Overview of ACI 238.1 R-08

Report on Measurements of Workability and Rheology of Fresh Concrete

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Importance

- Fresh concrete properties are related to the properties of hardened concrete.
- Poor placement or consolidation leads to problems of durability and placement.
- Fresh concrete properties are not always properly measured or predicted.
Workability

that property of freshly mixed concrete or mortar that determines the ease with which it can be mixed, placed, consolidated, and finished to a homogenous condition.
### Classes of workability measurement

*(Tattersall 1991)*

<table>
<thead>
<tr>
<th>Class I qualitative</th>
<th>To be used only in a general descriptive way without any attempt to quantify</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workability, flowability, compactability, finishability, pumpability, etc.</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Class II quantitative empirical</th>
<th>To be used as a simple quantitative statement of behavior in a particular set of circumstances</th>
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<tbody>
<tr>
<td>slump, compacting factor, Vebe time, flow table spread, etc.</td>
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</table>

<table>
<thead>
<tr>
<th>Class III quantitative fundamental</th>
<th>To be used strictly in conformity with standard definitions</th>
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<tbody>
<tr>
<td>viscosity, mobility, fluidity, yield value, etc.</td>
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</table>
Report ACI 238: Main Goal

- **How to select** the proper test for the application at hand?
- **How to interpret** the results obtained to predict the performance of the concrete in the field in the fresh state?
Workable concrete

- no flow (zero-slump)
- flow like a liquid (self-consolidating concrete [SCC])
- Anything in between

It depends on the application!!
Example of applications

- Use of gyratory tester to measure workability of no-slump concrete
- Using rheological measurements to solve problem with flooring grouts
- Measuring batch-to-batch consistency of self-consolidating concrete
- Troubleshooting self-consolidating concrete mixtures
**Workability**

- Slump
- Slump flow
- Stability static
- Filling capacity
- Passing ability

**Rheology**

- Viscosity
- Yield stress

Diagram:
- Torque
- Gap
- Radius R
- Radius R1
Definitions

Some concepts
Bingham Model

\[ \tau = \tau_0 + \mu \dot{\gamma} \]

Shear Stress

Yield Stress

Shear rate

Plastic Viscosity

Yield stress

Stress

Shear strain rate

Plastic Viscosity
Bingham model concept

Yield stress = Slump

Same Yield Stress
BUT
Different Plastic Viscosity

Same Plastic Viscosity
BUT
Different Yield Stress

Stress

Shear strain rate

Stress

Shear strain rate

Plastic Viscosity
Flow Curves

Shear stress vs. Shear rate graph showing:
- Newtonian flow
- Herschel-Buckley flow
- Bingham flow
- Dilatant/shear thickening
- Pseudoplastic/shear thinning
Viscosity definition

\[ \eta_{ni} = \frac{\tau_i}{\dot{\gamma}_i} \]
Non-Newtonian Viscosity

\[ \eta_{ni} = \frac{\tau_i}{\dot{\gamma}_i} \]

Yield stress

A critical shear stress value below which an ideal plastic or viscoplastic material behaves like a solid (that is, will not flow).

Once the yield stress is exceeded, a plastic material yields (deforms plastically), while a viscoplastic material flows like a liquid.

A=Yield stress
B= related to viscosity
Yield stress is between A & B. B is taken as the yield stress as it is easily determined.

A = Yield stress
B = related to viscosity
Segregation

- Bleeding
- Segregation
- Separation
- Stability
  - stability, dynamic
  - stability, static
Segregation - Rheology

Yield stress and viscosity

Yield stress > Weight of aggregate
Aggregate stable

Yield stress < weight of aggregate
Sedimentation
Depends on viscosity how fast the aggregate will settle
Consolidation
From SCC to no-slump concrete

**SCC:**
- low yield stress
  - Flow on its own weight
- high viscosity
  - Cohesion, avoid segregation

**No-slump concrete:**
- High yield stress
  - Vibration reduced yield stress
- Viscosity
Finishing

leveling, smoothing, consolidating, and otherwise treating surfaces of fresh or recently placed concrete or mortar to produce desired appearance and service.

No standard tests; Related to

- The viscosity of the paste?
- Bleeding (yield stress/viscosity of bulk)?
Consistency

the degree to which a freshly mixed concrete, mortar, grout, or cement paste resists deformation

- **Normal:** Meets requirements for application
- **Plastic:** deformation would be sustained continuously in any direction without rupture.
- **Wettest stable:** maximum water content at which cement grout and mortar will adhere to a vertical surface without sloughing.
Outline of report

- Chapter 1 —Introduction
- Chapter 2 —Rheological terms related to concrete
- Chapter 3 —Test methods, (Koehler)
- Chapter 4 —Factors affecting workability of concrete, (Billberg)
- Chapter 5 —Examples of using workability test methods (Daczko, Khayat)
Acknowledgements

All members of ACI 238
– Former ACI 236A