Andra Call for Projects
with the support of the
Investments for the Future Programme

UCOMP

Ultra-fluid cementitious composite for the disposal of radioactive waste subject to fire hazard

Project supported by Andra under the "Investments for the Future Programme" ("Investissement d'Avenir") - Selected under the Andra Call for Projects: "Optimisation of post-dismantling radioactive waste management", organised in cooperation with the French National Research Agency (ANR).

Duration: 42 months

Project launch: 02/2017

Total project cost: €1.52 million

Sum covered under the Investments for the Future Programme: €540,000

Type of financial support: Subsidy with ROI guarantees for the State

Locations: Anglet, Épernon, Champs-sur-Marne

Coordinator: University of Pau and Pays de l'Adour (UPPA)

Partners:

- Centre d'Études et de Recherche de l'Industrie du Béton (CERIB)
- Centre Scientifique et Technique du Bâtiment (CSTB)
- Institut Français des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux (IFSTTAR)

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BACKGROUND

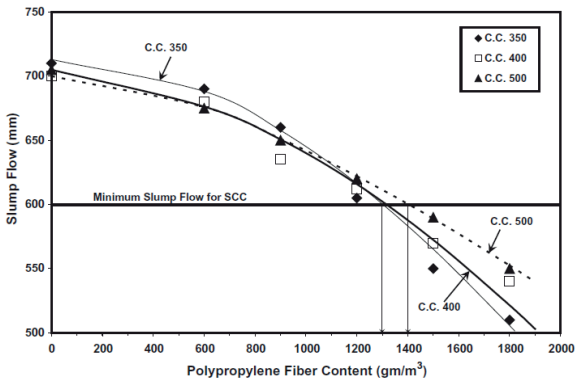
To dispose of long-lived intermediate-level radioactive waste, reinforced concrete containers will be used. They mainly have a mechanical function for structural resistance during transport and to stack packages. They also contribute to limit the transport of radionuclides outside the disposal facility (low transfer properties and retention of certain radioactive elements due to the chemical properties of concretes). For the Cigeo project (disposal of the most highly radioactive waste 500 metres underground), it is necessary to consider a fire scenario at the end of which the containers must keep their function. However, such thermal loading can induce very large cracks on concrete, instability phenomena (explosion, chipping, etc.) that is highly detrimental to mechanical strength if the concrete formulation is not appropriate. It is therefore necessary to develop specific concretes capable of maintaining mechanical strength after a fire.

OBJECTIVES

The goal of the UCOMP project is to design cementitious materials capable of withstanding very high temperatures (fire scenario) to be used in the manufacture of radioactive waste containers.

The project proposes to use a cementitious material composite, i.e., polypropylene fibres. Concretes containing organic fibres are already known and used for tunnel construction because of their fire resistance. As the temperature increases, the fibres melt and a porous network appears in addition to the initial porosity. This porous network enables evacuation of the water vapour contained in the concrete which, when confined, applies pressure that can cause damage to the structure. The UCOMP project thus proposes to transpose the developments already achieved in the field of civil engineering to radioactive waste conditioning. In particular, the challenge is to develop a concrete that maintains sufficient fluidity to ensure quality implementation.

Fire tested concrete blocks: left, plain concrete and right, polypropylene fibre reinforced concrete (Shuttleworth, 2001)[1]



Evolution of flow as a function of proportion of polypropylene fibre (El-Dieb, 2012)[2]

1. Shuttleworth, P. (2001). "Fire protection of precast concrete tunnel linings on the Channel Tunnel Rail Link." Concrete 35 : 4, pp. 12-22

2. A.S. El-Dieb and M.M. Reda Taha, "Flow characteristics and acceptance criteria of fiber-reinforced self-compacted concrete (FR-SCC)", Construction and Building Materials 27 (2012) 585–596

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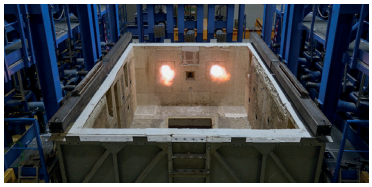
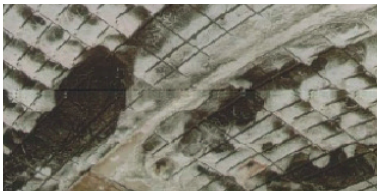
CSTB Vulcain furnace (13.5 MW vertical furnace for testing elements that are 3 metres wide and up to 9 metres high with the possible application of mechanical loading)



CERIB Promethee furnace (16 MW horizontal furnace for testing elements up to 6 x 4 metres)

ILW-LL disposal container



Scaled concrete after exposure to fire in the Channel Tunnel in 1996 (reinforcement visible after destruction of concrete)

Polypropylene fibres

For this purpose, the UCOMP project proposes to study the cementitious matrices composites in an original way by adopting a comprehensive approach including rheological, mechanical and thermal aspects. Since fire resistance and fluidity act in opposite directions with the addition of organic fibres (the more organic fibres are added, the better the fire resistance while the fluidity of the material decreases) (see figures on the first page), the specific goal of the project is to identify the parameters to optimise these two properties.

PROJECT SEQUENCE

The project will run for 42 months and will test materials ranging from laboratory scale to actual size.

The first part of the project will focus on laboratory studies in order to formulate concretes optimised for both their fluidity when they are fresh and their behaviour at high temperatures. The second part of the study will test small slabs with a surface of one square meter and a thickness of 15 cm on a medium scale. Lastly, two full-scale fire tests will be carried out on samples with geometry similar to the disposal containers.

EXPECTED RESULTS

Innovation

The goal of this project is to develop knowledge on concrete containing polypropylene fibres, and more specifically their rheological behaviour in the fresh state as well as their behaviour at high temperatures. Experiments at microscopic scale (tomography, SEM observation, rheometer tests, etc.) will allow to show and understand the predominant phenomena. Combined with numerical simulations, the results of the experiments will permit development of a methodology to optimise the concrete compositions. Innovation in this work is linked to the combined study of the rheology of fresh concrete and its behaviour at high temperatures on the one hand, and to the combination of experiments and numerical simulations on the other.

Beyond this contribution to the knowledge of phenomena, the UCOMP project will make it possible to develop an innovative formulation for fire-resistant cementitious material that is easy to use, even for complex shapes.

Economic impact

In addition to their fire resistance, the materials developed in UCOMP will have good workability, and should reduce costs compared to existing materials. Indeed, low concrete fluidity implies a concrete admixture (superplasticizers) or a higher processing energy (more labour), both sources of additional cost.

Impact on radioactive waste management

In the context of radioactive waste management, the project will contribute to the improvement of facility safety. The fire hazard identified for radioactive waste disposal must be taken into account in container design. The concretes developed in this project will meet this constraint, thus contributing to the safety conditions necessary for Cigeo's operation.

Application and commercialisation

Beyond the use for radioactive waste disposal, the development of these concretes will be useful both for infrastructures (tunnels, underground parking garages, etc.) and for buildings. These structures can be exposed to high temperatures during their service life and the use of concrete with organic fibres likely to provide protection against chipping is currently limited because it is more difficult to work with. The use of concretes developed during the UCOMP project will ensure their resistance during a fire and facilitate repair with a view to their reuse since they ensure a good level of resistance after a fire. In addition, the quality of the concrete (mechanical characteristics, durability, quality of cladding, etc.) is directly linked to how well it has been executed. The use of ultra-fluid concrete both facilitates its execution and eliminates the noise pollution related, in particular, to the vibration of the concrete, which is no longer necessary.