results of reference

One specifies below the vertical displacement measured at the end of plate in the modeling of reference.

Size	Component	Reference solution
DEPL - POINT_1	*DZ*	-87.1E-6

For modeling C, ON tests displacement vertical at the end of plate, as well as the constraint in the membrane at the end of plate. The results are compared with a reference solution obtained with another modeling (membrane in small disturbances).

Identification	Component	Solution of reference
DEPL - PRUBBED WITH OIL_1	*DZ*	-1.037995323E-4
DEPL - PRUBBED WITH OIL_2	*DZ*	-1.036247553E-4
SIEF_NOEU - PRUBBED WITH OIL_2	*NXX*	2317.098784

2.3 Bibliographical references

[1] DAVID MR. , Approach multi-scale of the mechanical behavior of the reinforced concrete structures – Application to the containment systems of the nuclear power plants . Doctorate

3 Modeling A

3.1 Characteristics of modeling

One represents the tablecloths of reinforcement on the faces lower and higher by a model of equivalent membrane. The coefficients of rigidity of this membrane are calculated by a method of homogenisation detailed in the reference [1]. The value of these coefficients is specified in the table below:

Parameter	Value (Pa.m)
M_{LLLL}	5.46223E8
M_{LLTT}	3.90776E7
M_{TTTT}	1.23452E8
M_{LTLT}	5.73664E7

These coefficients are expressed in the total reference mark (nautical angles of rotation of the reference mark worthless).

3.2 Characteristics of the grid

The grid contains 12 712 nodes, 8 018 quadratic tetrahedrons (TETRA10) and 500 quadratic triangles (TRIA6) to represent the tablecloths of reinforcement.

3.3 Sizes tested and results

One tests vertical displacement at the end of plate, as well as the strain and the stress in the membrane at the end of plate.

Identification	Component	Type of reference	Value of reference	Tolerance
DEPL – POINT_1	DZ	'AUTRE_ASTER'	-87.1E-6	0.3%

Identification	Component	Type of reference	Tolerance
DEPL – POINT_1	DZ	'NON_REGRESSION'	1.E-6
EPSI_NOEU – POINT_2	EXX	'NON_REGRESSION'	1.E-6
SIEF_NOEU – POINT_2	NXX	'NON_REGRESSION'	1.E-6

4 Modeling B

4.1 Characteristics of modeling

One represents the tablecloths of reinforcement on the faces lower and higher by a model of grid.

4.2 Characteristics of the grid

The grid is the same one as that of modeling A.

4.3 Sizes tested and results

One tests vertical displacement at the end of plate, as well as the strain and the stress in the grid at the end of plate.

Identification	Component	Type of reference	Value of reference	Tolerance
DEPL – POINT_1	DZ	'AUTRE_ASTER'	-87.1E-6	4%

Identification	Component	Type of reference	Tolerance
DEPL – POINT_1	DZ	'NON_REGRESSION'	1.E-6
EPSI_NOEU – POINT_2	EXX	'NON_REGRESSION'	1.E-6
SIEF_NOEU – POINT_2	SIXX	'NON_REGRESSION'	1.E-6

5 Modeling C

5.1 Characteristics of modeling

One wants to compare itS operationS membrane in great and small deformations. The membrane into large deformations takes into account only isotropic behaviors, one thus models the tablecloths of reinforcements by isotropic membranes having the characteristics of steel.
One uses the law of behavior of Coming Saint Kirchhoff for the membrane in great deformations.

5.2 Characteristics of the grid

The grid contains 12,712 nodes, 8,018 quadratic tetrahedrons (TETRA10) and 500 quadratic triangles (TRIA6) to represent the tablecloths of reinforcements.

5.3 Sizes tested and results

Displacement is tested vertical at the end of plate, as well as the constraint in the membrane at the end of plate.

Identification	Component	Type of reference	Value of reference	Precision
DEPL - PRUBBED WITH OIL_1	*DZ*	'WithUTRE_ASTER '	-1.037995323E-4	0.3%
DEPL - PRUBBED WITH OIL_2	*DZ*	'WithUTRE_ASTER '	-1.036247553E-4	0.3%
SIEF_NOEU - PRUBBED WITH OIL_2	*NXX*	'WithUTRE_ASTER '	2317.098784	0.5%

5.4 Remarks

The modeling of the membrane in great deformations with the law of behavior néo-Hookéenne gives similar results.

It is noted that the results are in concord with the reference solution, which validates the good behavior in small disturbances of the element of membrane in great transformations.

6 Summary of the results

This test validates the principle of the representation of the tablecloths of reinforcement by a model of grid or homogenized membrane. This validation rests on a comparison with a three-dimensional model of reference, supplemented by several tests of not-regression.

The model of homogenized membrane gives excellent results in elastic mode, but he asks the preliminary identification of the coefficients of rigidity of the membrane via elementary calculations of homogenisation. This makes its use delicate in an industrial context.

The model of grid gives acceptable results although a little less precise. It is on the other hand much simpler to use.

With regard to the membrane in great deformations, results are coherent, the behavior of the element is validated.