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)

Class I qualitative Workability, flowability, compactability, finishability, pumpability, etc.	To be used only in a general descriptive way without any attempt to quantify
Class II quantitative empirical slump, compacting factor, Vebe time, flow table spread, etc.	To be used as a simple quantitative statement of behavior in a particular set of circumstances
Class III quantitative fundamental viscosity, mobility, fluidity, yield value, etc.	To be used strictly in conformity with standard definitions

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**

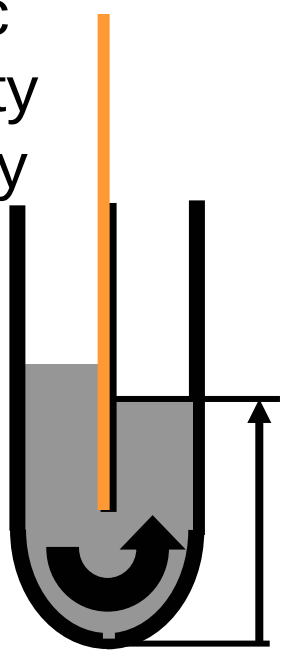
It depends on the application!!

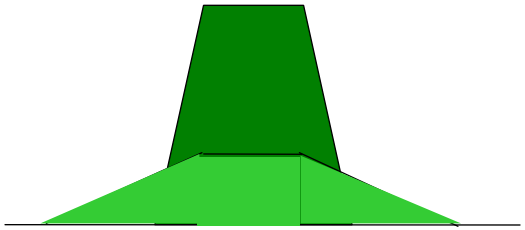
Example of applications

- 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

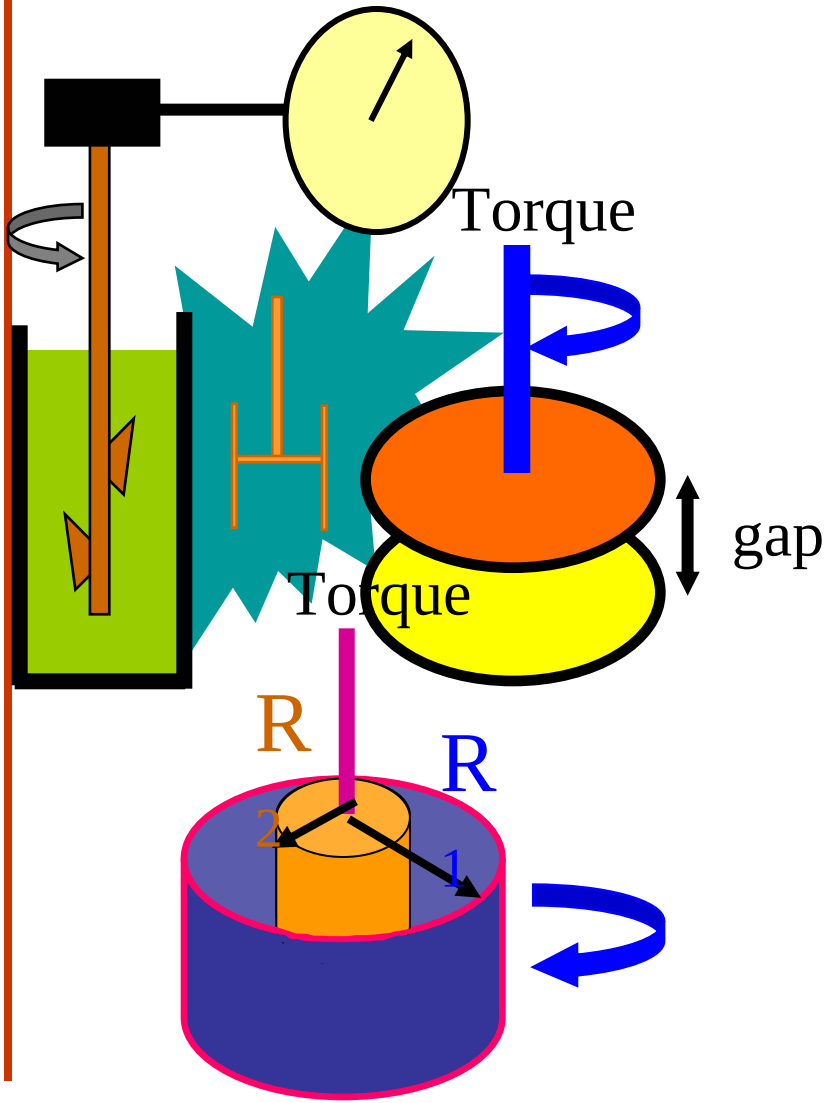
Slump
Slump flow
Stability static
Filling capacity
Passing ability





