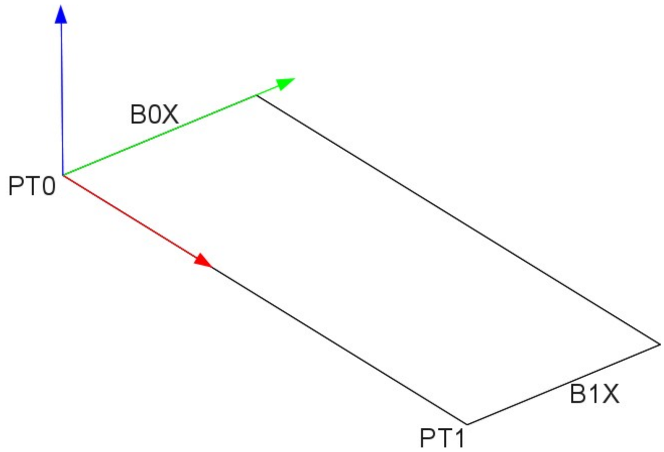
SSNS111 - Bending of a reinforced concrete slab under distributed load

Summarized:
This test relates to a reinforced concrete slab subjected to a uniform distributed load.
This problem makes it possible to test:

- finite elements of the multi-layer type DKT,
- finite elements of the type GRILLE_EXCENTRE,
- constitutive laws associated with the studies with civil engineer: MAZARS, VMIS_CINE,

1 Problem of reference

1.1 Geometry



Pave: $5\mathrm{m}\times3\mathrm{m}$, of thickness $0.25\,m$, on simple bearings in $B0X$ and $B1X$.
Higher three-dimensions function of reinforcements: $8\phi\,12=9.0478\,cm^2$, coating of $2.5\,cm$.
Lower three-dimensions function of reinforcements: $8\phi\,25=39.27\,cm^2$, coating of $2.5\,cm$.

1.2 Properties of the materials

command DEFI_MATER_GC is used to define concrete material:

```
BETON = DEFI_MATER_GC (
   MAZARS=_F (UNITE_LONGUEUR= " M", FCJ=51.0E+06,
              EIJ=43.0E+09, FTJ=4.2E+06, AT=0.9 ),
)
```

the echo of the command:

```
== Paramètres of model MAZARS [Pa] ==
Partie elasticity:
  E = 4.3000E+10, NU = 2.000E-01,
Left nonlinear:
  BT = 1.02380952E+04, AC = 1.31859827E+00, SIGM_LIM = 3.0600E+07, AT = 9.000E-01,
  BC = 1.53770784E+03, K = 7.00000000E-01, EPSI_LIM = 3.5000E-03,
  EPSD0 = 9.76744186E-05,
For information:
  FCJ = 5.100E+07, FTJ = 4.200E+06, EPSI_C = 2.29922344E-03,
```

command DEFI_MATER_GC is used to define the material steel:

```
ACIER =DEFI_MATER_GC (
   ACIER=_F (E=2.0E+11, SY=500.0E+06, NU=0.30),
)
```

the echo of the command:

```
 == Paramètres of model ECRO_LINE ==
Partie elasticity:
  E = 2.000E+11, NU = 3.000E-01,
Left nonlinear:
  SY = 5.000E+08, SIGM_LIM = 4.54545E+08, EPSI_LIM = 1.00E-02, D_SIGM_EPSI = 2.00E+07,
For information:
  EPSI_ELAS = 2.5000E-03,
```

1.3 Conditions of loadings

Line $B0X$: blocking of the degrees of freedom DX, DZ
formula $B1X$: blocking of the degrees of freedom DZ
At the points $PT0$ and $PT1$: blocking of the degrees of freedom DY
Distributed load on all surfaces of slab: $P[N/m^2]$

2 Reference solution

2.1 Quantities and results of reference

the reference solution is determined by a checking of the reinforced concrete section led to the limiting states. The characteristics of the materials are those resulting from the echo of commands DEFI_MATER_GC.

The computation stresses with the absolute limit of service is carried out with a distributed load on all the surface of slab of $P=80.5\ KN/m^2$. The ultimate stresses obtained are:

$$\begin{cases} \sigma_{bc} &= 32.3\,MPa \\ \sigma_{sc} &= 98.0\,MPa \\ \sigma_{st} &= 319.0\,MPa \end{cases}$$

of the assumptions of computation to the absolute limit of service is that strength in tension of the concrete is null. During computation with the finite elements concrete material follows a constitutive law of the type MAZARS which has a tensile strength. It will thus exist a light difference between the results resulting from a reinforced concrete computation type and a computation of type finite element.

The computation to the ultimate absolute limit the ultimate load gives $P=127.5\ KN/m^2$ (operation out of pivot A). The search by computation with the finite elements of the ultimate load is rather delicate, because it should be increased until obtaining a horizontal asymptote in the diagram force-displacement. This ultimate load must be close to that given by the approach reinforced concrete.

