Simulation of Formwork Filling by Cement Fluid: the Effect of the Formwork Structure on Yield-stress Fluid

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Introduction: The flow of Self-Consolidating Concrete (SCC), a relatively new type of concrete which does not require any energy for consolidation, in formworks was simulated. Limiting values for the rheological properties of concrete, for which the occurrence of construction defects (dead zone) is likely, were investigated in relation to the formwork configuration [1].

Computational Methods: The SCC flow was simulated as a single phase incompressible yield-stress fluid in a laminar flow regime. The expression for the viscosity, μ, is given by Bingham model with a numerical correction factor, ε, to prevent zero shear rate [2].

$$\mu = \mu_p + \tau_y/(\gamma' + \varepsilon)$$

(μ_p : plastic viscosity, τ_y yield stress, and γ' : shear rate)

Formworks with four different configurations were simulated with varying the rheological properties of the SCC flows.

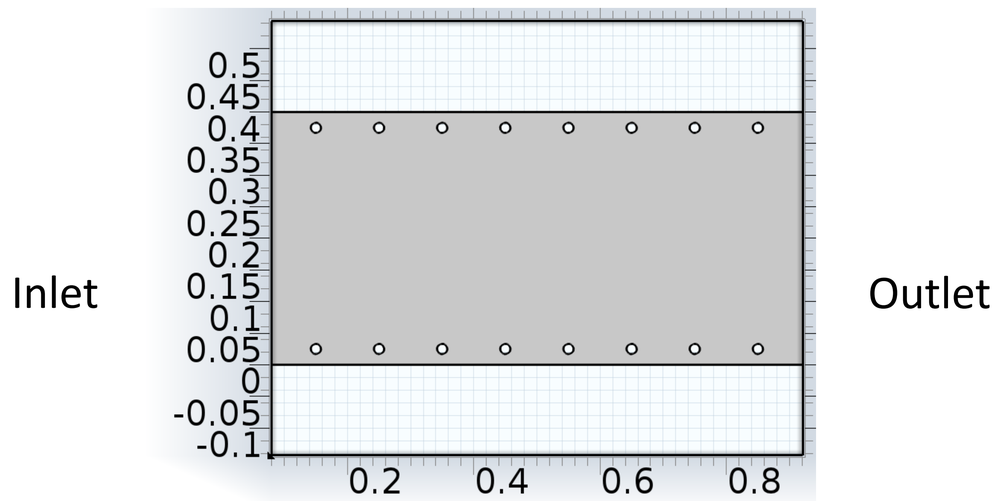

Figure 1. Geometry of Formwork

Case	d_w (m)	d_p(m)	Description
A1	0.025	0.1	Small d_w
A2	0.05	0.1	Largel d_w
B1	0.0375	0.05	Small d_p
B2	0.0375	0.025	Large d_p

Table 1. Formwork Configurations

μ_p(Pa·s)	τ_y (Pa)	μ_p(Pa·s)	τ_y (Pa)
100	2	60	21
90	5	50	30
80	9	40	40
70	14	30	52

Table 2. Properties of SCC [3]

Results: For each configuration, a set of minimum μ_p and maximum τ_y, which gives no dead zone (unyielded zone in low velocity regions) were found and the pressure drop was evaluated.

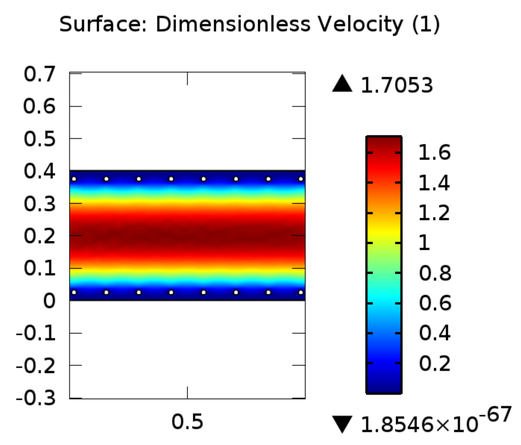

Figure 2. Velocity map from Case A1 with μ_p = 100 Pa·s and τ_p = 2 Pa

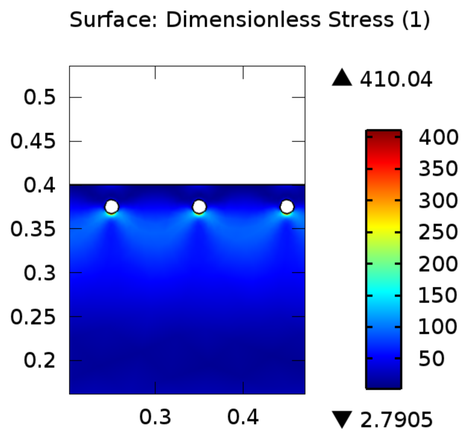

Figure 3. Stress map from Case A1 with μ_p = 100 Pa·s and τ_p = 2 Pa

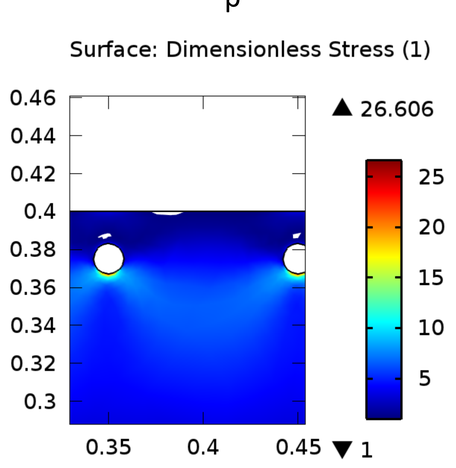

Figure 4. Stress map from Case A1 with μ_p = 60 Pa·s and τ_p = 21 Pa

Case	μ_p(Pa·s)	τ_y (Pa)	$\%\Delta P/\Delta P_{100}$
A1	70	14	81%
A2	60	21	73%
B1	90	5	92%
B2	50	30	76%

Table 3. Optimized Properties

Conclusions: With increasing d_w or d_p, the combination of lower μ_p and higher τ_p can be used to obtain adequate SCC flow in the formwork, Furthermore, this results in a reduction of the energy needed for the placement of concrete.

References:

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2. Denn M.M., Bonn D., "Issues in the flow of yield-stress liquids," *Rheol. Acta*, **50**, 307-315 (2011).
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