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1D vs 3D modelling of the tendons in a Representative Structural Volume of a concrete containment building

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ABSTRACT

In high-power French nuclear power plants (1300 and 1450 MWe), the concrete containment vessel represents the third passive barrier. Integrity tests, consisting in an internal pressure inside the structure, are carried out every ten years to verify its air leak tightness. As the gas transfer through concrete is directly influenced by its mechanical degradation, and as experiments can be hardly carried out because of the difficult environmental conditions, numerical studies remain a convenient way to understand the degradation process.

Containment buildings are steel bar reinforced and prestressed concrete structures. To ease the meshing process, tendons are generally modelled using truss elements, associated with fictitious sections corresponding to the real in site ones. The aim of this contribution is to evaluate the influence of this modelling choice on the global (maximum admissible pressure) and local (distributions of the damage) finite element results. As the dimensions of the containment buildings are very large and would require a too expensive computational effort if a sufficient level of details was required, a Representative Structural Volume is defined. It contains concrete, passive steel bars and pretensioned cables with acceptable dimensions to ease computations (1.2 x 1.8 x 2 m^3). The mesh discretisation is fine enough to allow comparisons between two modelling approaches where tendons are either represented by truss elements (bars), or 3d solid element. In the latest, each tendon is modelled with an exact meshing of the cables as shown in figure 1. The applied loading consists in the prestressing of hoop tendons, followed by an internal pressure over the inner surface of the containment vessel model.

Different simulations are performed, using the finite element code Cast3M [1], in order to evaluate the influence of the modelling choice: influence of the mesh (coarse, normal and fine meshes) using a local softening damage law for concrete [2] (figure 2), influence of the modelling of the tendons (1d vs 3d) (figure 2), influence of the regularization techniques (local vs non local law), and finally influence of the boundary conditions (non uniform vs uniform displacement on the top face) (figure 3).

These results clearly show the role of the mesh for the local responses, with a higher

dependency with the 1d modelling of the tendons. It also provides the differences in the damage distributions between the simulations using 1d and 3d tendons, with in some cases, a different damage initiation, with distinct growth patterns. With a 3d meshing of the cables, an effective heterogeneity is included in the model, with consequences depending on boundary conditions (less significant with a non uniform displacement of the top face, figure 3). The 1D approach fails to reproduce this effect as the geometrical heterogeneity is absent. Finally, the non local computations provide the opportunity to investigate the key role played by the characteristic length.

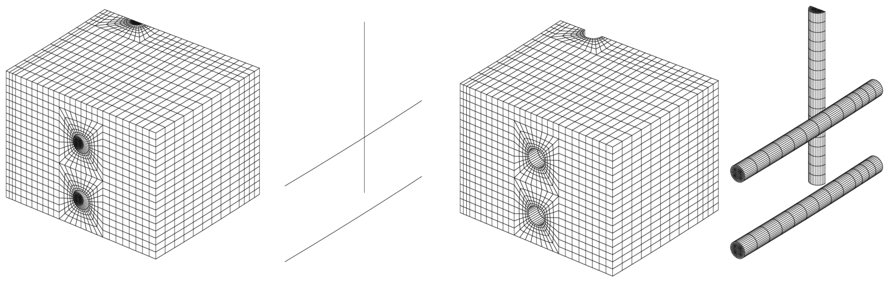

Figure 1. Different modelling techniques for the prestressing tendons.

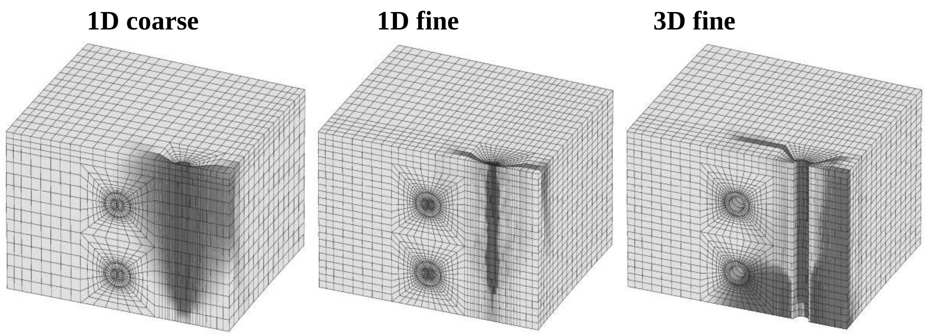

Figure 2. Influence of the mesh and influence of the tendon modelling on the concrete damage (dark areas represent strong damage).

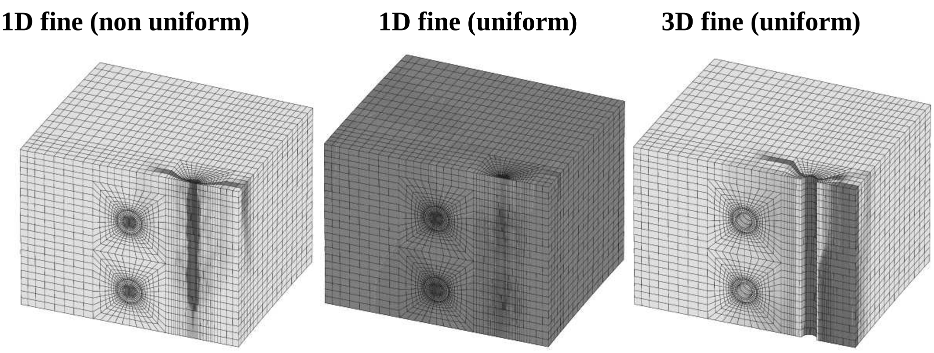

Figure 3. Influence of the boundary conditions with non uniform or uniform displacement on the top face and influence of the tendon modelling (dark areas represent strong damage)

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