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Numerical Simulation of Self-Consolidating Concrete Flow as a Heterogeneous Material in L-Box Set-up: Effect of Rheological Parameters on Flow Performance

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Abstract. A computational fluid dynamics (CFD) software was used to simulate the effect of rheological parameters on the heterogeneous performance properties of self-consolidating concrete (SCC) in the horizontal and vertical directions of the L-Box set-up. These properties consist of flowability, blocking resistance, and dynamic segregation. Different suspending fluids having five plastic viscosity values (10-50 Pa.s), three yield stress values (14-75 Pa), two fluid densities (2000 and 2500 kg/m^3), and two shear elasticity modulus values (100 and 1000 Pa) were considered. The suspensions consisted of a number of 135 in total spherical particles with 20-mm in diameter and 2500 kg/m^3 density.
The results of 25 simulations in total are found to correlate well with the rheological parameters of the suspending fluid. Plastic viscosity of the suspending fluid was shown to be the most dominant parameter affecting flow performance of SCC in the L-Box test. A new approach was also proposed to classify SCC mixtures based on the filling ability properties.

Keywords: *Dynamic Stability; Flowability; L-Box Test; Numerical Simulation; Passing Ability; Self-Consolidating Concrete*

1. Introduction

Dispersion of suspended particles has a significant effect on flow behavior of materials in various domains, including debris flow [1], snow avalanche [2], conventional hydrotransport processes [3-5], and industrial applications [6-8]. On the other hand, separation of coarse particles from the suspending fluid has negative influence on the performance of the suspensions and must be prevented in production processes. Therefore, there is a wide concern to study particle migration in granular flow motion and suspension dynamics transport [9-13]. Segregation of solid particles can be due to the gravitational and shear induced particle migration. Gravitational segregation occurs when there is a gradient in gravitational forces between the coarse particles and the suspending fluid due to a difference of density of the materials [14]. On the other hand, shear-induced segregation is defined as the migration of particles from regions of higher shear rates to the regions of lower shear. This results in a decrease in the suspensions viscosity after a given shearing period even though the viscosity of the homogeneous suspending fluid remains constant under a given shear history applied on the suspension [9, 15-17]. Recently, there is a great interest to study shear-induced migration and gravitational settlement of solid particles suspended in Non-Newtonian suspending fluids [18-21]. Numerical simulation using computational fluid dynamics (CFD) was employed as a powerful tool to study these heterogeneous behaviors of the suspensions [22-25].

Self-consolidating concrete (SCC) has pushed back traditional limits concerning the casting of densely reinforced and complex structural elements in concrete construction [26]. SCC is a suspension of fine and coarse aggregates in a viscoelastoplastic cement paste. SCC is characterized by a relatively high fluidity compared to conventional concrete, which makes it more sensitive to segregation during flow (i.e., dynamic segregation) and thereafter at rest (i.e., static segregation) [27-29]. Static segregation occurs when the concrete is at rest, and aggregate particles can settle down