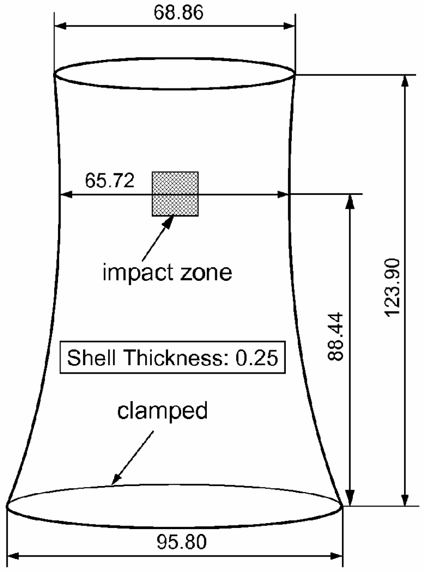
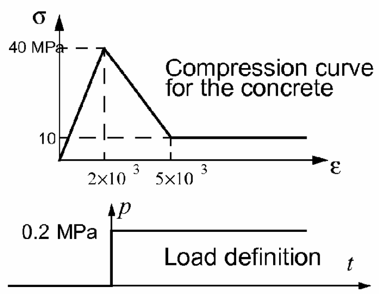
Exercise 3 – Impact on Cooling Tower

- Problem definition:



Layer N.	φ_L	Material
1	0.1	concrete
2	0.0025	steel
3	0.795	concrete
4	0.0025	steel
5	0.1	concrete



49

TITLE:
Towe02: impact against a cooling tower.

PROBLEM:
This problem is a very schematic simulation of an impact against a cooling tower. The parabolic tower is 123.9 m high and has a ground diameter of 95.8 m, a minimum diameter of 65.72 m (at a height 0f 88.44 m) and a top diameter of 68.86 m. It is schematized (very roughly) by a shell of constant thickness, equal to 0.25 m, made of reinforced concrete. The geometry is axisymmetric, but the loading is not so the problem has to be treated in 3D. The applied load is a time-dependent pressure in a localised zone near the top, simulating an impact of a projectile or flying object. The base of the tower is assumed completely blocked and thanks to the presence of a vertical symmetry plane, only one half of the tower needs be modeled.

MESH:
The model is 3D and uses 800 triangular plate/shell elements COQI.

MATERIALS:
The tower is made of reinforced concrete, modelled by the DPSF material for the concrete and VMSF for the steel reinforcement. The structure is composed of 5 layers of which 3 are concrete and 2 reinforcement. The respective thickness fractions are 0.1, 0.0025, 0.795, 0.0025 and 0.1.

BOUNDARY CONDITIONS:
The tower is entirely blocked along the bottom basis. A symmetry plane is imposed.

LOADING:

The system is initially at rest, and starting at the initial time a step-wise external pressure is applied onto a square region near the top of the tower, simulating the impact zone. The pressure stays constant for a duration of 500 ms, then goes linearly to 0 in 100 ms.

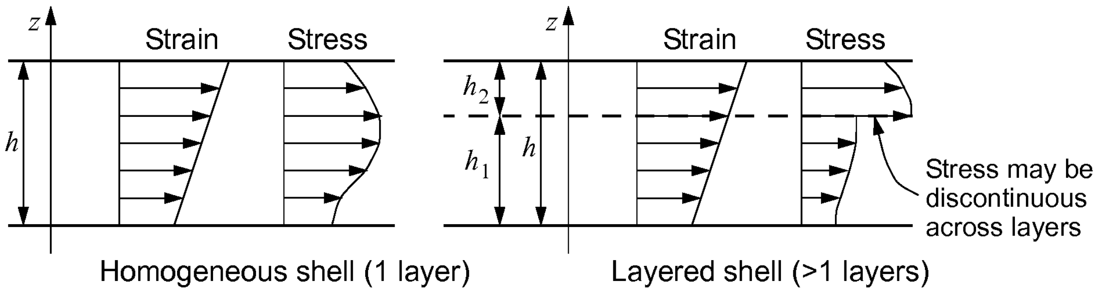
CALCULATION:
The calculation is performed up to 2000 ms. At the final time, the tower has undergone large plastifications in the impact zone and to some extent in the surrounding area.

RESULTS:
Although no comparison with experiments can be done on this problem, the results appear physically correct.

