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Numerical analysis of the thermal active restrained shrinkage ring test to study the early age behavior of massive concrete structures

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ABSTRACT

Several tests, devoted to the study of cracking due to autogenous and drying shrinkage, exist in the literature. They are generally not relevant for the study of massive structures for which thermal strains plays a key role. Therefore, an active ring test has been developed to study cracking due to restrained thermal shrinkage. This test is an evolution of the restrained shrinkage ring test which allows us to take into account both autogenous and thermal shrinkage. With this test, the early age cracking due to thermal restrained shrinkage (effect of the temperature rate), the influence of reinforcement and construction joints have been studied (Briffaut et al. (2011) [1]).

Nevertheless, in this test, several phenomena occur simultaneously (hydration, shrinkage, creep…) and their effect cannot be easily decoupled. So, complementary tests have been performed to study each phenomenon separately and the ring test has been numerically simulated in order to identify coupling between creep and damage and to quantify the strength decrease due to construction joints. A good agreement between experimental and numerical results has been obtained for ring with reinforcement and construction joints. With the proposed model and the identified materials parameters validated on the active restrained ring test, numerical simulations of the construction of a real massive structure have been performed, and a parametric study has been achieved to highlight the creep effect.

1. Introduction

An active ring test has been developed to study cracking due to restrained thermal shrinkage which is a major concern in massive concrete structures. This new test is an evolution of the restrained shrinkage ring test which allows for taking into account the autogenous shrinkage as well as the thermal shrinkage. With this test, the early age cracking due to thermal restrained shrinkage (effect of the temperature decrease rate), the influence of reinforcement and construction joints (which are representative of nuclear concrete containment construction) have been studied in Briffaut et al. [1].

Nevertheless, in this test and during building operation, many phenomena occur simultaneously (hydration, shrinkage, creep, etc.) and their effect cannot be easily decoupled. Therefore, a numerical analysis of the test should be performed. After the presentation of the model (based on the one proposed by Benboudjema and Torrenti [2]) and the complementary test required to identify materials parameters, the numerical analysis of the restrained ring tests is described. This analysis consists to identify a coupling coefficient between creep and damage, to analyse the stress profile analysis and to study of the construction joints and reinforcement bars effects. All these investigations are undertaken for a concrete representative of French nuclear power plant. Finally, numerical simulations of the construction of a real massive structure will be performed in order to unveil the creep effect.

2. Model: constitutive equations

In order to study the early-age behavior of massive concrete structures by means of finite element calculations, several models have been proposed. Ayotte et al. [3] and Xiang et al. [4] performed a thermo-elastic analysis using time-dependent evolutions of heat release (due to hydration) and material properties. De Borst and van den Boogaard [5], Niu et al. [6] and Meschke [7] also incorporated in their model basic creep and cracking. Aggoun et al. [8], Mazars and Bournazel [9] and Waller et al. [10] used the maturity concept but performed thermo-elastic analyses (without creep). A similar approach, taking into account the creep strains, has been achieved by Hattel and Thorborg [11]. Ulm and Coussy [12] and

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