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SIMULATION OF FRESH CONCRETE FLOW

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ABSTRACT

The modeling of flow of freshly mixed concrete is very important for the construction industry because concrete is usually put into place in its plastic form. In the construction field, subjective terms like workability, flow-ability, and cohesion are used, sometimes interchangeably, to describe the behavior and flow properties of fresh concrete. These factors depend on flow (rheological) properties of concrete, that have direct influence on the strength and durability of concrete. The modeling of fresh concrete flow can significantly contribute to the durability and strength of a structure and it is necessary for design optimization of casting procedure. This contribution addresses the numerical aspects of fresh concrete flow modeling with general, unstructured grids.

The fresh concrete is considered as a fluid. This assumption is valid, when a certain degree of flow can be achieved and when the concrete is homogeneous. This is usually satisfied, because concrete is put in place in its plastic form in majority of industrial applications. It is widely recognized, that concentrated suspensions, such as concrete, typically behave as non-Newtonian fluids. The constitutive equations that have a physical basis should include at least two parameters, one being the yield stress. The Bingham model is considered, with the yield stress and plastic viscosity as parameters.

As the characteristic flow velocity will be very small compared to the speed of sound in the fresh concrete, the fluid will be treated as incompressible. In a case of incompressible flow, the mass and momentum conservation equations, together with the incompressibility condition and constitutive equation form a complete system.

The numerical solution is based on the finite element method and the interface-capturing method to track the position of a free surface. The solution algorithm is based on a stabilized FEM formulation to prevent potential numerical instabilities. The stabilization techniques include streamline-upwind Petrov-Galerkin (SUPG) and pressure-stabilizing Petrov-Galerkin (PSPG) formulations [1,2].

In this paper, the interface-tracking techniques based on level set method, introduced by Osher and Sethian [3], is utilized. The idea is not to track the interface position directly, the interface is defined as a zero level set of a suitable higher-dimensional function (called level set function). For, example, in

two dimensions, the level set method represent given curve in the plane as the zero level set of a two-dimensional auxiliary function. The interface is not manipulated directly, it is manipulated implicitly through the level set function. The advantages of this approach consist in natural handling of topological changes and straight forward generalization into multiple dimensions.

As an alternative, an interface-capturing method, based on Volume-of-Fluid (VOF) has been developed, which introduces another unknown - fluid volume fraction in each grid cell. In principle, if we know the amount of fluid in each cell it is possible to locate surfaces, as well as determine surface slopes and surface curvatures. To compute the evolution of surfaces with time, a technique is needed to move volume fractions through a grid in such a way that the step-function nature of the distribution is retained and overall volume is conserved.

The algorithms were implement in the framework of OOFEM code (open source, finite element solver [4]), which is distributed under GNU Public License. The interface tracking technique is verified using broken dam problem and application of the numerical model is demonstrated on an analysis of several casting problems (slump test, L-box test).

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