SSLS132 – Plate cantilever under loading of bending

Summarized

This quasi-static test enters the frame of the validation of the elements GRILLE_EXCENTRE, GRILLE_MEMBRANE and MEMBRANE. A concrete plate (modelization COQUE) is covered with two three-dimensions functions of reinforcement on its sides higher and lower, each one offset of the same quantity. The loadings are of three types:

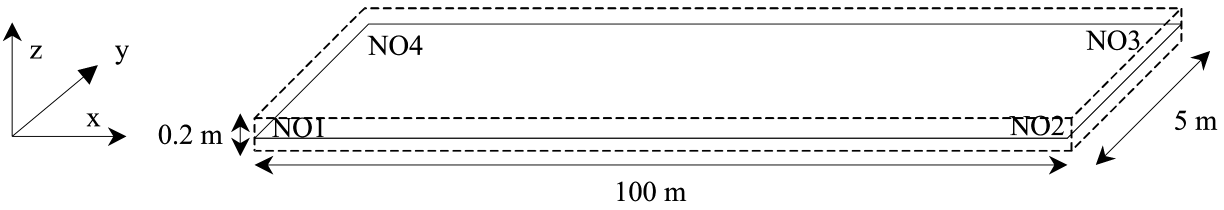
1) clamped edge and bending of the plate
2) effect of gravity and the inertia loading
3) predeformations in the two three-dimensions functions of reinforcements to make compress the plate

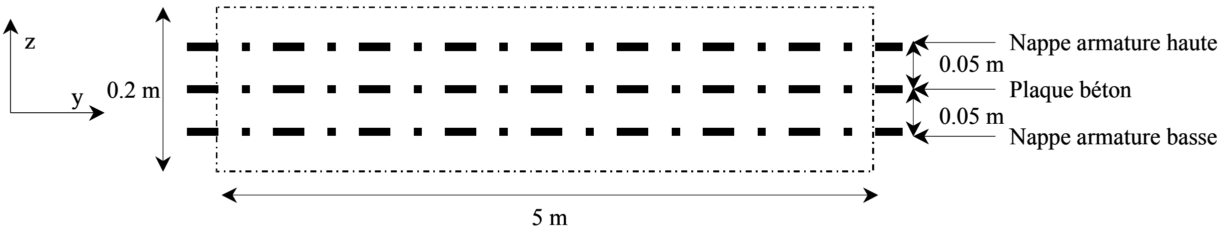
the results of simulation are compared with analytical solutions.

The interest of this test is to validate the modelization GRILLE_EXCENTRE, GRILLE_MEMBRANE and MEMBRANE under loadings of bending, gravity and by imposing predeformations.

1 Problem of reference

1.1 Geometry





the cantilever out of concrete and the three-dimensions functions of reinforcement will be respectively modelled by modelizations COQUE (`DKT`) and GRILL (`GRILLE_MEMBRANE` when there are not an eccentring or `GRILLE_EXCENTRE` when reinforcements are offset)

1.2 Properties of the materials

Comforts out of concrete: $E=3\text{E}+10\,Pa$, $\nu=0$

Thickness of the cantilever: $0.2\,m$; `ANGL_REP = (0; 0)`

Three-dimensions functions of steel reinforcement: $E=2\text{E}+11\,Pa$, $\nu=0$

Three-dimensions function of high reinforcement: section per linear meter = $0.2\,m^2/ml$; eccentring = $0.05\,m$; `ANGL_REP = (0; 0)`

Three-dimensions function of low reinforcement: section per linear meter = $0.2\,m^2/ml$; eccentring = $-0.05\,m$; `ANGL_REP = (0; 0)`

1.3 Boundary conditions and loadings

the boundary conditions and the loadings break up in the following way:

Modelization A and b:
Edge $NO1NO4$ ($B0X$) embedded
$DZ=1.0$ on edge $NO2NO3$ ($B1X$) (bending)

Modelization C, D and G:
Edge $B0X$ and $B1X$ clamped
Gravity

Modelization E, F and H;

Clamped $B0X$ edge

Predeformations EXX imposed on the two three-dimensions functions of reinforcements, equal to 0.001 .

The modelizations and the loadings considered are summarized in the following table:

Modelizations	Bending	Gravity	Predeformation
GRILLE_EXCENTRE	A and B	C	E and F
GRILLE_MEMBRANE		D	
MEMBRANE		G	H

2 Reference solution

2.1 Flexbeam

One seeks to calculate the resultant F_Z of the forces applying to a reinforced concrete plate (2 three-dimensions functions of reinforcement) of size $L_1 \times L_2 \times e$ (L_1 is dimension according to the principal direction of reinforcements), embedded on an edge and which one subjects to a displacement of bending on opposite edge (U_z).

