SSLV115 - Prestressed concrete element in compression and gravity

Summarized:

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

The concrete element is voluminal, and the cable elements of prestressing are elements of bar.

The modelizations A, B and C makes it possible to test the application of gravity on elements of bar, for two directions of gravity.

The values tested are the resultants of the reactions on the bearings, equal to the total weight of the modelization.

This case test also makes it possible to validate command CALC_PRECONT for different element types $3D$ (parallelepipeds, pyramids and tetrahedrons). For that, one checks the values of the calculated stresses.

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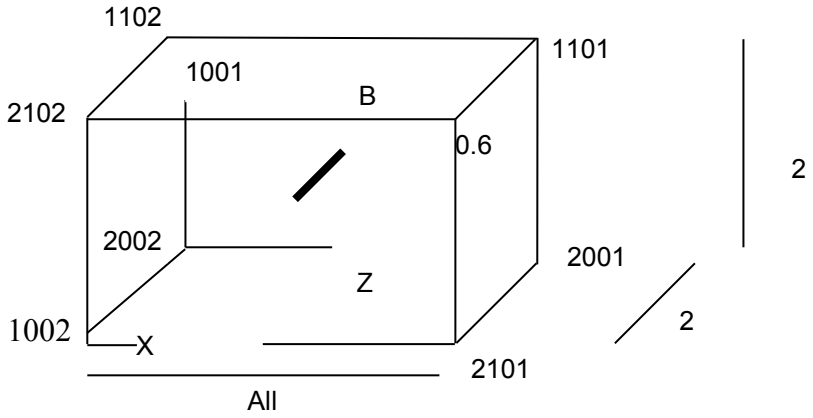
1 Problem of reference

1.1 Geometry

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



dimensions are there in meters. The area 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 plane (Oyz) is defined by the point $(1.,0.3)$.

1.2 Material properties

$E=2.1\,10^{11}\,Pa$ for the cable, and $E=3.10^{10}\,Pa$ 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 $N=2.10^5\,N$.

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2 Reference solution

2.1 Method of calculating used for the analytical reference solution

Solution:

The resultant of the forces (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 statically determinate. The prestressing forces auto--are balanced.

Are S_b the area of the concrete in a plane perpendicular to the cable $S_b = (2 \times 0,6) m^2$, E_a and the E_b moduli of steel and concrete, N_a the tension in the cable and σ_b the stress in the concrete after setting in tension.

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

Since macro command CALC_PRECONT `is used`, 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 strain of the concrete is: $\varepsilon_b = \frac{\sigma_b}{E_b}$

2.2 Results of reference

Resulting from the forces: $R = 132\ N$

Stress in the concrete: $\sigma_b = -1,66666667\ 10^5\ Pa$

Normal force in steel: $N_a = 2\ 10^5\ Pa$

Strain in the concrete: $\varepsilon_b = -5,555555555\ 10^{-6}$

2.3 Uncertainty on the analytical

solution Solution.

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

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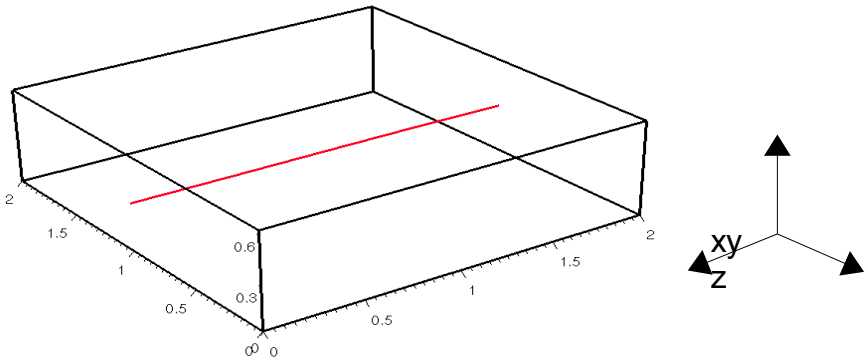
3 Modelization A

3.1 Characteristic of the modelization

the volume of concrete is modelled by only one hexahedral element. The cable of prestressing is modelled by 4 elements BARS.

3.2 Characteristics of the mesh

4 meshes SEG2, a mesh HEXA8



3.3 Values tested and results of the Standard modelization

A	Identification of reference	Reference	Tolerance
Gravity according to $-z$	"ANALYTIQUE"	132	$10^{-8}\%$
Gravity according to $-x$	"ANALYTIQUE"	132	$10^{-8}\%$
Stress in concrete SIXX	"ANALYTIQUE"	$-1{,}6666666710^{5}$	$0{,}1\%$
normal Force in steel	N'ANALYTIQUE"	210^{5}	$0{,}1\%$
Strain in the concrete: EPXX	"ANALYTIQUE"	$-5{,}5555555510^{-4}$	$0{,}001\%$

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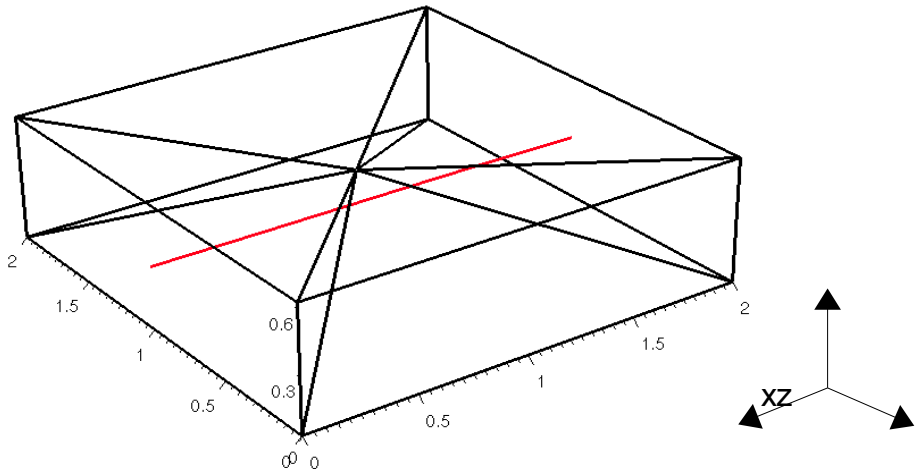
4 Modelization B

4.1 Characteristic of the modelization

the volume of concrete are modelled by 6 elements pyramidal. The cable of prestressing is modelled by 4 elements BARS.

4.2 Characteristics of the mesh

4 meshes SEG2, 6 meshes PYRAM5



4.3 Résultats of the Standard modelization

B	Identification of reference	Reference	Tolerance
Gravity according to $-z$	"ANALYTIQUE"	132	10^{-8} %
Gravity according to $-x$	"ANALYTIQUE"	132	10^{-8} %
Stress in concrete SIXX	"ANALYTIQUE"	$-1{,}66666667\,10^{5}$	10^{-6} %
Strain in the concrete: EPXX	"ANALYTIQUE"	$-5{,}555555555\,10^{-4}$	10^{-6} %

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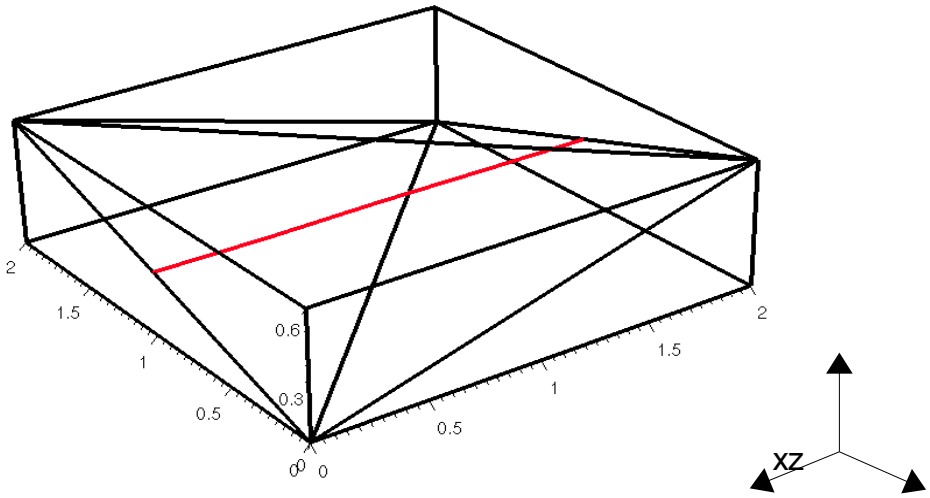
5 Modelization C

5.1 Characteristic of the modelization

the volume of concrete are modelled by 5 elements 3D. The cable of prestressing is modelled by 4 elements BARS.

5.2 Characteristics of the mesh

4 meshes SEG2, 5 meshes TETRA4



5.3 Résultats of the Standard modelization

C	Identification of reference	Reference	Tolerance
Gravity according to $-z$	"ANALYTIQUE"	132	10^{-8} %
Gravity according to $-x$	"ANALYTIQUE"	132	10^{-8} %
Stress in concrete SIXX	"ANALYTIQUE"	$-1{,}66666667\,10^{5}$	10^{-6} %
Strain in the concrete: EPXX	"ANALYTIQUE"	$-5{,}555555555\,10^{-4}$	10^{-6} %

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6 Summary of the results

This test, very simple, makes it possible simultaneously to check the correct operation of gravity in the elements of bar of prestressing, 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.

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