Rheology

Viscosity
Yield stress



Definitions
Some concepts

Bingham Model

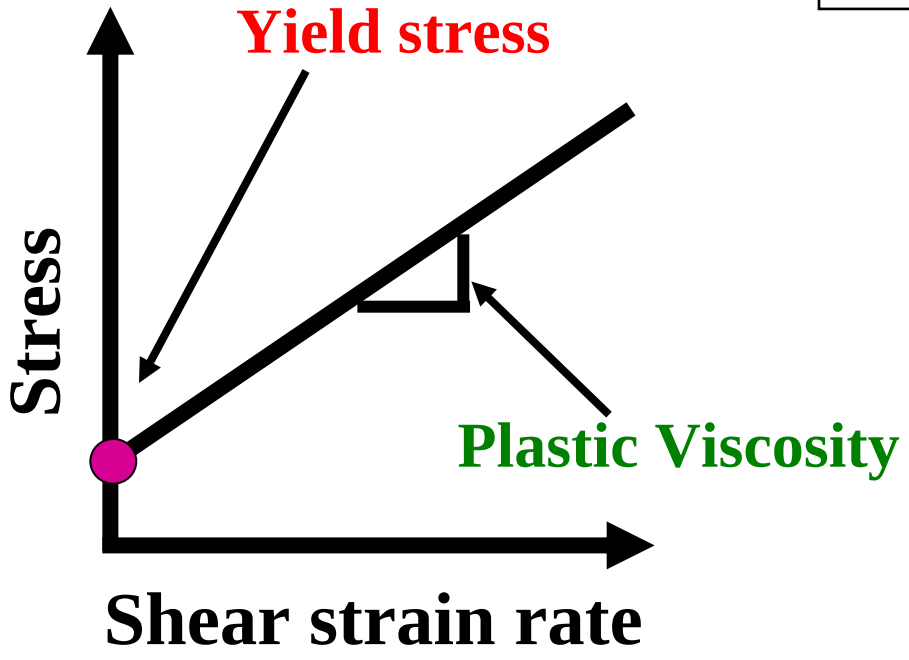
Shear Stress

Shear rate

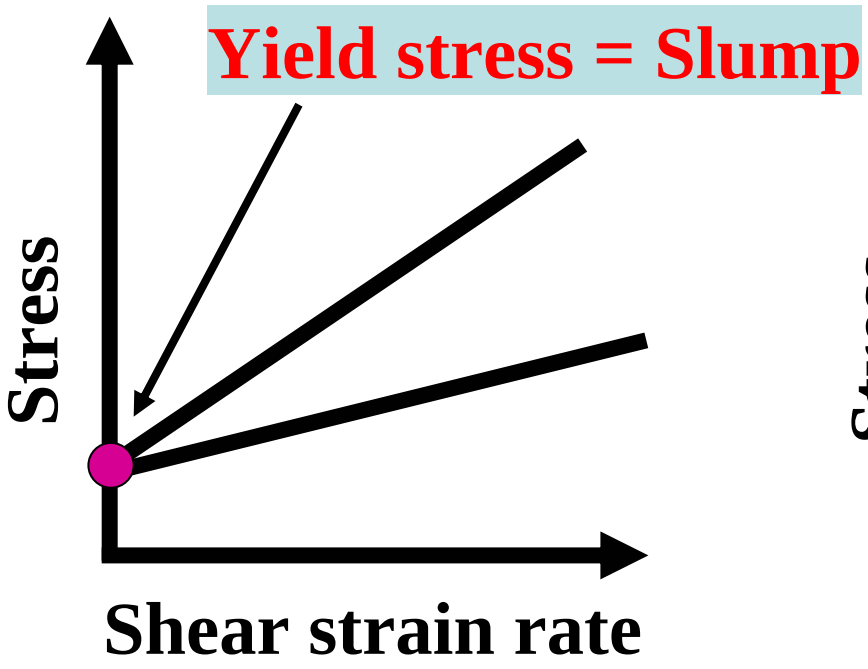
