SOGIN
We protect the present
We guarantee the future
COMSOL CONFERENCE 2016 MUNICH

Numerical Analysis And Experimental Verification of a Fire Resistant Overpack for Nuclear Waste

P. Geraldini[1], A.Lorenzo[2] - Sogin S.p.A., Waste Management and Decommissioning- Via Marsala 51C, 00185, Rome – ITALY - geraldini@sogin.it[1], lorenzo@sogin.it[2]

INTRODUCTION: For facilities containing radioactive materials, DOE Standard states at least structure's fire resistance for a two hours fire exposure. The aim of this study was to design a Fiber Reinforced Concrete (FRC) overpack that assure thermal insulation and structural integrity of the containement, limiting the release in environment in case of fire event. A standard curve (UNI EN 1363-1:2012) was used to describe the 2-hours fire event and a numerical simulation has been carried out. A thermo-elastic analysis was performed using the thermal field computed in the previous study as input, to evaluate the stress field induced in the concrete. Two prototypes were tested in a certified laboratory to confirm thermal numerical results.

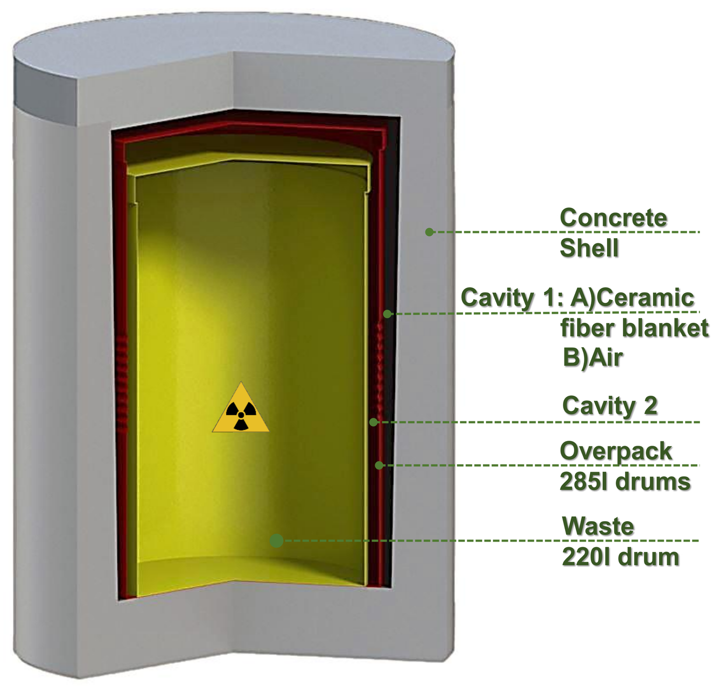

Figure 1. Waste Confinement system

Figure 2. Experimental set up

COMPUTATIONAL METHODS: The numerical analysis is performed with Comsol Multiphysics 5.2a modules in the following steps: 1)Heat Transfer transient study (single-phase compressible flow); 2) Stationary Structural Mechanical study.

Two thermal cases have been studied: CASE A (fiber ceramic blanket in the cavity 1) and CASE B (air in the cavity 1). The fluid flow is computed in both cases with turbolent Low Reynolds k-ε closure model (integration up to the wall).

$$\frac{\partial\rho}{\partial t}+\nabla\cdot(\rho\boldsymbol{u})=0 \qquad q=\varepsilon\cdot(G-\sigma\cdot T^4)$$

$$\frac{D\rho\boldsymbol{u}}{Dt}=-\nabla p+\nabla\cdot\boldsymbol{\tau}-\frac{2}{3}\mu\cdot\nabla\cdot\boldsymbol{u})I+\rho\boldsymbol{g} \qquad \nabla\cdot S+F_v=0$$

$$\rho C_p\left(\frac{\partial T}{\partial t}+(\boldsymbol{u}\cdot\nabla)T\right)=\nabla\cdot(k\nabla T)+\boldsymbol{Q} \qquad \varepsilon_{th}=\alpha\cdot(T-T_{ref})$$

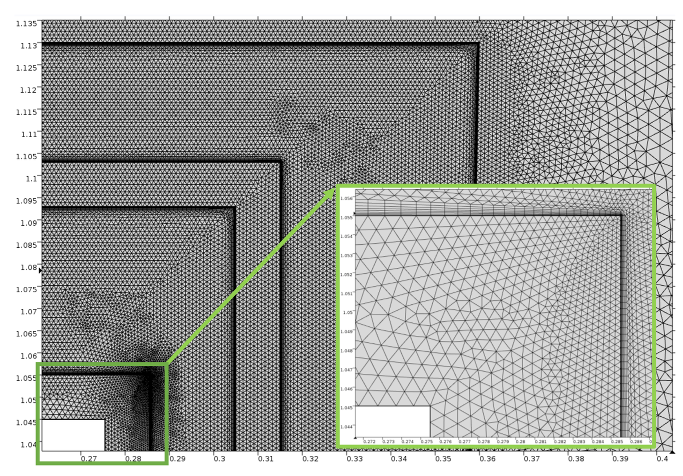

Figure 3. Particular of mesh

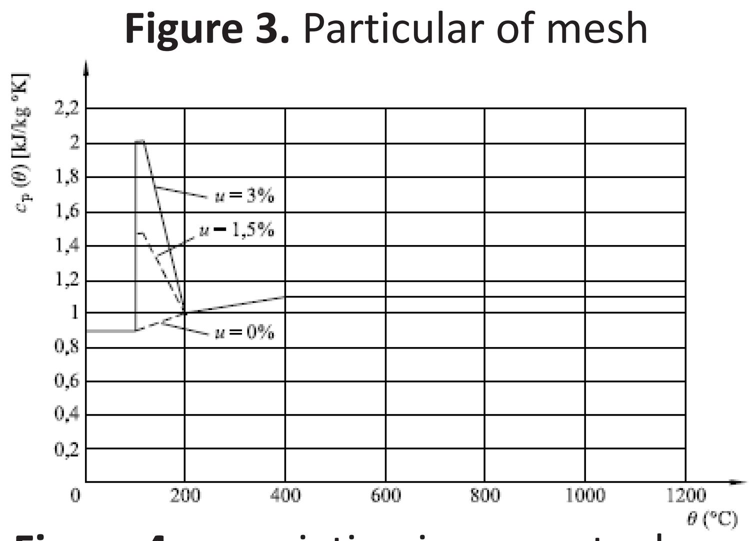

Figure 4. c_p variation in concrete depending on temperature (UNI EN 1992-1-2:2005)

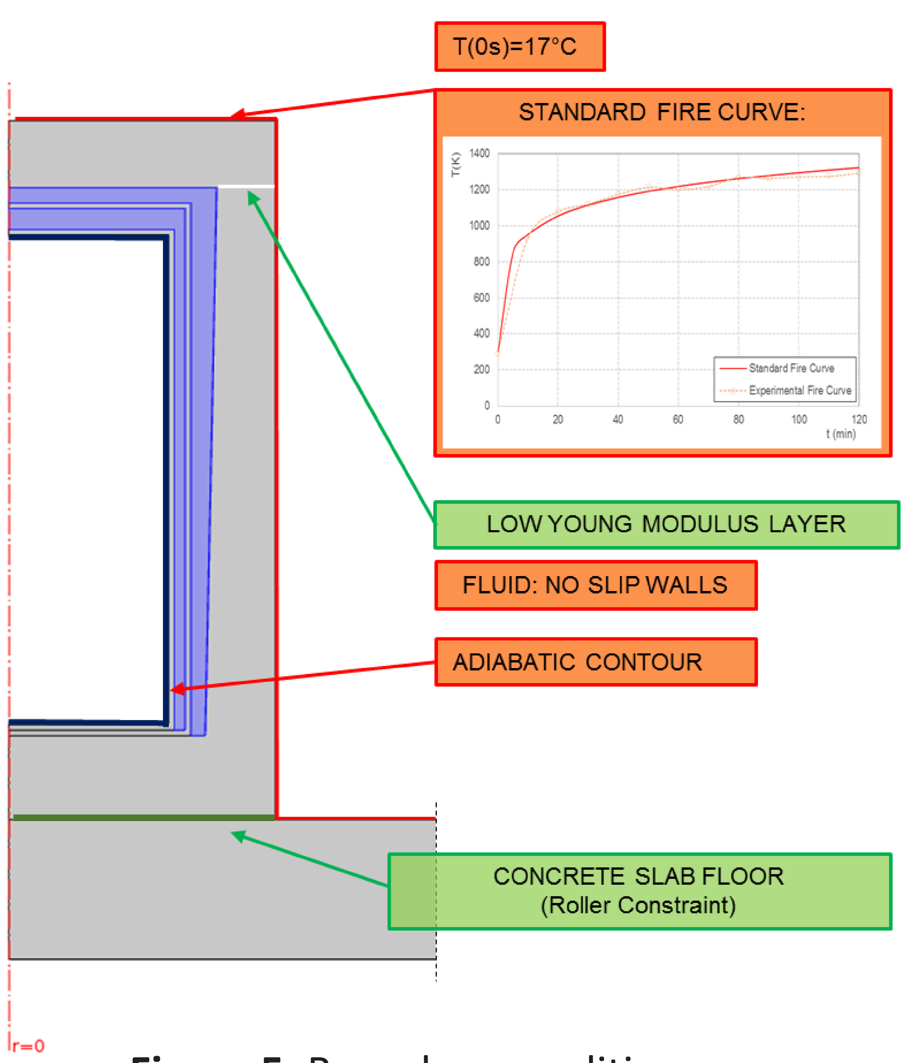

Figure 5. Boundary conditions

RESULTS: Figures below show the comparison between numerical results and experimental data. Figures 6 and 7 show the variation of temperatures on the cutline at z=850mm (left side).

Figures 6 (Case A) and 7 (Case B) show the difference between the average of numerical results and experimental data at 120 minutes (right side). The differences are less than 10%.

In Figure 8, the streamlines colored by the velocity magnitude are shown. The maximum calculated velocity is 0.45m/s in cavity 1. Both the cases satisfy the requirements. In Figure 9, thermal stresses and displacement field are shown for t=120min. Tensile stresses are distributed on the inner surface walls and reach maximum values near to the bottom. Steel reinforcement bars have been designed taking into account the distribution of thermal stresses and steel temperature.

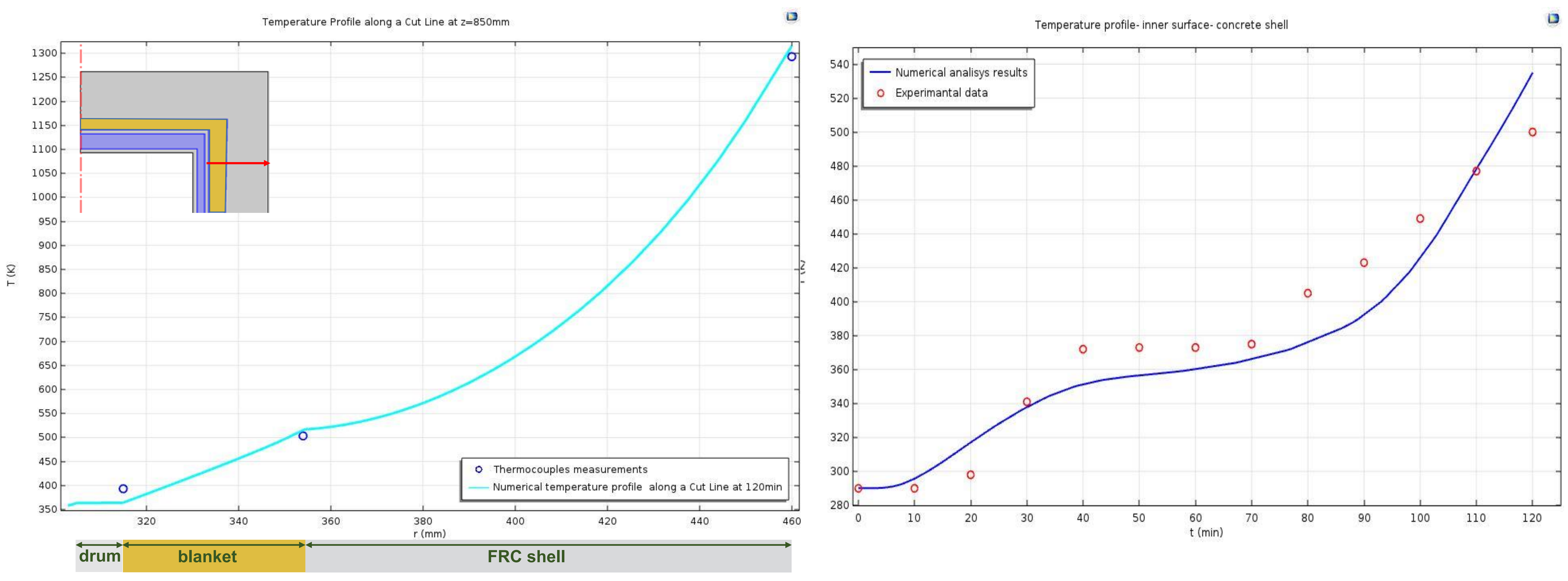

Figure 6. CASE A: Comparison between numerical results and experimental data

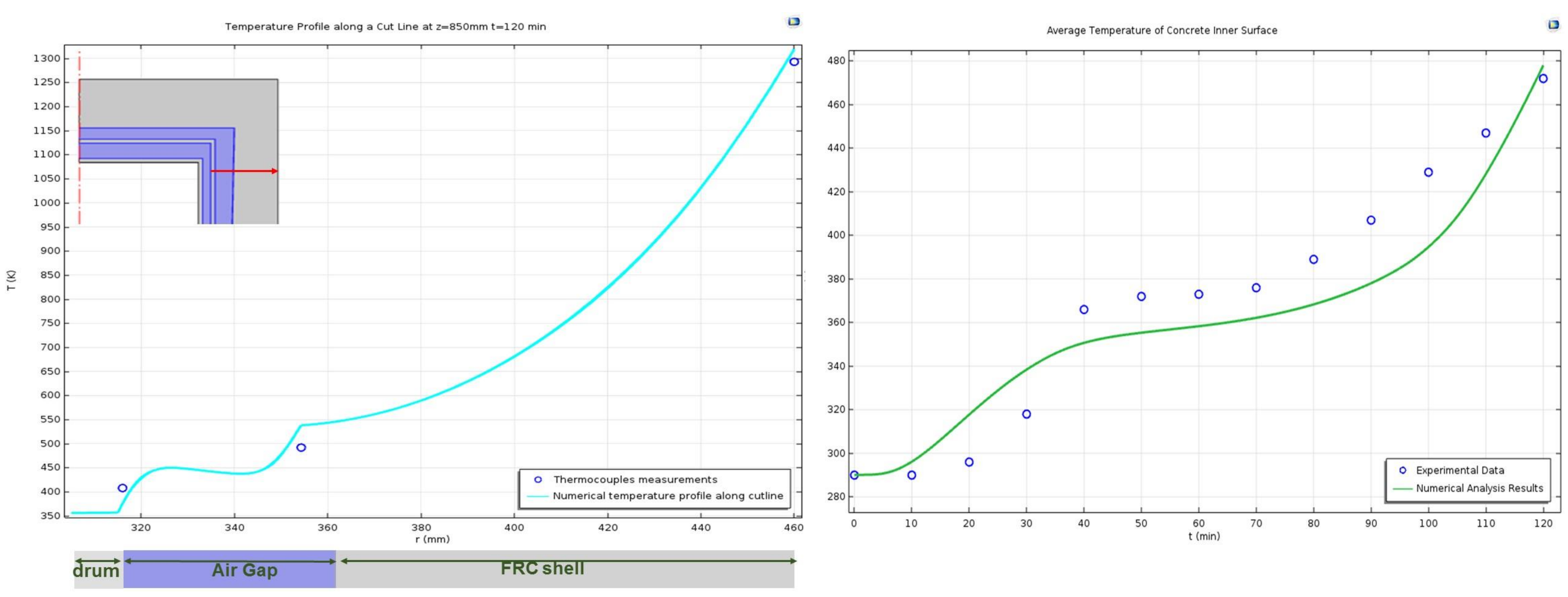

Figure 7. CASE B: Comparison between numerical results and experimental data

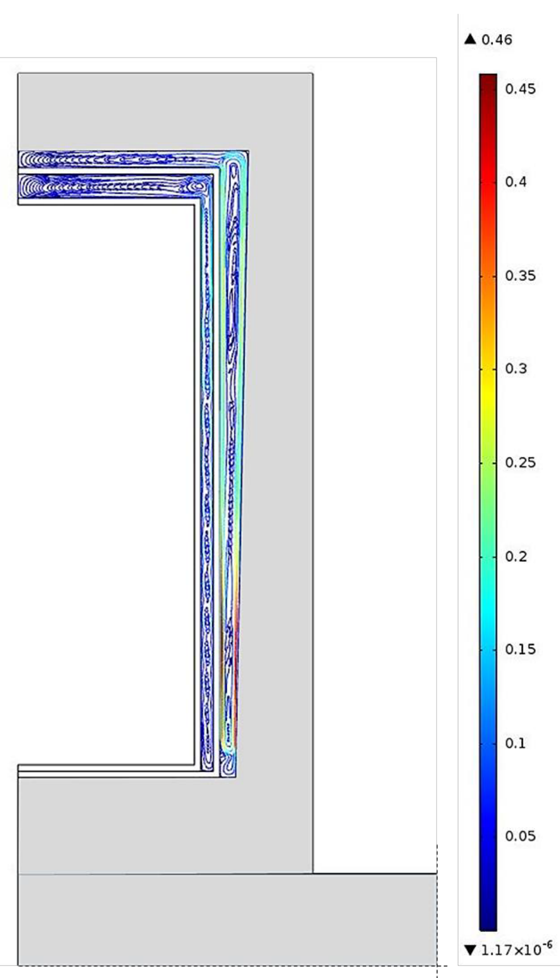

Figure 8. CONFIGURATION B Fluid velocity field (m/s)

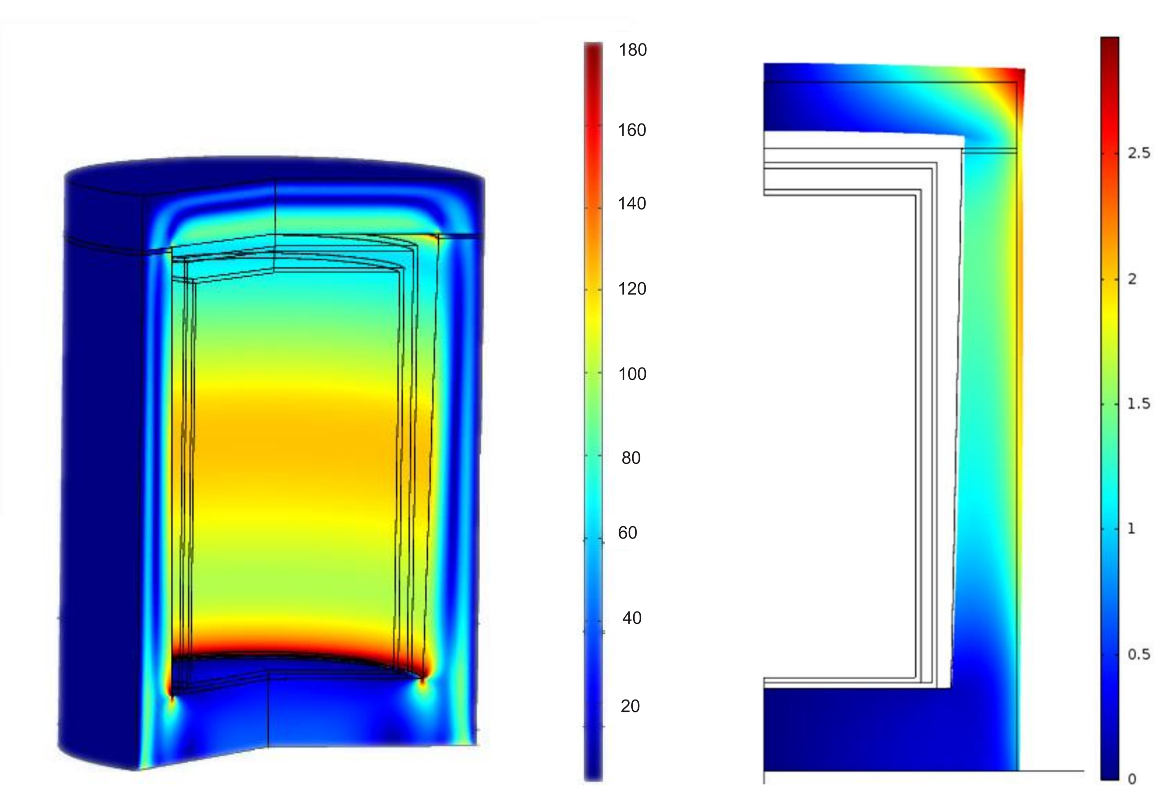

Figure 9. Thermal stress (MPa) and displacement field(mm)

CONCLUSIONS: The comparison between numerical results and experimental data shows a good match and confirms the capability of COMSOL Multiphysics® as a multiphysics simulation tool. The development of this work enabled us to optimize the design of fire resistant overpack.