3 Modelization A

3.1 Characteristic of the modelization and the mesh

The mesh of slab is regular:

- cutting in 40 elements in the length, and 24 elements in the width is 960 elements $QUA4$.
- the steel three-dimensions functions are obtained by duplication of meshes of concrete then per eccentring:

```
MAILTOT =CRÉA_MAILLAGE (
    MAILLAGE=MAILL0,
    CREA_GROUP_MA= (
       _F (NOM=' ACPLUS',  GROUP_MA=' DALLE', PREF_MAILLE=' It,),
       _F (NOM=' ACMOINS', GROUP_MA=' DALLE', PREF_MAILLE=' You,),
    ),
)

LACAR=AFFE_CARA_ELEM (
    MODELE=LEMOD,
    COQUE=_F (GROUP_MA= ("SLAB",), EPAIS= 25.0E-02, COQUE_NCOU= 5,
              ANGL_REP= (0.0, 0.0,),),
    GRILL= (
            _F  (GROUP_MA=' ACPLUS',    SECTION=   9.0478E-04, ANGL_REP=
(0,0,),
            EXCENTREMENT= 0.10,),
             _F  (GROUP_MA=' ACMOINS', SECTION= 39.2700E-04, ANGL_REP=
(0,0,),
            EXCENTREMENT=-0.10,),
    ),
)
```

the load is distributed on all the surface of slab:

Times	distributed Urgent
1 formula	$80.5\,KN/m^2$
2 Charges	$127.5\,KN/m^2$
Urgent 3	$132.0\,KN/m^2$

3.2 Quantities tested and results

the quantities of the type forced are tested with CRITERE=' ABSOLU'. TOLE_MACHINE is thus modified consequently (VALE_REFE * $1.0E\text{-}06$), so that CRITERE=' ABSOLU' is correctly taken into account.

The quantities tested and analyzed with the absolute limit of service are:

- the minimal value of the stresses for the concrete in compression,
- the maximum stress for steels in tension,
- the minimal stress for steels in compression.
- variable SIGM_LIM for the concrete, steels.

ELS (Time 1)	Values		Forced
Tolerance	compressed Concrete	-33.0E+06	1.00E+05
	compressed Steel	-102.8E+06	2.50E+05
	Steel tightened	313.0E+06	2.00E+05
sIGM_LIM	compressed Concrete	-1.0860	0.20%
	compressed Steel	-0.2263	0.20%
	Steel tightened	the 0.1565	0.01%

quantities tested and analyzed with the ultimate absolute limit is:

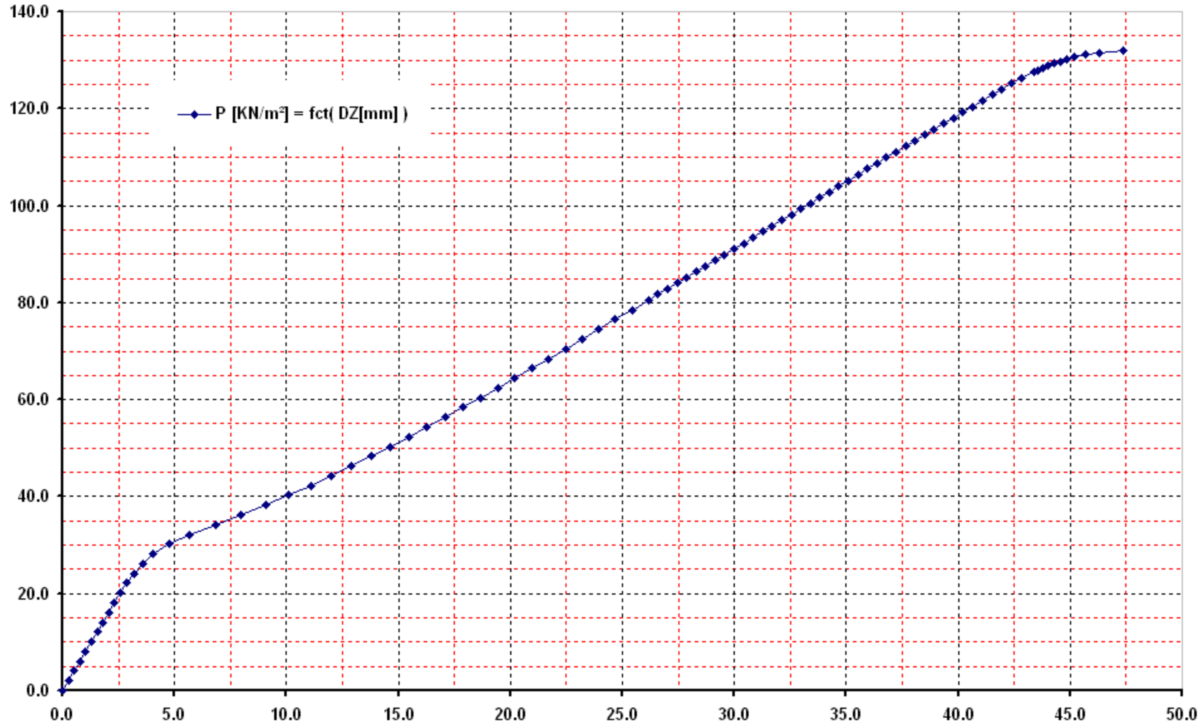
- the minimal value of the stresses for the concrete in compression,
- the maximum stress for steels in tension,
- the minimal stress for steels in compression.
- variable EPSI_LIM for the concrete, steels

ELU (Time 2)	Values		Forced
Tolerance	compressed Concrete	-48.13E+06	1.00E+05
	compressed Steel	-169.50E+06	7.00E+05
	Steel tightened	500.00E+06	1.00E+04
EPSI_LIM	compressed Concrete	-0.3836	0.20%
	compressed Steel	-0.0848	0.30%
	Steel tightened	the 0.2680	0.30%

quantity tested, corresponding to the beginning of the asymptote on the curve charges distributed according to maximum vertical displacement, and corresponds to variable EPSI_LIM of tended steels.

Time 3	Values		Tolerance
EPSI_LIM	Steel tightened	the 0.45921	0.02%

curve below, distributed load according to maximum displacement, shows that one reached the asymptote when the distributed load is close to $132.0\,KN/m^2$ (time 3).



4 Summary of the results

This case test shows the good correspondence between computations with the finite elements and a lawful approach.