The force is written:

$$F_z = K_Z U_z$$

with K_z the stiffness according to z data by:

$$K_z = \frac{3(EI)_{tot}}{L_1^3}$$

with $(EI)_{tot}$ equal to

$$(EI)_{tot} = (EI)_{beton} + (EI)_{armatures}$$

where

$$(EI)_{armatures} = 2.E_{armat}.(s.L_2).e_{exc}^2$$

with E_{armat} the Young's modulus of steel, s the section of reinforcements per linear meter and e_{exc} the eccentring of the three-dimensions functions of reinforcements compared to the average average

$$(EI)_{beton} = E_{béton}.L_2.\frac{e^3}{12}$$

where $E_{béton}$ is the Young's modulus of the concrete.

Knowing imposed vertical displacement and by means of the preceding formulas, it is possible to go back to the analytical value of the force.

2.2 Effect of gravity

One is interested now in a reinforced concrete plate embedded at its two ends and subjected to the effect of gravity.

One seeks to calculate the resultant of the vertical forces associated F_z

$$F_z = F_{z,armat} + F_{z,beton}$$

where $F_{z,beton}$ and $F_{z,armat}$ are respectively the effects of gravity related on the concrete and reinforcements.

$$F_{z,beton} = L_1.L_2.e.\rho_{beton}.g$$

with g the acceleration of gravity

$$F_{z,armat} = 2.s.L_2.L_1.\rho_{armat}.g$$

with ρ_{armat} the density of steel reinforcements, and s the section per linear meter.

By combining the preceding equations, it becomes possible to determine the value of the vertical force related to gravity and to deduce the vertical resultant from it from the reactions of bearing.

2.3 Predeformations

One seeks to calculate the following average displacement Ux of free edge of a reinforced concrete plate embedded with other edge. One applies to reinforcements a predeformation ε_{xx}.

By considering the homogeneous strain and equalizes on the three-dimensions functions of reinforcements and in the concrete, one writes simply:

$$U_x = \varepsilon_{xx}.L_x$$

with L_x the dimension of the plate in the direction x (equal to L_1 in this case)

One can thus determine the value of displacement sought.

3 Modelization A

3.1 Characteristic of the modelization

One tests here a loading of bending with elements GRILLE_EXCENTRE. The concrete cantilever is with a grid with 1616 elements TRIA3

3.2 Results of the modelization A

One tests the value of the reaction following z on clamped edge (BOX)

Value of reference (analytical solution) : $-3.299\text{E}3\,N$

Value provided by *Code_Aster* : $-3.3\text{E}3\,N$

Variation : 0.016%

4 Modelization B

Modelization identical to the modelization A, with a mesh of 500 elements QUAD4.

The results of the modelization B are the same ones as those of modelization A.

5 Modélisation C

5.1 Characteristic of the modelization

One tests here a loading of gravity with elements GRILLE_EXCENTRE. The concrete cantilever is with a grid with 500 elements QUAD4.

5.2 Results of the modelization C

One tests the value of the reaction following z on clamped edges ($BOX+B1X$)

Value of reference (analytical solution) : $1.7756\text{E}+07\,N$

Value provided by *Code_Aster* : $1.7756\text{E}+07\,N$

Variation : 0.

6 Modelization D

One tests here a loading of gravity with elements GRILLE_MEMBRANE. The eccentring of reinforcements is considered null. The mesh is identical to that of the modelization C.

the results of the modelization D are the same ones as those of the modelization C.

7 Modelization E

7.1 Characteristic of the modelization

One tests here a loading of predeformation with elements GRILLE_EXCENTRE. The mesh to that of modelization A. Résultats of

7.2 the modelization E One is

identical tests the value of average displacement following x of free edge $B1X$

Value of reference (analytical solution) : $0.1\,m$

Value provided by *Code_Aster* : $0.1\,m$

Variation : 0.

8 Modelization F

Modelization identical to the modelization E, with a mesh of 500 elements QUAD4.

The results of the modelization F are the same ones as those of the modelization E.

9 Modelization G

9.1 Characteristic of the modelization

One tests here a loading of gravity with elements MEMBRANE. The mesh to that of modelization A. Résultats of

9.2 the modelization G One is

identical tests the value of the reaction according to z on clamped edges ($BOX+B1X$)

Value of reference (analytical solution) : $1.7756\mathrm{E}+07\,N$

Value provided by *Code_Aster* : $1.7756\mathrm{E}+07\,N$

Variation : 0.

10 Modelization H

10.1 Characteristic of the modelization

One tests here a loading of predeformation with elements MEMBRANE . The mesh to that of modelization A. Résultats of

10.2 the modelization H One is

identical tests the value of following average displacement x free edge $B1X$

Value of reference (analytical solution) : $0.1\,m$

Value provided by *Code_Aster* : $0.1\,m$

Variation : 0.

11 Conclusions

One validates by this various benchmark modelizations of the behavior of a plate comforts under loading of bending, the effect of gravity and by imposing predeformations on the three-dimensions functions of reinforcement. One validates thus the modelizations `GRILLE_EXCENTRE`, `GRILLE_MEMBRANE and MEMBRANE`.

The results of simulations are in agreement with the values of the analytical solutions.