Self Compacting Concrete

CONCRETEClass - Back to Basics 2:2
Jul 9, 2026

Manu Santhanam
Surendra and Dorothie Shah Chair Professor
Civil Engineering, IIT Madras, India

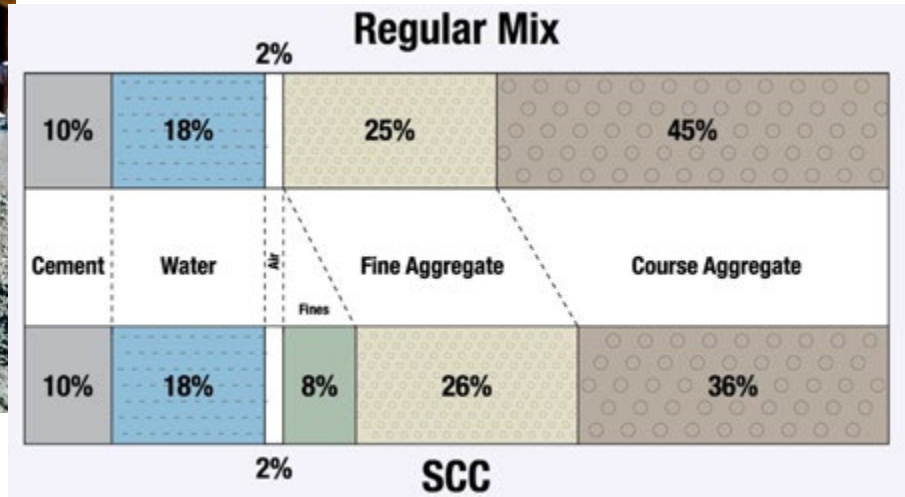
Outline

- SCC – introduction and applications
- Challenges with SCC
- Rheological control of SCC
- Assessment of fresh properties
- Issues pertaining to design and quality control
- Summary

Self compacting concrete

https://theconstructor.org/concrete/self-compacting-concrete-properties-tests/7683/

Little or no vibration required



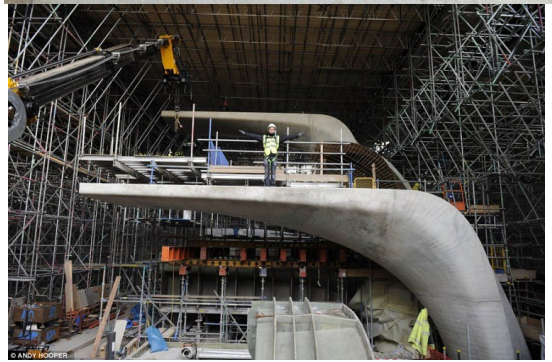
http://www.selfconsolidatingconcrete.org/mixdesign.html

EFNARC Guidelines – guiding document on SCC

World of possibilities with SCC

http://www.sika.com/en/concrete-redirect/concrete-additives/concrete-handbook-2013/concrete-application/self-compacting-concrete--scc-.html

http://www.arcspace.com/features/unstudio/mumuth/



http://www.dailymail.co.uk/sport/olympics/article-1340539/EXCLUSIVE-Sportsmails-Magnificent-7-2012-Olympic-Village.html

Concrete best suited to meet architects' demands!

http://www.tectonica-online.com/products/1683/glenium_concrete_compacting_hac_scc_superplasticizer/

Manu Santhanam

SCC applications

Traditional mix

SCC mix

https://www.youtube.com/watch?v=xEdzTuO4wrc

Trial at L&T ECC, Chennai, 2003

Famous early applications

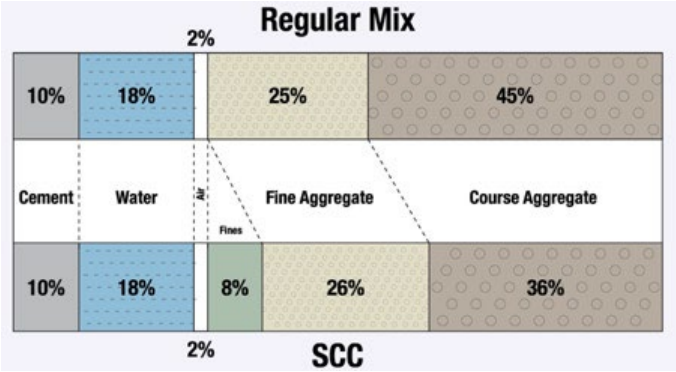
- Anchorages for Akashi-Kaikyo bridge, Japan
- Wall for LNG tank in Osaka, Japan
- Viaduct in Yokohama city, Japan
- Number of bridges in Sweden

More recently – Burj Khalifa (world record for concrete vertical pumping)

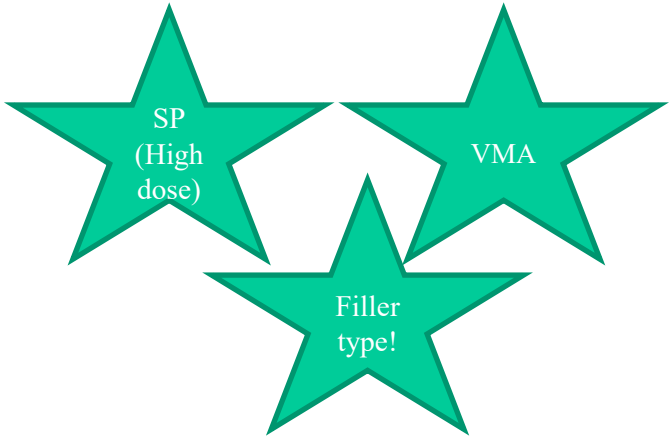
Challenges with SCC

- Optimal mixture design to obtain fresh characteristics – many ingredients lead to complex interplay of factors
- Resistance to cracking when fresh
- Suitable hardened concrete characteristics

Sufficiently complicated concrete



http://www.selfconsolidatingconcrete.org/mixdesign.html



Ingredients:	Special
Mix design:	Special
Concrete mixing:	Special
Flow retention:	Special
Transportation:	Special
Formwork:	Special
Placement:	Special
Hardened concrete:	Normal!