$$\tau = \tau_0 + \mu \dot{\gamma}$$

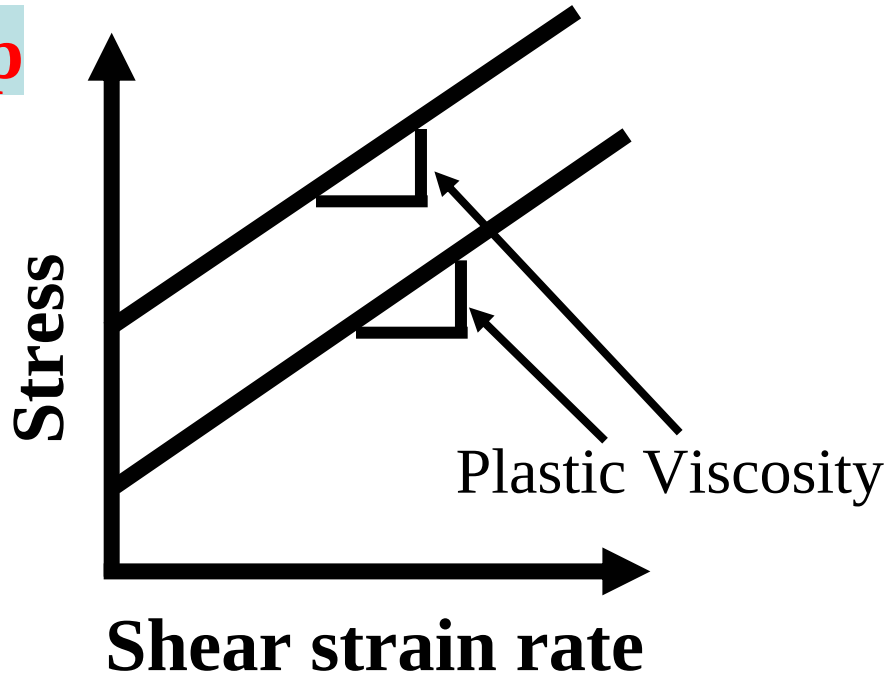
Yield Stress

Plastic Viscosity



Bingham model concept

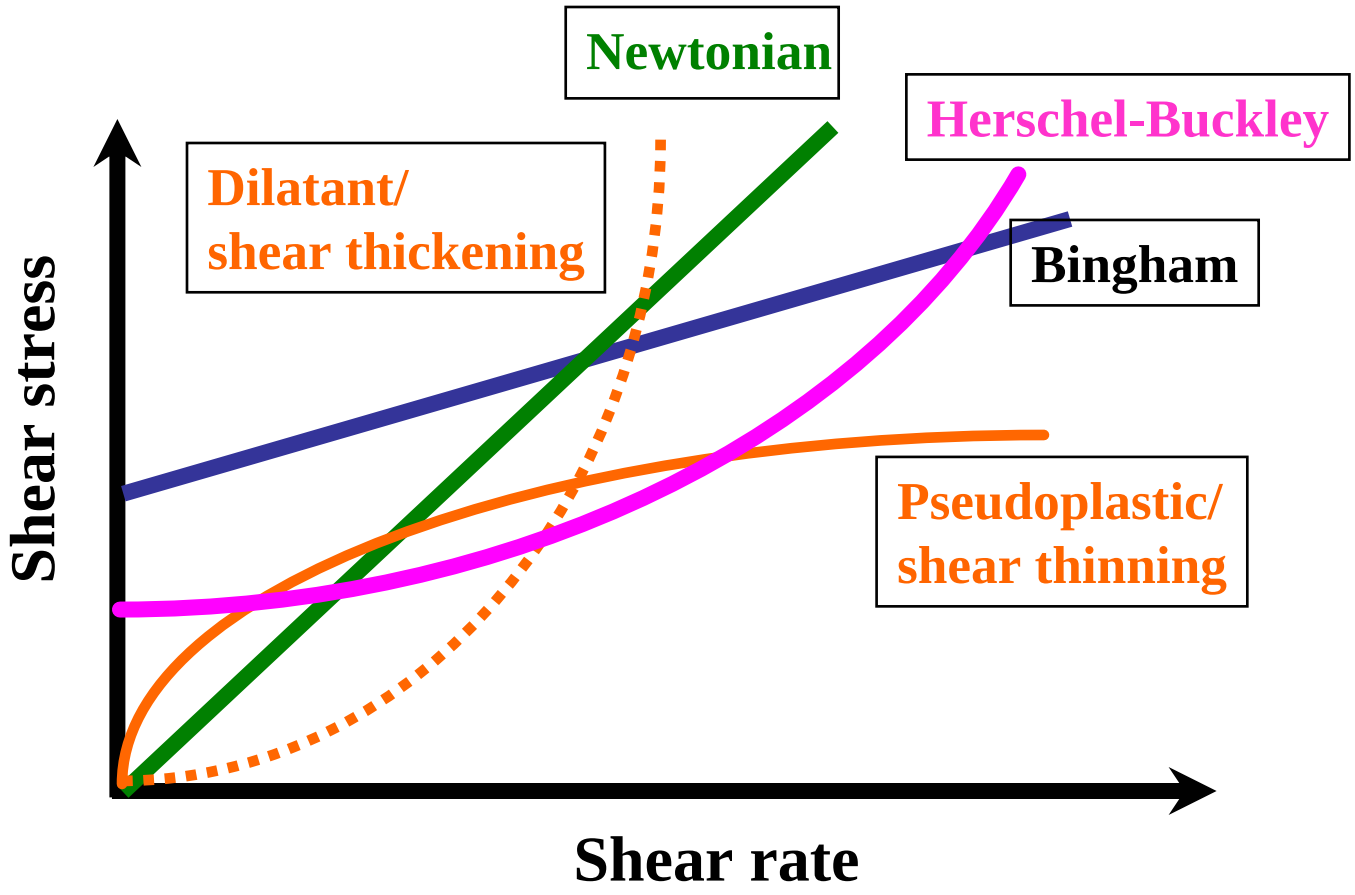




Same Yield Stress
BUT
Different Plastic Viscosity

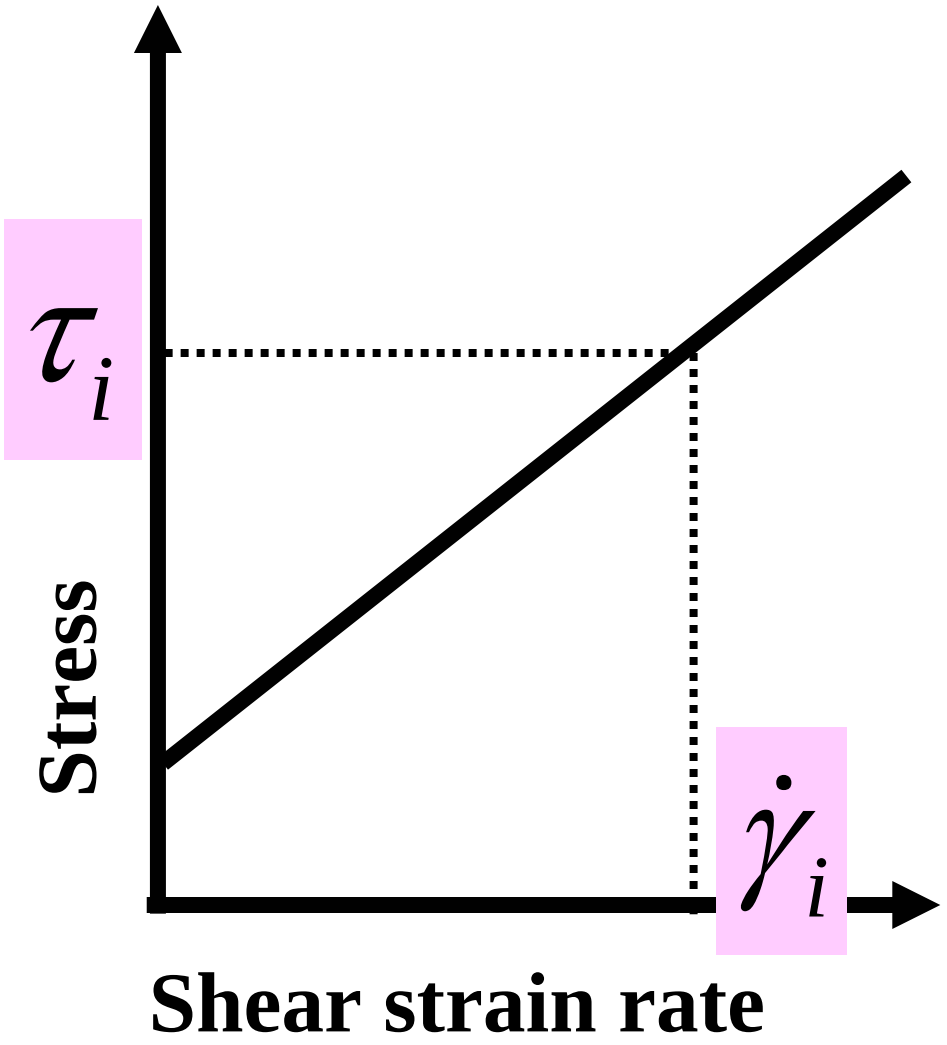
Same Plastic Viscosity
BUT
Different Yield Stress

Flow Curves


Newtonian
Herschel-Buckley
Dilatant/
shear thickening
Bingham
Pseudoplastic/
shear thinning
Shear stress
Shear rate

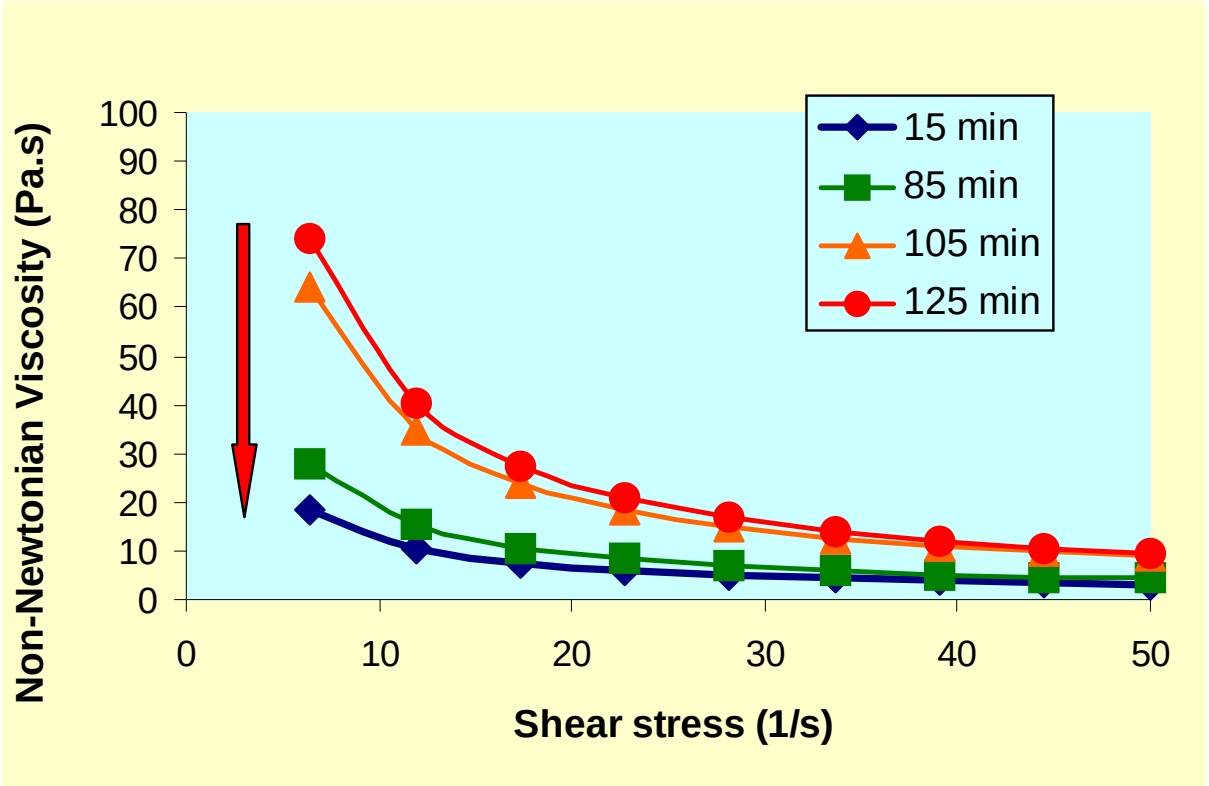
Viscosity definition

$$\eta_{ni} = \frac{\tau_i}{\dot{\gamma}_i}$$



Non-Newtonian Viscosity

$$\eta_{ni} = \frac{\tau_i}{\dot{\gamma}_i}$$

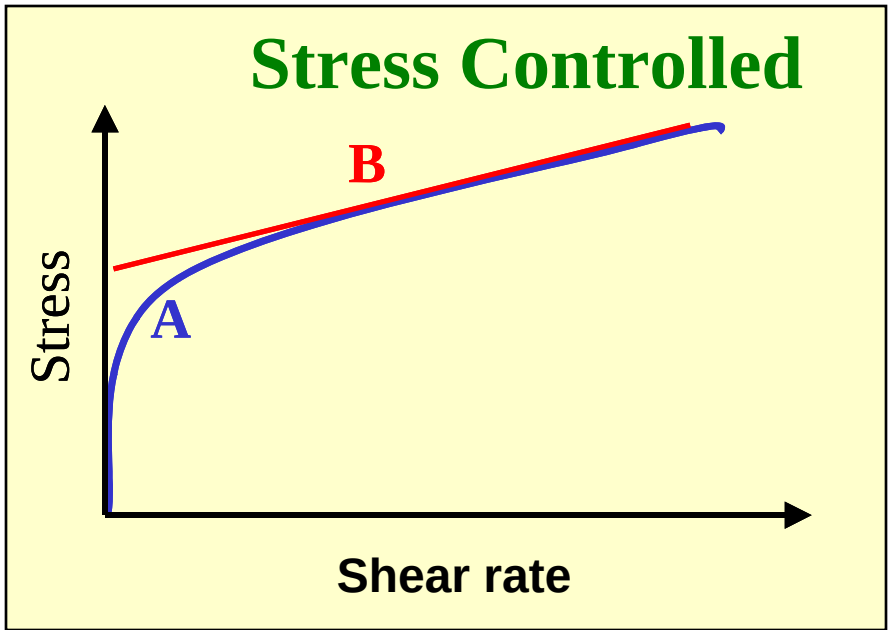


Amziane S., Ferraris C.F. “Cementitious Paste Setting Using Rheological and Pressure Measurements”, ACI Materials Journal, vol. 104 #2, 2007 pp. 137-145

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.

