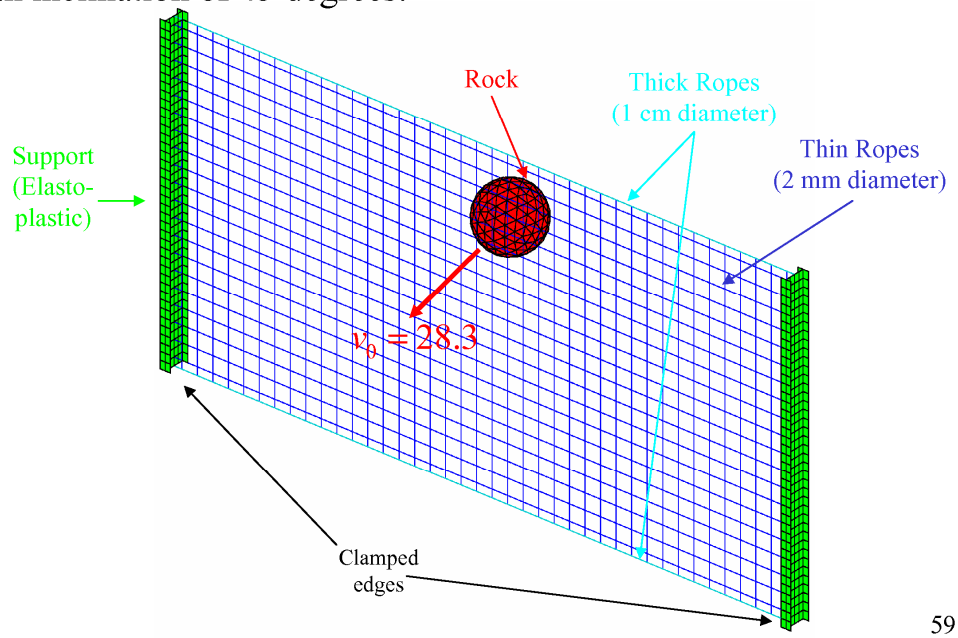
Example 7d – Falling Rock Catcher

- A falling rock catcher of 6 m by 3 m is hit by a spherical rock of 0.6 m diameter and a mass of 283 kg, at a speed of 100 km/h (28.3 m/s) and with an inclination of 45 degrees:



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TITLE:
Falling rock catcher.

PROBLEM:
A rather rigid falling rock impacts a catcher made of an elasto-plastic net supported by two double-T shaped structures at the extremities. The net is 6 m and 3 m high. The rock has a diameter of 60 cm and a mass of 283 kg. Its initial velocity is 100 km/h (28.3 m/s) and it impacts the catcher at the position shown above (3/4 of height, centred horizontally) at an angle of 45 degrees. The net cables have a diameter of 2 mm, except the lower and higher horizontal cables which have a diameter of 1 cm. The thickness of the supports is 5 mm.

MESH:
Specialized 3D cable elements (FUN3) are used to discretize the net, 6720 elements altogether. The two supports are modelled by 640 shell elements (Q4GR). The falling mass is modelled by a material point.

MATERIALS:
The VM23 (Von Mises law with isotropic hardening) material is assigned to the supports, while the cables use the specialized FUNE material, characterized by no resistance in compression and an elasto-plastic behaviour in traction. Two solutions are presented, corresponding to rupture strains of 50% and 5%, respectively.

BOUNDARY CONDITIONS:

The two supports are clamped at the base. Contact between the falling mass and the net is modelled by pinballs, without taking into account any friction.

LOADING:
No external loads are assumed.

INITIAL CONDITIONS
The falling rock has an initial velocity of 100 km/h at an angle of 45 degrees towards the net.

CALCULATION:
The calculation is performed up to 100 ms. At the final time, the falling rock has completely perforated the net.

POST-TREATMENT
A detailed animation of the computed results from this calculation is available on the EUROPLEXUS Consortium Web site.

Numerical Solutions

NETCF6

Solution with a cables rupture strain of 50%. The mesh generation file is:

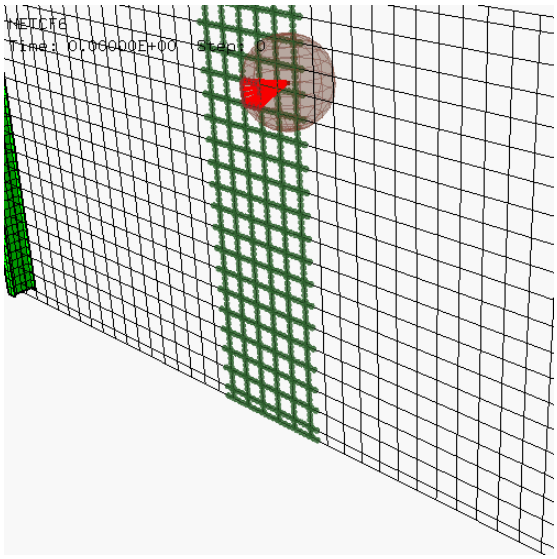
```
*%siz 300
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'netcf6.msh';
opti trac psc ftra 'netcf6_mesh.ps';
*
p0 = 0 0 0; tol = 0.001;
lx = 6.0; lz  = 3.0;
nx = 40; nz = 20;
fx = 4; fz = 4;
dx = lx / nx;
dz = lz / nz;
vx = dx 0 0; vz = 0 0 dz;
pa = (dx/2) 0 0;
pb = (dx/2) 0 lz;
cv = pa d (fz*nz) pb;
pc = 0 0 (dz/2);
pd = lx 0 (dz/2);
ch = pc d (fx*nx) pd;
clow = (ch plus (0 0 (0-dz/2))) coul turq;
chig = (clow plus (0 0 lz)) coul turq;
*
repe loopx nx;
  si (ega &loopx 1);
    netv = cv;
  sinon;
    cv = cv plus vx;
    netv = netv et cv;
  finsi;
fin loopx;
netv = netv coul bleu;
*
repe loopz nz;
  si (ega &loopz 1);
    neth = ch;
  sinon;
    ch = ch plus vz;
    neth = neth et ch;
  finsi;
fin loopz;
neth = neth coul bleu;
*
net = netv et neth et clow et chig;
elim tol net;
*
*trac qual net;
*net1 = chan 'POI1' net;
*trac qual net1;
list (nbel net);
list (nbno net);
*
tx = 0.1; ty = 0.2;
ta = (0-tx/2) (0-ty/2) 0;
tb = (  tx/2) (0-ty/2) 0;
tc = 0        (0-ty/2) 0;
td = (0-tx/2) (  ty/2) 0;
te = (  tx/2) (  ty/2) 0;
tf = 0        (  ty/2) 0;
ntx = 1; nty = 2;
t1 = ta d ntx tc d ntx tb;
t2 = td d ntx tf d ntx te;
t3 = tc d nty p0 d nty tf;
tt = t1 et t2 et t3;
elim tol tt;
supp1 = (tt tran (2*nz) (0 0 lz)) coul vert;
supp2 = (supp1 plus (lx 0 0)) coul vert;
supp = supp1 et supp2;
list (nbel supp);
list (nbno supp);
stru = supp et net;
elim tol stru;
*trac cach face stru;
list (nbel stru);
list (nbno stru);
*
bloq = supp poin plan p0 (1 0 0) (0 1 0) tol;
list (nbno bloq);
*trac bloq;
*
rfall = 0.3;
pfall = (lx/2) (rfall) (3*lz/4);
list pfall;
fall = (manu 'POI1' pfall) coul roug;
*trac cach face (stru et fall);
*
fac = 1.5;
*rfall2 = fac*rfall*rfall;
rfall2 = fac*rfall;
xf yf zf = coor pfall;
n = nbel net;
ni = 0;
repe loop3 n;
  ei = net elem &loop3;
  xb yb zb = coor (bary ei);
  dx = xb - xf;
* dz = zb - zf;
* d2 = (dx*dx) + (dz*dz);
  si (abs(dx) < rfall2);
* si (d2 < rfall2);
    ni = ni + 1;
    si (ega ni 1);
      neti = ei;
    sinon;
      neti = neti et ei;
    finsi;
  finsi;
fin loop3;
*neti = neti coul roug;
list ni;
*trac qual neti;
neto = diff net neti;
*trac qual neto;
trac face cach (neti et neto et supp et fall);
*
mesh = supp et neti et neto et fall et bloq;
tass mesh;
sauv form mesh;
*
fin;
```

The input file is:

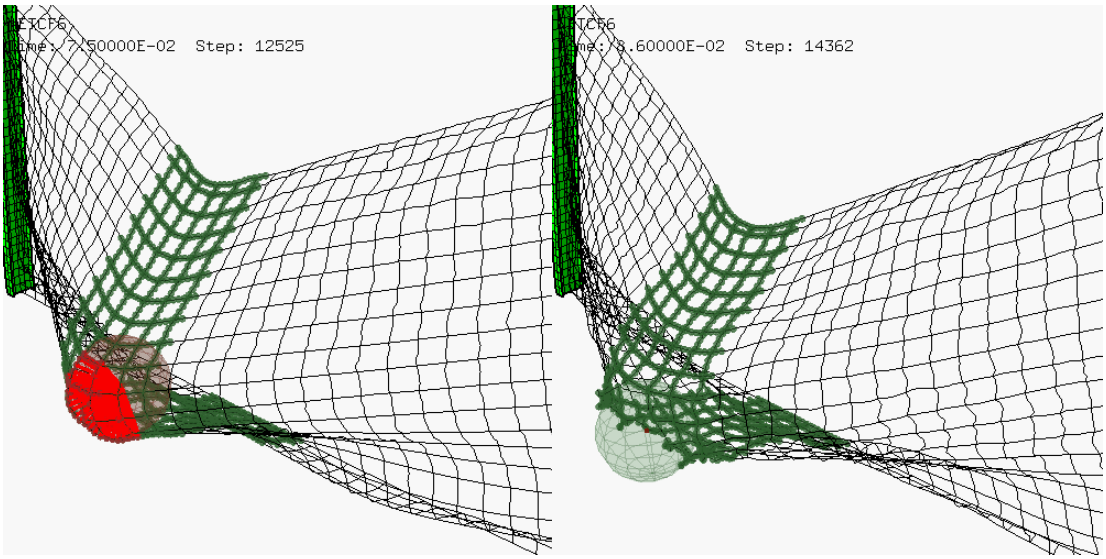
```
NETCF6
*------------------------------------------------------------------------
ECHO
 conv win
CAST mesh
*-------------------------------------------------------------Problem type
TRID NONL LAGR FAIL
*-------------------------------------------------------------Dimensioning
DIME
   PT6L 738 PT3L 5859 FUN3 6720 PMAT 1 Q4GR 640 ZONE 3
TERM
*--------------------------------------------------------------------Geometry
GEOM FUN3 net PMAT fall Q4GR supp TERM
*-----------------------------------------------------Geometric Complements
COMP EPAI 3.14E-6 LECT netv neth TERM ! 2 mm diameter
     EPAI 7.85E-5 LECT clow chig TERM ! 1 cm diameter
     EPAI 0.6     LECT fall TERM ! only for graphical representation
     EPAI 0.005   LECT supp TERM      ! 5 mm thickness
*-------------------------------------------------------------Material data
MATE FUNE RO 8000. YOUN 2.0E11 NU 0.3 ERUP 0.5
          ELAS 0.440D9
          TRAC 5 0.440D9 2.200D-3 0.735D9 0.156D0
                 0.900D9 0.283D0 1.077D9 0.475D0 1.142D9 0.600D0
          LECT net TERM
```

```
     MASS 282.75 LECT fall TERM
     VM23 RO 8000. YOUN 1.95D11 NU 0.3 ELAS 1.95E+8
          TRAC 4 1.95E+8 .001 2.16E+8 .005 2.6E+8 .02 2.6E8 10.
          LECT supp TERM
*-------------------------------------------------------Boundary conditions
LINK COUP BLOQ 123456 LECT bloq TERM
     PINB BODY MLEV 0   LECT neti TERM
          BODY DIAM 0.6 LECT fall TERM
*-------------------------------------------------------Initial conditions
INIT VITE 2 -20 LECT fall TERM ! v_0 = about 100 km/h
     VITE 3 -20 LECT fall TERM
*-------------------------------------------------------------------Outputs
ECRI VITE TFRE 100.E-3
     FICH ALIC      TFRE 1.E-3
*-------------------------------------------------------------------Options
OPTI NOTE
     LOG 1
*-----------------------------------------------Transient calculation
CALC TINI 0 TFIN 0.100
*=================================================================ANIMATION
PLAY
CAME   1 EYE   8.41798E+00 -6.59217E+00  1.20611E+01
!        Q     8.68252E-01  3.25861E-01  9.16021E-02  3.62715E-01
         VIEW -3.95456E-01  4.99408E-01 -7.70848E-01
         RIGH  7.20094E-01  6.89555E-01  7.73214E-02
         UP   -5.70157E-01  5.24506E-01  6.32309E-01
         FOV   2.48819E+01
!CAME   2 EYE   4.76084E+00 -1.97370E+00  4.93234E+00
!!       Q     8.68252E-01  3.25861E-01  9.16021E-02  3.62715E-01
!        VIEW -3.95456E-01  4.99408E-01 -7.70848E-01
!        RIGH  7.20094E-01  6.89555E-01  7.73214E-02
!        UP   -5.70157E-01  5.24506E-01  6.32309E-01
!        FOV   2.48819E+01
CAME   2 EYE   8.34687E+00 -4.82530E+00  4.41693E+00
!        Q     7.83098E-01  4.84674E-01  2.27182E-01  3.16603E-01
         VIEW -6.62709E-01  6.15242E-01 -4.26958E-01
         RIGH  6.96303E-01  7.16080E-01 -4.89126E-02
         UP   -2.75643E-01  3.29707E-01  9.02948E-01
         FOV   2.48819E+01

!Sequence 01: Title (30 frames)
!------------------------------
scen geom navi free
     colo pape
titl tit1 'EUROPLEXUS (C) Animation'
     tit2 'Falling Rock Catcher'
     tit3 'Author: F. Casadei'
sler cam1 1        nfra 30
trac offs fich avi      nocl nfto 905 fps 10 kfre 10 comp -1 rend

!Sequence 02: Title (30 frames)
!------------------------------
titl tit2 'Geometry and Pinballs'
sler cam1 1        nfra 30
trac offs fich avi cont nocl                                    rend

!Sequence 03: Still from cam1 (15 frames)
!----------------------------------------
scen geom navi free
          line sfre !heou
          poin sphp
         !pinb pare cdes
     colo pape
     lima on
sler cam1 1        nfra 15
trac offs fich avi cont nocl                                    rend

!Sequence 04: Still from cam1 with pinballs (15 frames)
!-----------------------------------------------------
scen geom navi free
          line sfre !heou
         !poin sphp
          pinb pare cdes
     colo pape
     lima on
sler cam1 1        nfra 15
trac offs fich avi cont nocl                                    rend

!Sequence 05: Slerping from cam1 to cam2 (30 frames)
!---------------------------------------------------
scen geom navi free
          line sfre !heou
         !poin sphp
          pinb pare cdes
     colo pape
     lima on
sler cam1 1 cam2 2 nfra 30
trac offs fich avi cont nocl                                    rend

!Sequence 06: Transient (100 frames)
!-----------------------------------
sler cam1 2        nfra 1
freq 0 tfre 1.e-3
gotr loop 99 offs fich avi cont nocl obje nfai lect tous term rend
go
trac offs fich avi cont nocl obje nfai lect tous term              rend

ENDPLAY
*=========================================================POST-TREATMENT
SUIT
NETCF6 POST
*-------------------------------------------------------------------------
ECHO
 conv win
*
RESU ALIC GARD PSCR
*
OPTI PRIN
*
SORT VISU NSTO 1
*=================================================================ANIMATION
PLAY
CAME   1 EYE   8.41798E+00 -6.59217E+00  1.20611E+01
!        Q     8.68252E-01  3.25861E-01  9.16021E-02  3.62715E-01
         VIEW -3.95456E-01  4.99408E-01 -7.70848E-01
         RIGH  7.20094E-01  6.89555E-01  7.73214E-02
         UP   -5.70157E-01  5.24506E-01  6.32309E-01
         FOV   2.48819E+01
CAME   2 EYE   8.34687E+00 -4.82530E+00  4.41693E+00
!        Q     7.83098E-01  4.84674E-01  2.27182E-01  3.16603E-01
         VIEW -6.62709E-01  6.15242E-01 -4.26958E-01
         RIGH  6.96303E-01  7.16080E-01 -4.89126E-02
         UP   -2.75643E-01  3.29707E-01  9.02948E-01
         FOV   2.48819E+01
CAME   3 EYE   1.19987E+00 -1.01152E+00  8.34224E-01
!        Q     7.57665E-01  5.12725E-01  2.51753E-01  3.15716E-01
         VIEW -7.05240E-01  6.17983E-01 -3.47466E-01
         RIGH  6.73888E-01  7.36574E-01 -5.77375E-02
         UP   -2.20254E-01  2.74872E-01  9.35913E-01
         FOV   2.48819E+01

!Sequence 07: Title (30 frames)
!------------------------------
scen geom navi free
     colo pape
titl tit2 'Geometry only'
sler cam1 1        nfra 30
trac offs fich avi cont nocl                                    rend

!Sequence 08: Transient from cam1 (101 frames)
!--------------------------------------------
scen geom navi free
          line sfre heou
          face sbac
          poin sphp
         !pinb pare cdes
     colo pape
     lima on
sler cam1 1        nfra 1
trac offs fich avi cont nocl
     obje nfai lect tous term rend
gotr loop 99 offs fich avi cont nocl
     obje nfai lect tous term rend
go
trac offs fich avi cont nocl
     obje nfai lect tous term rend
ENDPLAY
*=================================================================
     VISU NSTO 1
*=================================================================
PLAY

!Sequence 09: Title (30 frames)
!------------------------------
scen geom navi free
     colo pape
titl tit2 'Velocities'
sler cam1 1        nfra 30
trac offs fich avi cont nocl rend

!Sequence 10: Transient from cam1 (101 frames)
!--------------------------------------------
scen geom navi free
          line sfre heou
          face sbac
          poin sphp
         !pinb pare cdes
     colo pape
     lima on
     VECT SCCO FIEL VITE SCAL USER PROG 2 PAS 2 28 TERM
     text vsca
sler cam1 1        nfra 1
trac offs fich avi cont nocl
     obje nfai lect tous term rend
gotr loop 99 offs fich avi cont nocl
     obje nfai lect tous term rend
go
trac offs fich avi cont nocl
     obje nfai lect tous term rend
ENDPLAY
*=================================================================
     VISU NSTO 1
*=================================================================
PLAY

!Sequence 11: Title (30 frames)
!------------------------------
scen geom navi free
     colo pape
titl tit2 'Strain in Cables'
sler cam1 1        nfra 30
trac offs fich avi cont nocl rend

!Sequence 12: Transient from cam1 (101 frames)
!--------------------------------------------
scen geom navi free
          line sfre heou
          face sbac
          poin sphp
         !pinb pare cdes
     colo pape
     lima on
     ISO  FILL FIEL ECRO 1 SCAL USER PROG 1.E-2 PAS 1.E-2 14.E-2 TERM
               SUPP LECT net TERM
     text isca
sler cam1 1        nfra 1
trac offs fich avi cont nocl
     obje nfai lect tous term rend
gotr loop 99 offs fich avi cont nocl
     obje nfai lect tous term rend
go
trac offs fich avi cont nocl
     obje nfai lect tous term rend
ENDPLAY
*=================================================================
     VISU NSTO 1
*=================================================================
PLAY

!Sequence 13: Title (30 frames)
!------------------------------
scen geom navi free
     colo pape
titl tit2 'Hardening in Supports'
sler cam1 1        nfra 30
trac offs fich avi cont nocl rend

!Sequence 14: Transient from cam1 (101 frames)
!--------------------------------------------
scen geom navi free
          line sfre heou
          face sbac
          poin sphp
          !pinb pare cdes
     colo pape
     lima on
     ISO  FILL FIEL ECRO 7 SCAL USER PROG 1.95E8 PAS 0.05E8 2.6E8 TERM
               SUPP LECT supp TERM
     text isca
sler cam1 1        nfra 1
trac offs fich avi cont nocl
     obje nfai lect tous term rend
gotr loop 99 offs fich avi cont nocl
     obje nfai lect tous term rend
go
trac offs fich avi cont nocl
     obje nfai lect tous term rend
ENDPLAY
*=================================================================
     VISU NSTO 1
*=================================================================
PLAY

!Sequence 15: Title (30 frames)
!------------------------------
scen geom navi free
     colo pape
titl tit2 'Zoom on Support 1'
sler cam1 1        nfra 30
trac offs fich avi cont nocl rend

!Sequence 16: Slerp from cam1 to cam3 (30 frames)
!-----------------------------------------------
scen geom navi free
          line heou sfre
          face sbac
          poin sphp
         !pinb cdes
     colo pape
     lima on
sler cam1 1 cam2 3 nfra 30
trac offs fich avi cont nocl rend

!Sequence 17: Transient from cam3 (101 frames)
!--------------------------------------------
scen geom navi free
          line heou sfre
          face sbac
          poin sphp
         !pinb cdes
     colo pape
     lima on
     ISO  FILL FIEL ECRO 7 SCAL USER PROG 1.95E8 PAS 0.05E8 2.6E8 TERM
               SUPP LECT supp1 TERM
     text isca
sler cam1 3        nfra 1
trac offs fich avi cont nocl
     obje lect supp1 net term rend
gotr loop 99 offs fich avi cont nocl
     obje lect supp1 net term rend
go
trac offs fich avi cont
     obje lect supp1 net term rend
ENDPLAY
*=================================================================
FIN
```

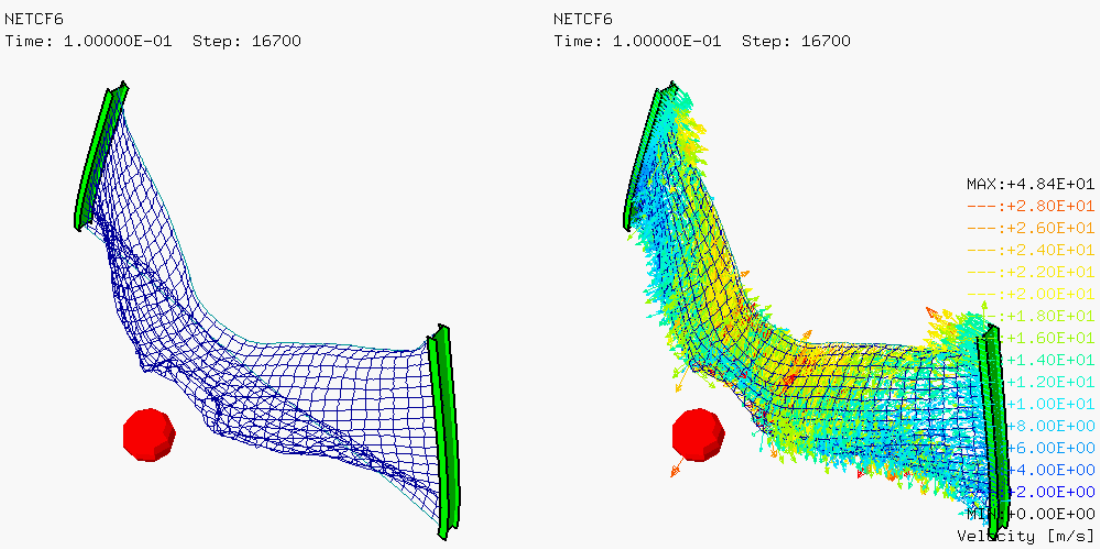
The initial configuration with pinballs shown is:



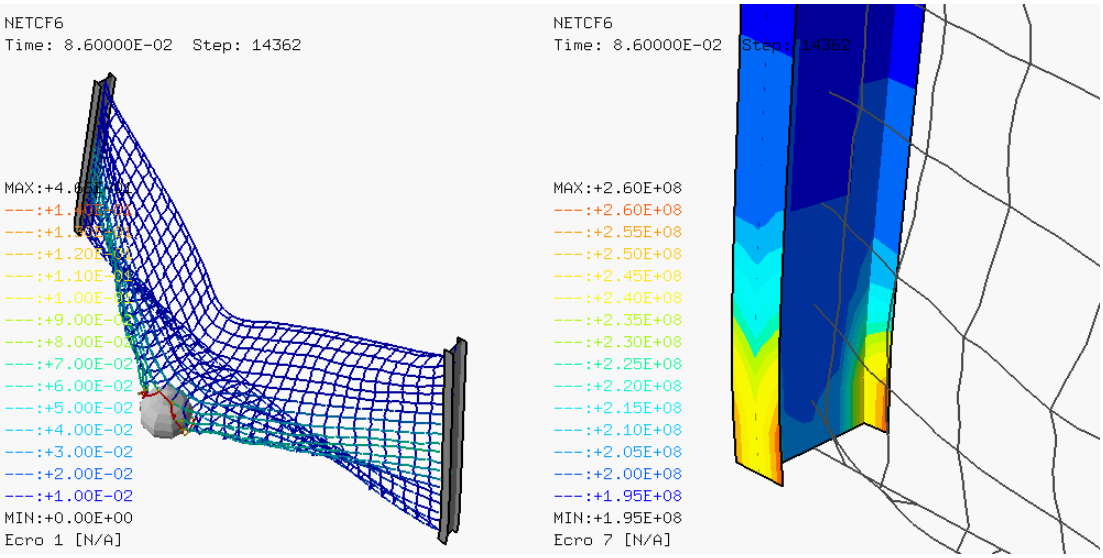
Rupture of the cables starts at around 75 ms and is completed at about 86 ms:



The final configuration (geometry only) and the final velocities are:

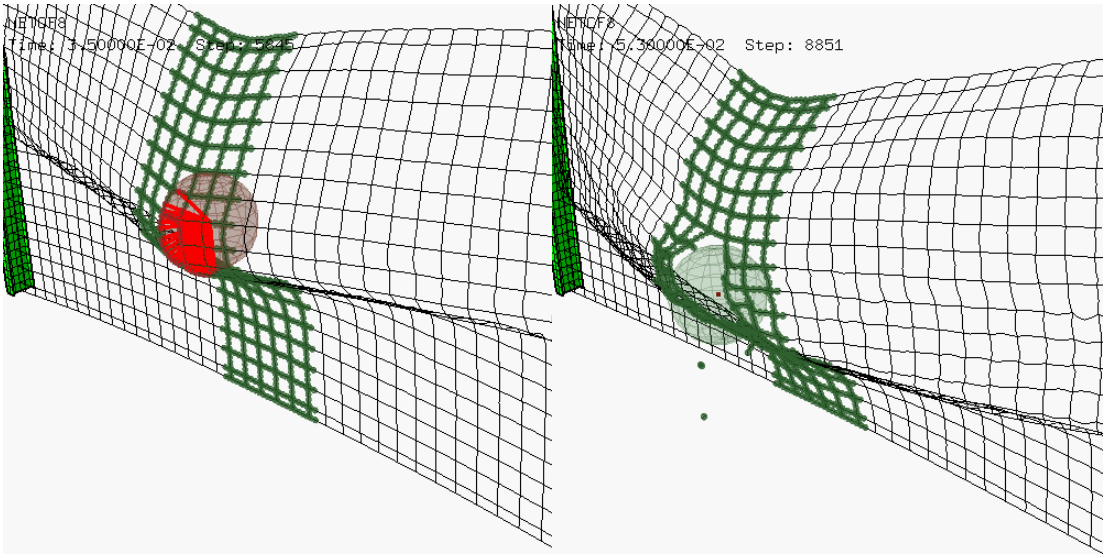


The strain in the cables at 86 ms and the hardening in the suuports is:

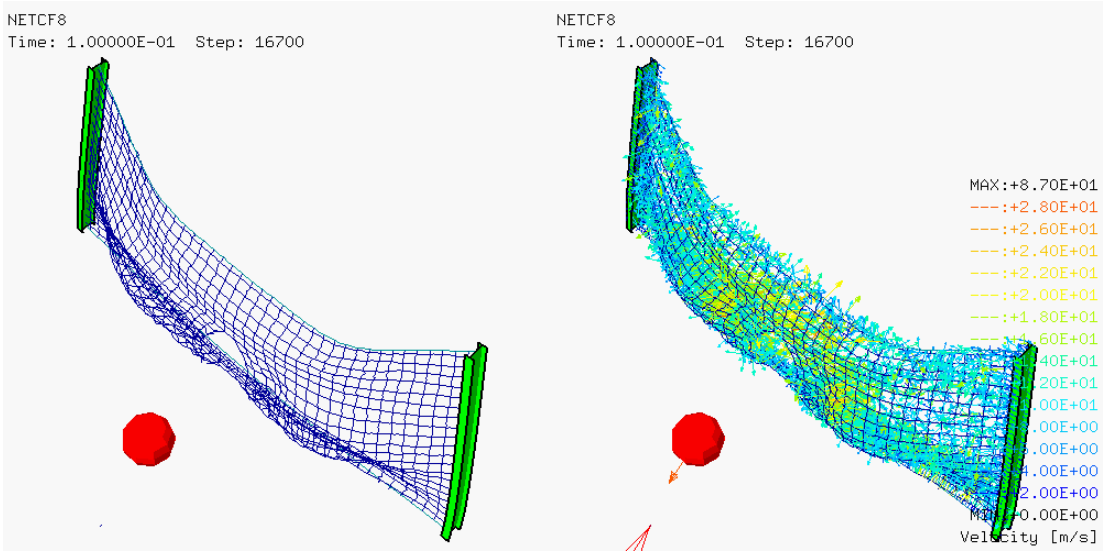


NETCF8

Solution with a cables rupture strain of 5%. Rupture of the cables starts at around 35 ms and is completed at about 53 ms:



The final configuration (geometry only) and the final velocities are:



The strain in the cables at 53 ms and the hardening in the supports are: