SSLV115 - Prestressed concrete element in compression and gravity

Summary:

This test allows a simple checking of calculations of gravity for the concrete elements with cables of prestressing, in linear mechanics of the structures static.

The concrete element is voluminal, and the elements of cable of prestressing are elements `BAR` or of the elements `CABLE_GAINE` with an adherent law.

Modelings A , B and C allow to test the application of gravity on elements `BAR` or of the elements `CABLE_GAINE` , for two directions of gravity.

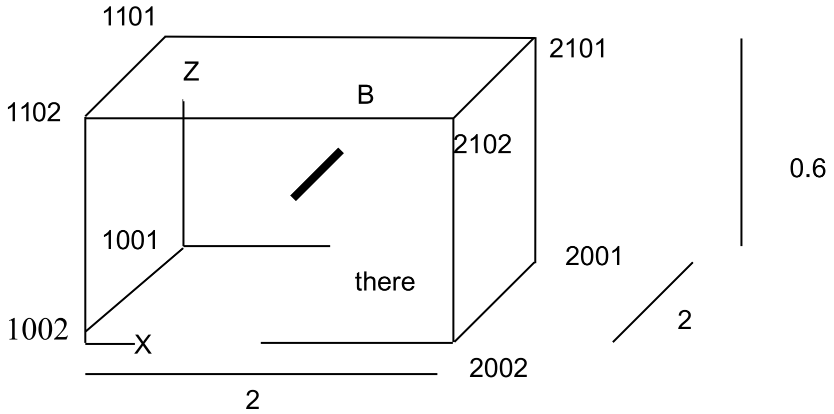
The values tested are the resultants of the reactions on the supports, equal to the total weight of modeling.

This case test also makes it possible to validate the order **CALC_PRECONT** for various types of elements $3D$ (parallelepipeds, pyramids and tetrahedrons). For that, one checks the values of the calculated constraints.

1 Problem of reference

1.1 Geometry

A right-angled parallelepiped modelling the concrete, and a line included in this volume modelling the cable of prestressed:



All dimensions are in meters. The surface of the cross sections of the cable is worth $A=0.00015\,m^2$ The cable is parallel to the axis x. Its intersection with the plan (Oyz) is defined by the point $(1.,0.3)$.

1.2 Material properties

$E=2.1\,10^{11}\,Pa$ for the cable, and $E=3.10^{10}\,Pa$ for the concrete.
$\rho_c=2\,10^4\,kg/m^3$ for the cable, and the concrete, $\rho_b=3\,kg/m^3$ (nonphysical values intended to make dominating the weight of the cable)

1.3 Boundary conditions and loadings

$DY=0$ at the point 1001, $DZ=0$ for all the nodes of the face $z=0$, and $DX=0$ for all the nodes of the face $x=0$.

Only one loading is applied: gravity, with $g=10\,m/s^2$, successively in the direction $-z$ then $-x$.

There exists also an initial tension in the cable $N=2.10^5\,N$.

2 Reference solution

2.1 Method of calculating used for the reference solution

The problem is solved in an analytical way.

The resultant of the efforts (equal to the total weight) is worth:

- weight of the concrete: $Pb=V\rho_b g$
- weight of the cable: $Pc=A L\rho_c g$

in the direction where gravity is applied.

The structure is isostatic. The prestressing forces auto--are balanced.

Are S_b the surface of the concrete in a plan perpendicular to the cable $S_b=(2\times 0{,}6)m^2$, E_a and E_b modules of steel and the concrete, N_a the tension in the cable and σ_b and the constraint in the concrete after setting in tension.

The balance of the concrete unit and cable is written: $N_a+\sigma_b S_b=0$ thus $\sigma_b=-\frac{N_a}{S_b}$

Since the macro order is used **CALC_PRECONT**, and as there is neither friction nor losses in the cable, the tension in the cable is equal to the initial tension, contrary if one uses **RELA_CINE_BP**, which undergoes the losses of prestressing due to the concrete contraction (see test SSNP108, [V6.03.108])

The deformation of the concrete is: $\varepsilon_b=\frac{\sigma_b}{E_b}$

2.2 Results of reference

- Resultant of the efforts: $R=132\,N$
- Constraint in the concrete: $\sigma_b=-1{,}66666667\,10^5\,Pa$
- Normal effort in steel: $N_a=2\,10^5\,Pa$
- Deformation in the concrete: $\varepsilon_b=-5{,}555555555\,10^{-6}$

2.3 Uncertainty on the solution

It is about an analytical solution.

The solution gives the average constraint in the concrete. When there are several elements (modelings B and C) it is necessary to make an average of the values of the meshs.

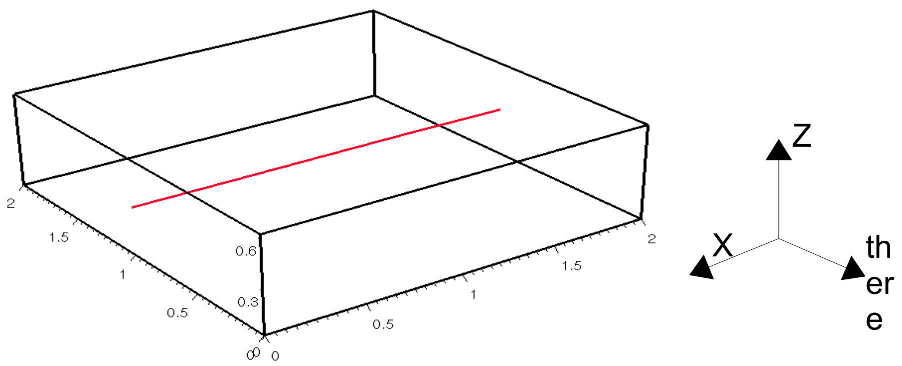
3 Modeling A

3.1 Characteristics of modeling

The volume of concrete is modelled by only one hexahedral element. The cable of prestressing is modelled initially by 4 elements BAR, then by 4 elements CABLE_GAINE.

3.2 Characteristics of the grid

With the cable modelled in BAR : 4 meshs SEG2, a mesh HEXA8
With the cable modelled in CABLE_GAINE : 4 meshs SEG3, a mesh HEXA8



3.3 Values tested and results of modeling A

The calculations are done for the first time with modeling BAR and second once with modeling CABLE_GAINE by using the adherent case of the law CABLE_GAINE_FROT .
The values tested are the same ones in both cases.

Identification	Type of reference	Reference	Tolerance
Gravity according to $-z$	'ANALYTICAL'	132	$10^{-8}\%$
Gravity according to $-x$	'ANALYTICAL'	132	$10^{-8}\%$
Constraint in the concrete SIXX	'ANALYTICAL'	$-1,66666667\,10^{5}$	$0,1\%$
Normal effort in steel NR	'ANALYTICAL'	$2\,10^{5}$	$0,1\%$
Deformation in the concrete: EPXX	'ANALYTICAL'	$-5,555555555\,10^{-4}$	$0,001\%$

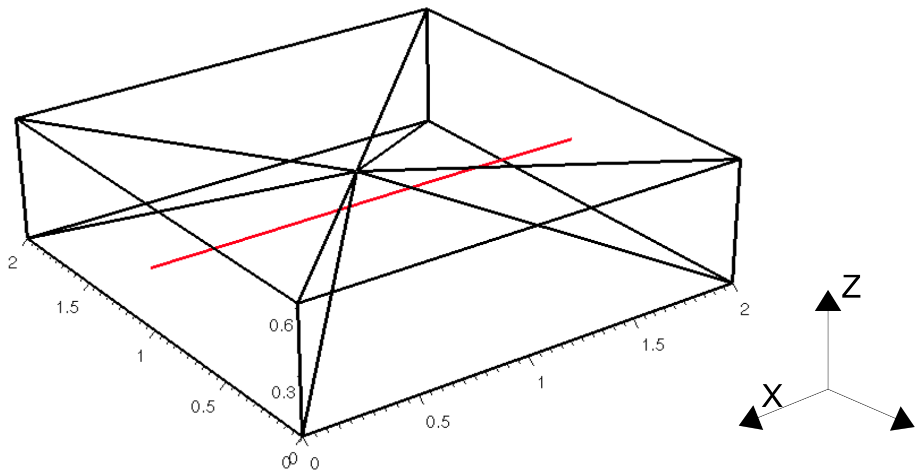
4 Modeling B

4.1 Characteristics of modeling

The volume of concrete is modelled by 6 elements pyramidal. The cable of prestressing is modelled by 4 elements BAR.

4.2 Characteristics of the grid

4 meshs SEG2, 6 meshs PYRAM5



4.3 Results of modeling B

Identification	Type of reference	Reference	Tolerance
Gravity according to $-z$	'ANALYTICAL'	132	10^{-8} %
Gravity according to $-x$	'ANALYTICAL'	132	10^{-8} %
Constraint in the concrete SIXX	'ANALYTICAL'	$-1{,}66666667\,10^{5}$	10^{-6} %
Deformation in the concrete: EPXX	'ANALYTICAL'	$-5{,}555555555\,10^{-4}$	10^{-6} %

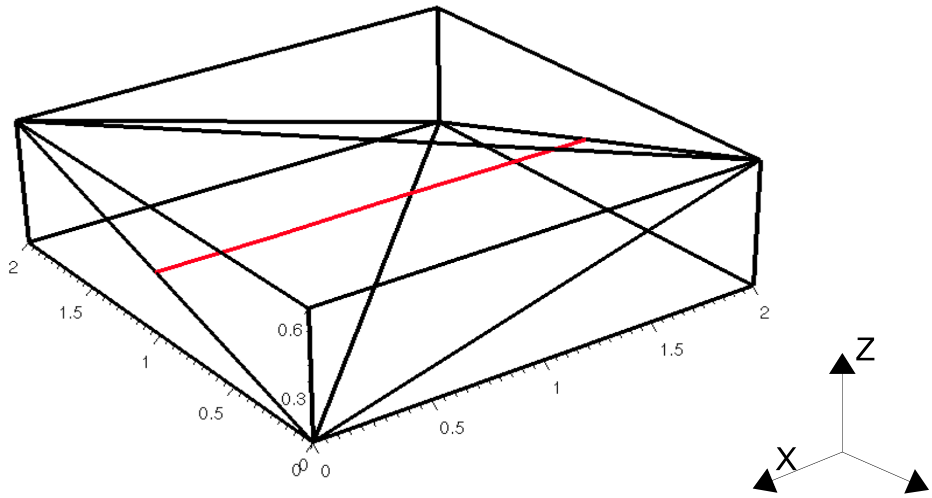
5 Modeling C

5.1 Characteristics of modeling

The volume of concrete is modelled by 5 elements 3D. The cable of prestressing is modelled by 4 elements BAR.

5.2 Characteristics of the grid

4 meshs SEG2, 5 meshs TETRA4



5.3 Results of modeling C

Identification	Type of reference	Reference	Tolerance
Gravity according to $-z$	'ANALYTICAL'	132	$10^{-8}\%$
Gravity according to $-x$	'ANALYTICAL'	132	$10^{-8}\%$
Constraint in the concrete SIXX	'ANALYTICAL'	$-1,66666667\,10^{5}$	$10^{-6}\%$
Deformation in the concrete: EPXX	'ANALYTICAL'	$-5,555555555\,10^{-4}$	$10^{-6}\%$

6 Summary of the results

This test, very simple, makes it possible simultaneously to check the good performance of gravity in the elements making it possible to model prestressing, namely BAR and CABLE_GAINE, which is checked by the perfect coincidence of the results with the analytical solution. It was introduced following the discovery of an anomaly on gravity into the bars, and makes it possible to validate the correction.
This test was enriched by two alternatives to test **CALC_PRECONT** in the case of various voluminal elements.