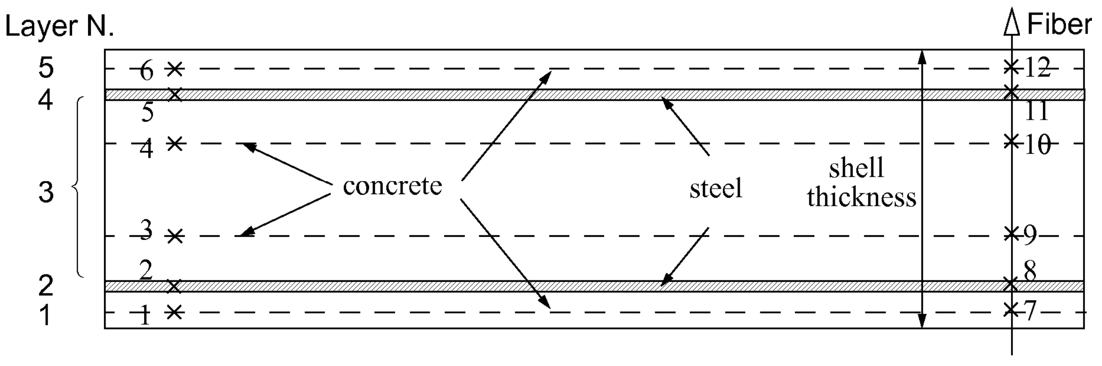
POST-TREATMENT
Several animations of the computed results from this calculation are available on the EUROPLEXUS Consortium Web site.

REFERENCES:
This calculation is detailed in:
1) J.J. Lopez Cela, F. Casadei and P. Pegon: "Fast Transient Analysis of Thin Shell Reinforced Concrete Structures with Drucker-Prager Model." SMiRT-14 Conference, Lyon (F), August 17-22, 1997.
For details on the reinforced concrete material model, see:
2) J.J. Lopez Cela, P. Pegon, F. Casadei: "Brittle Material Law with Drucker Prager Yield Surface and Softening Behaviour." Technical Note N. I.96.34, February 1996.
The layered shell model is described in:
3) F. Casadei, J.J. Lopez Cela: "A Multilayer Formulation for Shell Elements in PLEXIS-3C." Technical Note N. I.96.14, February 1996. (all these documents are available on the EUROPLEXUS Consortium Web site).

Shell model



Layers



Numerical Solutions

TOWE02

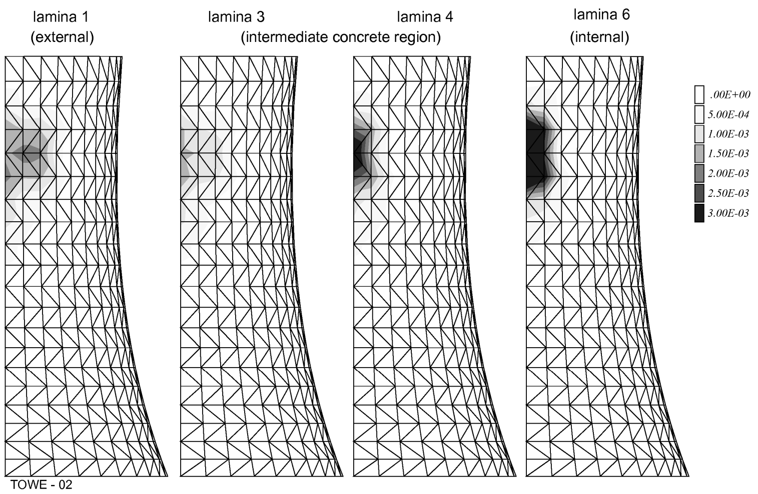
The mesh generation file (K2000):

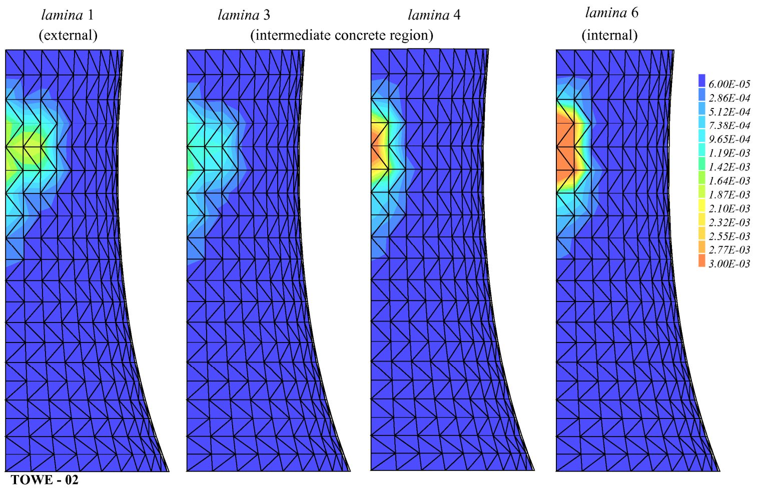
```
*%siz 50
*
opti echo 1;
*
opti trac psc ftra 'towe02_mesh.ps';
*
opti titr 'TOWE - 02';
opti dime 3;
*
ncir=10;
nlon=20;
*
p11=47.90 0.0 0.0;
p12=34.43 0.0 123.90;
p13=28. 0.0 50.;
p21=0.0 47.90 0.0;
*
opti elem seg2;
line1 = para nlon p11 p13 p12;
opti donn 5;
*
p4=0.0 0.0 0.0;
p5=0.0 0.0 123.90;
*
opti elem tri3;
surf1= line1 ncir ROTA 90. p4 p5;
*
oeilz=0.0 0.0 1000.0;
oeilx=1000.0 0.0 0.0;
oeily=0.0 1000.0 0.0;
*
p21=0.0 47.90 0.0;
p22=0.0 34.43 123.90;
p23=0.0 28.0 50.0;
*
opti elem seg2;
line2 = para nlon p21 p23 p22;
*
opti elem tri3;
surf2= line2 ncir ROTA 90. p4 p5;
*
p31=-47.90 0.0 0.0;
p32=-34.43 0.0 123.90;
p33=-28. 0.0 50.;
opti elem seg2;
line3 = para nlon p31 p33 p32;
*
surf=surf1 et surf2;
tol = 0.0001;
elim tol surf;
*
*
opti elem seg2;
*
bloc1 = cerc ncir p11 p4 p21;
bloc2 =cerc ncir p21 p4 p31;
bloc = bloc1 et bloc2;
*
*
mesh=surf et bloc et line3;
elim tol mesh;
*
opti sauv form 'towe02.msh';
sauv form mesh;
*
opti trac psc;
trac cach mesh;
fin;
```

