Field Measurements of Form Pressure Exerted by Self-Consolidating Concrete

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Comparison of Various Approaches to the Prediction of Formwork Pressure of SCC

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RILEM TC 233-FPC
"Form Pressure Generated by Fresh Concrete"
Committee started 2009 and chaired by P. Billberg and N. Roussel. 30 members

Deliverables:
✓ Committee report, state-of-the-art
✓ Evaluation of existing form pressure models
✓ Workshop
Work concluded at latest in 2015

Prediction Models Developed by
- Ovarlez/Roussel, France
- Perrot et al
- Proske (2 models)
- DIN 18218:2010-01 (2 models)
- Beitzel
- Khayat/Omran
- Gardner et al
- Lange/Tejeda-Dominguez

Key Parameters for the Models

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure decay curve</td>
<td>$P_s = \frac{\rho R}{\sqrt{\alpha t^2 + 1}}$</td>
</tr>
<tr>
<td>Undisturbed slump loss</td>
<td>$P_s = wR\left(t_s - \frac{t^2}{2t_s}\right)$</td>
</tr>
<tr>
<td>Structural build-up</td>
<td>$SBU = t_s(t)$</td>
</tr>
<tr>
<td>Setting time</td>
<td>$t_s$</td>
</tr>
</tbody>
</table>

Σ = 10 models
Test Area – CBI:s Backyard

- 2 walls per day
- 4 days in a row

Variables:
- proportioning
- casting rate
- wall geometry

Approximately 300 m²

Pressure Measurement

Concrete Fresh Properties

Stable SCC with slump-flow 600-700 mm (24-28”)

Adjusting Flowability

Characterization of Concrete
Relative Pressure vs. Casting Rate

Khayat/Omran

Structural build-up (lab tests)

y = 1.16x  
R² = 0.79

Ovarlez/Roussel

Structural build-up (analytical)

y = 1.22x  
R² = 0.77

Perrot et al

Structural build-up (incl. rebars)

y = 1.20x  
R² = 0.81

Lange/Tejeda-Dominguez

Pressure decay curve

y = 1.09x  
R² = 0.80

Gardner et al

Undisturbed slump loss

y = 1.30x  
R² = 0.86
Summary of Regressions

<table>
<thead>
<tr>
<th>Model by</th>
<th>Slope</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khayat/Omran</td>
<td>1.16</td>
<td>0.78</td>
</tr>
<tr>
<td>Ovarlez/Roussel</td>
<td>1.22</td>
<td>0.77</td>
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</tr>
<tr>
<td>Beitzel</td>
<td>1.23</td>
<td>0.82</td>
</tr>
<tr>
<td>Proske mean</td>
<td>1.23</td>
<td>0.69</td>
</tr>
<tr>
<td>Proske design</td>
<td>1.40</td>
<td>0.85</td>
</tr>
<tr>
<td>DIN 18218 mean</td>
<td>1.37</td>
<td>0.85</td>
</tr>
<tr>
<td>DIN 18218 design</td>
<td>1.42</td>
<td>0.85</td>
</tr>
</tbody>
</table>
Conclusions (1/2)

- Knowing the casting height, form geometry, concrete density and casting rate is not enough in order to calculate the form pressure. Concrete properties at rest must be accounted for. However, NOT the recipe or fresh properties such as slump-flow or T_{500}!
- All evaluated models are based on key parameters relating to the concrete behavior at rest (structural build-up, pressure decay, setting time or undisturbed slump-loss)

Conclusions (2/2)

- The models are all satisfactory in that they are conservative with good precision (R^2 = 0.69-0.86). None can be singled out as best and none can be excluded. Choice of model should be based on how to capture the key parameter in the easiest and most reliable (accurate) way.
- More field studies are needed in order to statistically define the reliability and confidence of the model chosen.

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