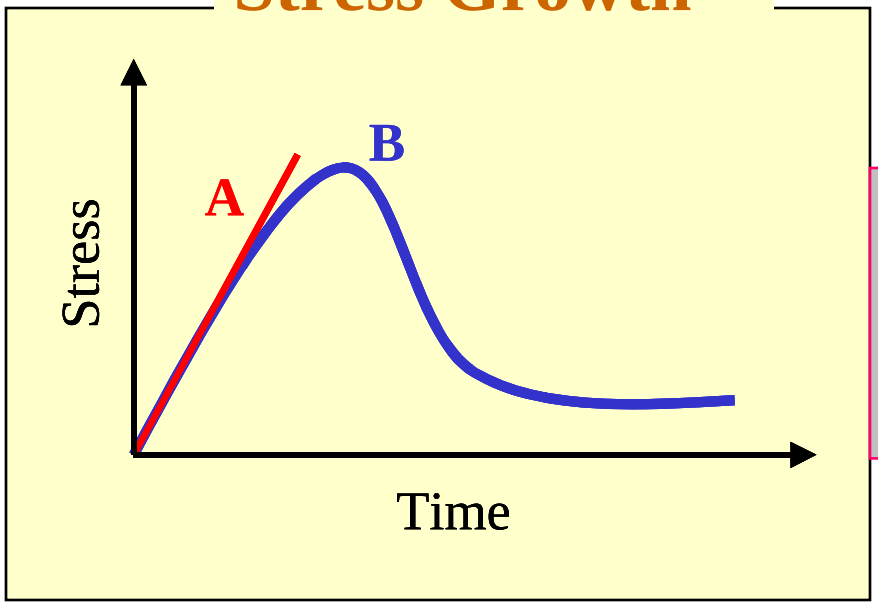


A=Yield stress

B= related to viscosity

Yield stress

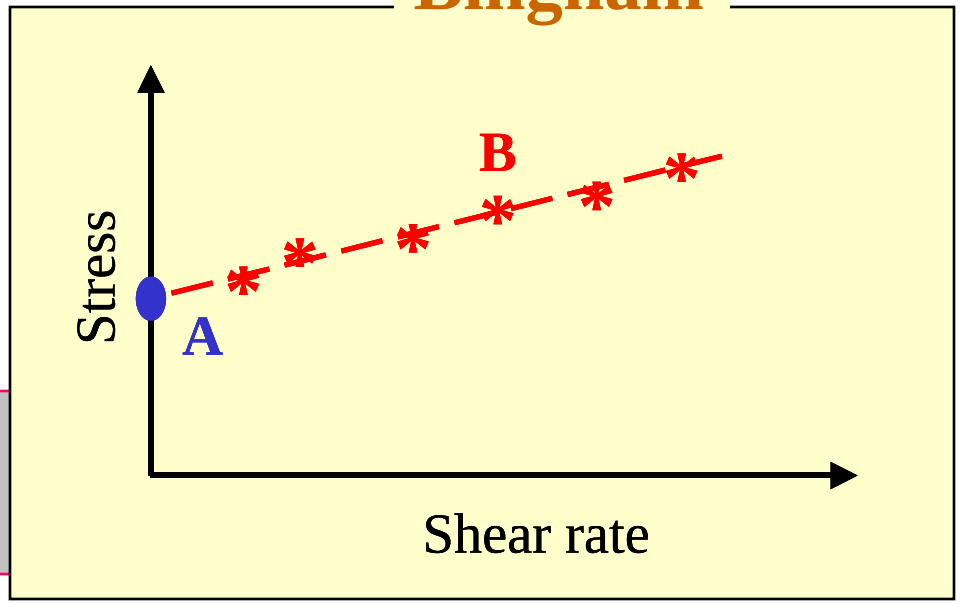
Stress Growth



Yield stress is between A & B

B is taken as the yield stress as it is easily determined

Bingham

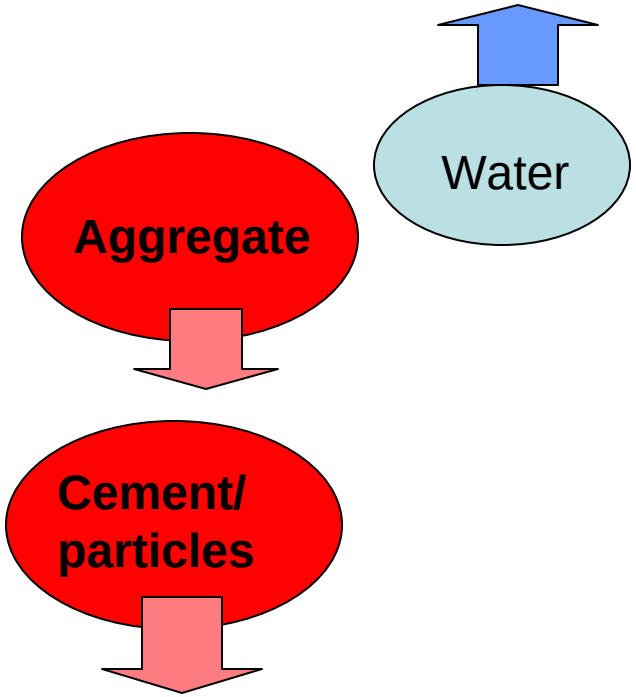


A=Yield stress

B= related to viscosity

Segregation

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



Segregation - Rheology

Yield stress and viscosity

Yield stress > Weight of aggregate

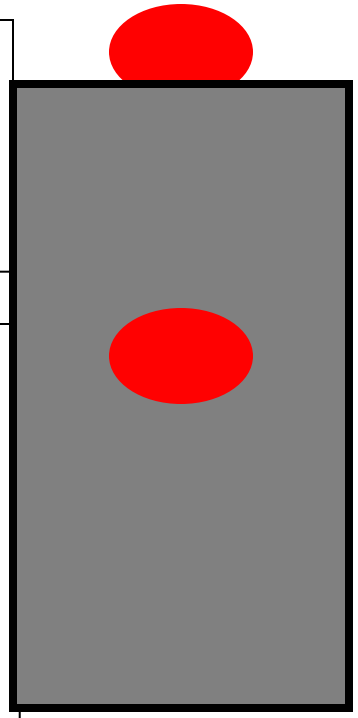
Aggregate stable

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