The EUROPLEXUS input file is:

```
TOWE - 02
$
ECHO
!CONV win
CAST MESH
TRID NONL LAGR
$
$ Dimensioning
$
DIME
  PT6L 861 COQI 800
  FNOM 1 FTAB 2 FCOE 2
  PRES 4 3
  TABL 10 5
  ecrou 273600
  mtpo 21
TERM
$
$ Geometry
$
 GEOM COQI SURF TERM
$
COMP
  EPAI 0.25 LECT SURF TERM
  LAYE 5 FRAC 0.1 0.0025 0.795 0.0025 0.1
         NGPZ 1 1 2 1 1 LECT SURF TERM
$
$ Materials
$
$ concrete (softening)
MATE DPSF RO 2.4E3 YOUN 2.E10 NU 0.2 ALF1 1.299
     C1 5.7735E6 BETA 0.20 ETA 2.E-3
     TRAA 3 1.299 0.0 1.299 5.E-4 1.299 5.E+2
     TRAC 3 5.7735e6 0.0 1.44338E6 5.15E-3 1.44338E6 5.E+2
     LECT SURF TERM LAYE LECT 1 3 5 TERM
$
$ steel (elastoplastic)
     VMSF RO 7.8E3 YOUN 2.1E11 NU 0.3 ELAS 6.8E8
     ETA 0. TRAC 2 6.8E8 3.23810E-03 6.8E8 5.E+2
     LECT SURF TERM LAYE LECT 2 4 TERM
$
$ Boundary Conditions
$
LINK COUP
     BLOQ 123456 LECT BLOC TERM
     CONT SPLA NX 0 NY 1 NZ 0 LECT LINE1 LINE3 TERM
$
$ Loads
$
CHAR 1 FACT 2 PRES COQU 2.E5
              LECTURE 31 32 33 34 TERM
              TABL 4 0. 1. 0.5 1. 0.6 0. 10. 0.
$
ECRI DEPL TFRE 500.D-3
     FICH K200 TFRE 50.E-3
               POIN TOUS
               VARI DEPL ECRO ECRC LECT 1 2 3 TERM
     FICH ALIC TFRE 2.E-2
     FICH ALIC TEMP FREQ 1
          POIN LECT 33 41 TERM
          ELEM LECT 1 TERM
$
OPTI NOTE K2FB 1
         !K2FB 3
         !K2FB 4
         !K2FB 6
     log 1
CALC TINI 0.0 TEND 2000.D-3
*==================================================================
SUIT
Post-treatment (time curves from alice temps file)
ECHO
*
RESU ALIC TEMP GARD PSCR
*
SORT GRAP
*
AXTE 1000.0 'Time [ms]'
*
COUR  1 'dx_n1' DEPL COMP 1 NOEU LECT 33 TERM
COUR  2 'dx_n2' DEPL COMP 1 NOEU LECT 41 TERM
*
trac 1 2 axes 1.0 'DISPL. [M]'
*
QUAL DEPL COMP 1 LECT 33 TERM REFE -9.79695E+0 TOLE 5.E-2
     DEPL COMP 1 LECT 41 TERM REFE -1.01268E+0 TOLE 5.E-2
*==================================================================
FIN
```

Some results: equivalent plastic strains in the 4 concrete laminae at 100 ms.





Final deformation (with superposed initial geometry) and Intermediate deformation with velocities: