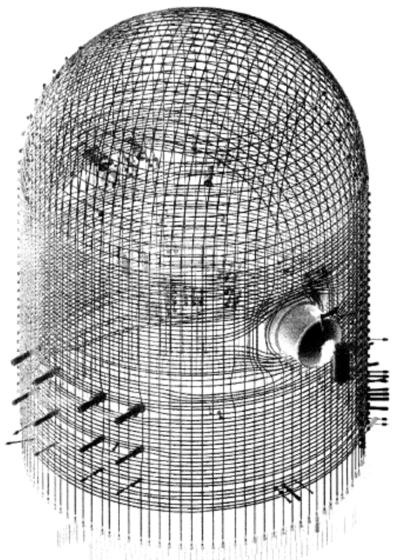
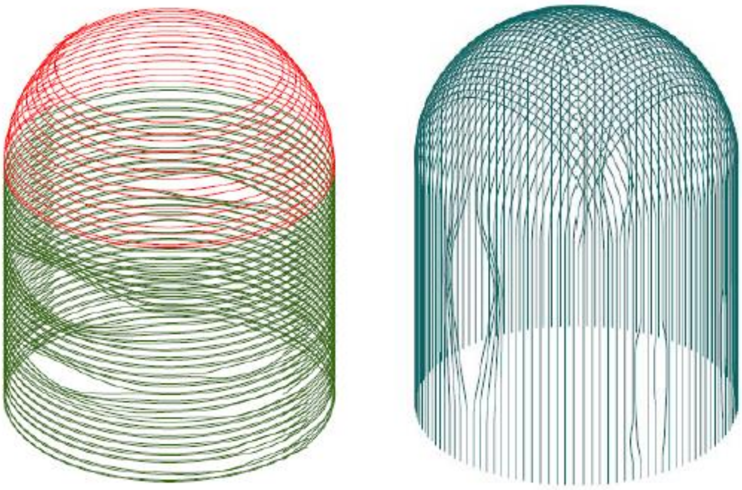
2015-2016 GCN PROJECT

Design of a double Containment with internal containment in prestressed concrete with 3rd generation 1200 MWe with liner





Presentation of the studied structure:

The inner containment of the project has a cylindrical structure of prestressed reinforced concrete with hemispherical dome and reinforced concrete foundation plate.

The cylinder has an internal diameter of 44.00 m and is 1.20m thick. The hemispheric dome has an internal radius of 22.00m and is 1.00 m thick. The total height of the cylindrical part of the containment is 41.60 m.

It is assumed to be embedded into its base in an infinitely stiff raft foundation.

The inner containment is reinforced by an outer containment in 0.60 metre thick reinforced concrete, with a space of 2.00m between containments.

The inner containment in prestressed concrete comprises a steel liner in the intrados. The internal structures of the reactor building rest on the foundations of the steel liner without being fixed on the metal liner.

The internal containment is sized to withstand during 60 years:

- To an accident of severe Accident type to P_d = 0.40 MPa relative related to a temperature that plasticises the liner;
- To a containment test to 1.15 P_d = 0.46 MPa relative.

Prestressing is determined to balance accident pressure or test pressure (including liner thrust) so as not to create concrete traction in standard areas.

For non-standard areas where there is normal tensile stress, the reinforcement equilibrates this normal force by limiting traction in the steel (reinforcement bars and prestress tendons) to 186 MPa. In case of greased sheated strands (TGG), the participation of the prestress tendons is not taken into account. In case of cement grouted strands, the participation of the prestress tensons is 40 % (40 % of the prestress section is taken as rebar).

The containment is prestressed by horizontal tendons in two layers and inverted U tendons (one layer in the vertical part and 2 layers in the dome). The containment has 2 vertical ribs diametrically implanted at 120 ° and 300 °. The horizontal tendons make a full turn of the containment. The ribs and the horizontal tendons are extended into the dome up to approximately halfway. The four groups of tendons are described in the following table.

Group name	Description
Horizontal tendons group 1	Horizontal tendons anchored in buttress at 120°
Horizontal tendons group 2	Horizontal tendons anchored in buttress at 300°
Vertical tendons group 1	Vertical tendons in direction of 30°
Vertical tendons group 2	Vertical tendons in direction of 120°

Two solutions are studied:

- One solution with cement grouted tendons
- One other solution with greased sheated tendons (TGG)

Characteristics of materials used:

Concrete:

- f_{ck} = 37,5 MPa
- E_c = 29 000 MPa
- ν_c = 0.20
- α_c = 10 10^{-6} /°C
- ρ_c = 2500 kg/m^3

Deferred strains calculations are made using EN 1992-2 laws, taking account of the bi-axial character of prestressing (according to ETC-C) without corrective coefficients.

These values are estimated assuming ambient humidity of RH = 50%.

Passive steel:

- f_{yk} = 390 MPa and ε_{uk} = 5 %
- Ec = 200 000 MPa
- The extrados reinforcement comprises 40cm²/m per direction.
- The intrados reinforcement comprises 25cm²/m per direction.
- Stirrup section of 10cm²/m².
- Covering is 50mm on the stirrup head.

Metal liner:

- in 6mm-thick P265GH type black steel
- Equivalent sheet and angle thickness:
  - Cylinder : 7mm
  - Dome: 9mm
  - $f_{l,ymin}$ = 255 MPa
  - $f_{l,ymoy}$ = 320 MPa (average value of elastic limit of liner)
  - E_l = 210 000 MPa
  - ν_l = 0.28
  - α_l = 12 10^{-6} /°C
  - ρ_l = 7850 kg/m^3

The horizontal angles that stiffen the cylinder are 120mm wide. The angles in the dome are 200mm wide.

Prestressed steel:

T 15 strands (15.7mm in diameter) class 1860 MPa TBR

Each tendon comprises 55 strands.

• Nominal section of a strand:	150mm^2
• Guaranteed strength load per strand:	279 kN
• Guaranteed Ultimate Strength f_{pk}:	1860 MPa
• Yield Stress:	1653 MPa
• Slip anchorage:	8 mm
• Young's modulus:	190 000 MPa
• Relaxation coefficient ρ_{1000}	2,5 %

The tendons are tensioned from the 2 extremities at 0.8 f_{pk}.

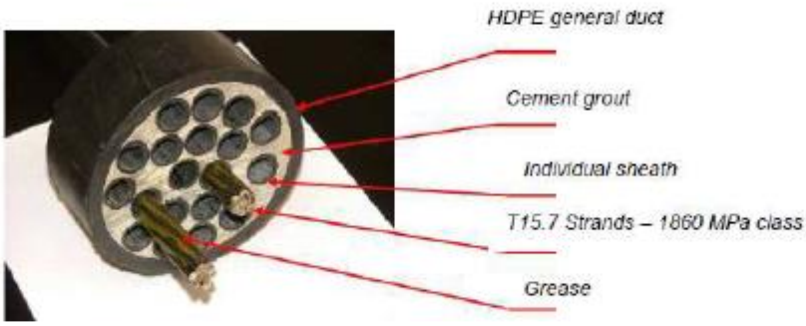
For the solution with cement grouted tendons:

Figure 0.2 Bonded tendons (grouted with cementitious grout)

- Ducts diameter: ϕ_P = 165 mm
- Friction coefficient on curve (μ): μ = 0.18 rd^{-1}(horizontal cables)
  μ = 0.16 rd^{-1}(vertical cables and dome)
- Loss coefficient due to local angular deviations in duct (k)
  k = 0.009 m^{-1} (horizontal cables and dome)
  k = 0.005 m^{-1}(vertical cables)

For the solution with greased sheated tendons (TGG)

Figure 0.5 Section view of a GSS tendon - Example of a tendon 19T15, 7



- Ducts diameter: ϕ_P = 200 mm
- Friction coefficient on curve (μ): μ = 0.05 rd^{-1}(all cables)
- Loss coefficient due to local angular deviations in duct (k)
  k = 0.012 m^{-1} (all cables)

Prestressing is assumed to be done:

- 1 year after concreting in the cylindrical section;
- 1 month after concreting in the dome.

WORK REQUESTED IN THE SCOPE OF THE PROJECT:

<u>"Design" deliverable</u>

1. Carry out a preliminary sizing of horizontal prestressing of the containment and the prestressing at the dome centre, for a lifespan of 60 years. (It will be assumed that the tendons number determined in the dome centre with inverted U tendons equilibrates the LOCA situation + earthquakes in the lower section of the containment. The verification of the quantities of vertical tendons due to LOCA+Earthquake is not required).
2. Define each type of tendon (horizontal and vertical tendons) and their spacing.
3. Create a simplified meshing of the embedded base containment making provisions for only one penetration (7.42 m diameter equipment hatch located halfway up the cylinder and between 2 ribs at 210 °) and taking the metal liner into account
4. Create a meshing of prestressed tendons.
5. Calculate the stress on EFs in linear elasticity in a test situation at end of life, taking the following into account:
    a) Actual weight
    b) Prestressing (to simulate prestressing it will be assumed that cables are stretched in 4 phases, in the following order:
        - 1 out of 2 vertical cables
        - 1 out of 2 horizontal cables
        - 1 out of 2 vertical cables
        - 1 out of 2 horizontal cables
    c) Creep and shrinkage in the form of deformations applied to the concrete
    d) Test pressure
    e) Pressure exerted by metal liner assuming it have an elastic behaviour.
6. Determine areas of the containment where normal membrane forces is traction in test situation – for example, using isovalue charts of normal stress and showing their progression at 40 years, 50 years and 60 years.
7. Determine any additional reinforcement in areas of traction by applying ETC-C criteria.
8. Determine the ultimate pressure in current area with the guaranteed properties of the materials.

9. The scope is to compare the two designs, with cement grouted tendons and with greased sheated strands: quantities of tendons, quantities of rebar and ultimate pressure.

<u>Transient Dynamic Deliverable</u>

Group 3: The group will have to calculate the effects of a shock wave due to an accidental blast. The considered structure will be the exhaust chimney. The data will be provided to the students during the application sessions by using the FEM code LS-Dyna.

Group 4: The group will have to calculate the effects of an aircraft crash onto the nuclear containment. The data will be provided to the students during the application sessions by using the FEM code LS-Dyna.

<u>Constructability Deliverable</u>

This part will be dealt directly with the support of J. Amiot during the dedicated sessions.