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SIMULATION OF SELF-COMPACTING CONCRETE FLOW IN J-RING USING SMOOTHED PARTICLE HYDRODYNAMICS

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ABSTRACT

In this study, an incompressible mesh-less smoothed particle hydrodynamics (SPH) methodology has been implemented to simulate the flow of self-compacting concrete (SCC) mixes in the J-ring test. A suitable Bingham constitutive model has been coupled with the Lagrangian momentum and continuity equations to model the flow. The capabilities of the SPH methodology are validated by comparing the simulation results with the actual J-ring tests carried out in the laboratory. The comparison shows that this methodology is efficient to predict precisely the behaviour of SCC in the sense that the simulated mixes meet the passing ability criterion and the shapes and diameters of the flow spread are nearly the same as observed in the laboratory test.

Keywords: *Self-compacting concrete (SCC); Smoothed particle hydrodynamics (SPH); Non-Newtonian fluid; J-ring test; plastic viscosity.*

1. Introduction

With the recent tendency towards the use of computer modelling in concrete technology, its application in self-compacting concrete (SCC) is in demand and increasingly becoming an important issue. In this regard, one of the important approaches offering considerable potential is the smoothed particle hydrodynamics (SPH). It is able to simulate flows that contain particles of different sizes. SPH is a particle-based method (it does not require re-meshing) to represent with an acceptable level of accuracy the rheological behaviour of heterogeneous flow. This method has been examined and proved to be efficient and accurate in modelling the flow of SCC in the cone slump flow and L-box tests [1, 2]. The goal of this paper is to extend its application to simulating the flow of SCC in the J-ring test. This methodology will provide a thorough understanding of whether or not an SCC mix can satisfy the self-compatibility criteria. For this purpose, a series of SCC mixes differing in target plastic viscosity and compressive strength were prepared in the laboratory. These mixes were designed according to the rational mix design method proposed in [3].

2. Numerical modelling

Fresh SCC is a non–Newtonian fluid best described by a Bingham–type constitutive model. From a practical computational perspective, it is expedient to approximate the bi-linear Bingham constitutive model, which has a kink at zero shear strain rate, by a smooth continuous function in which m is a very large number (e.g. $m = 10^5$).

$$\tau = \eta\dot{\gamma} + \tau_y\left(1 - e^{-m\dot{\gamma}}\right) \tag{1}$$

Here, τ, η, $\dot{\gamma}$ and τ_y represent shear stress tensor, mix plastic viscosity, shear strain rate and mix yield stress, respectively. The Bingham constitutive model of the mix is coupled with the Lagrangian continuity equation (Eq.2) and momentum conservation equation (Eq.3) to model the flow of the SCC mix:

$$\frac{1}{\rho}\frac{D\rho}{Dt} + \nabla.\mathbf{v} = 0 \quad , \quad \frac{D\mathbf{v}}{Dt} = -\frac{1}{\rho}\nabla P + \frac{1}{\rho}\nabla.\boldsymbol{\tau} + \mathbf{g} \tag{2), (3}$$

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