Manu Santhanam

Self Cracking Concrete

Cracks may go through depth also!

Possibilities of plastic shrinkage cracking very high!

- use of large amount of fines
- generally slower setting

Inadequate top cover in slabs can also cause plastic settlement!

Segregating Category Concrete

What causes segregation in SCC?

Inappropriate proportions of ingredients

Minor retempering or redosing

Inadequate design for blocking (especially at beam-column junctions)

Accidental / excess vibration

Pouring from a height

Rheological control of SCC essential

Manu Santhanam

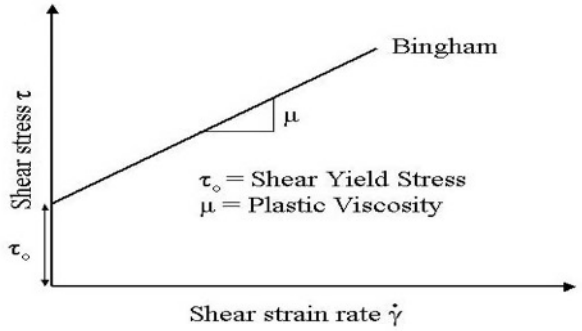
Rheology of cementitious materials

- Cement systems are yield stress fluids due to interparticle forces – links between particles are broken by shearing
- Shearing history therefor plays an important role in the rheological behavior
- Paste to mortar to concrete – increasing levels of complexity

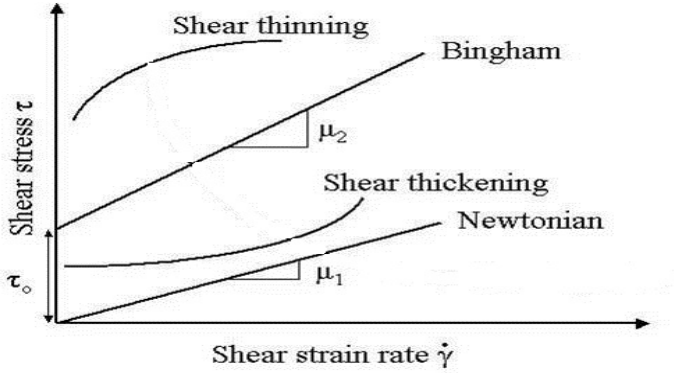
Rheological models

- Simplest – Newtonian fluid
- Bingham fluid – A convenient approximation for concrete flow properties
- Herschel-Bulkley fluid – To account for the non-linearity of test results as compared with Bingham model

Rheological models



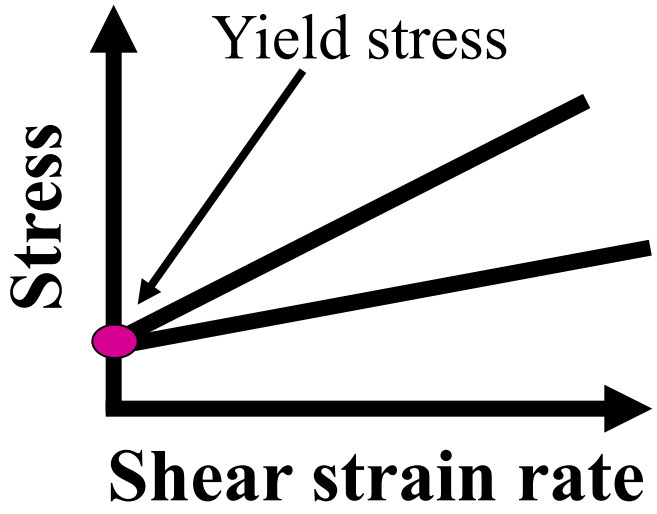
Bingham model



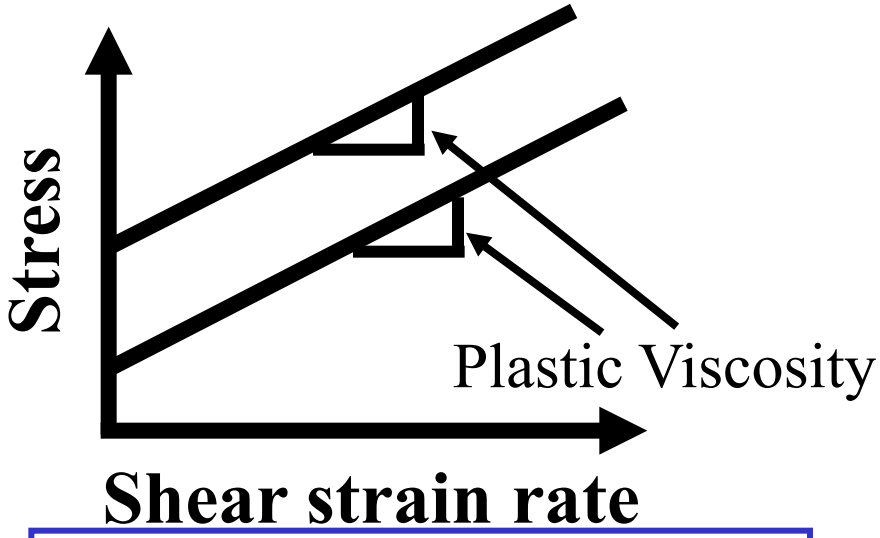
Other rheological models

Two important parameters: Yield stress and viscosity

Bingham model concept

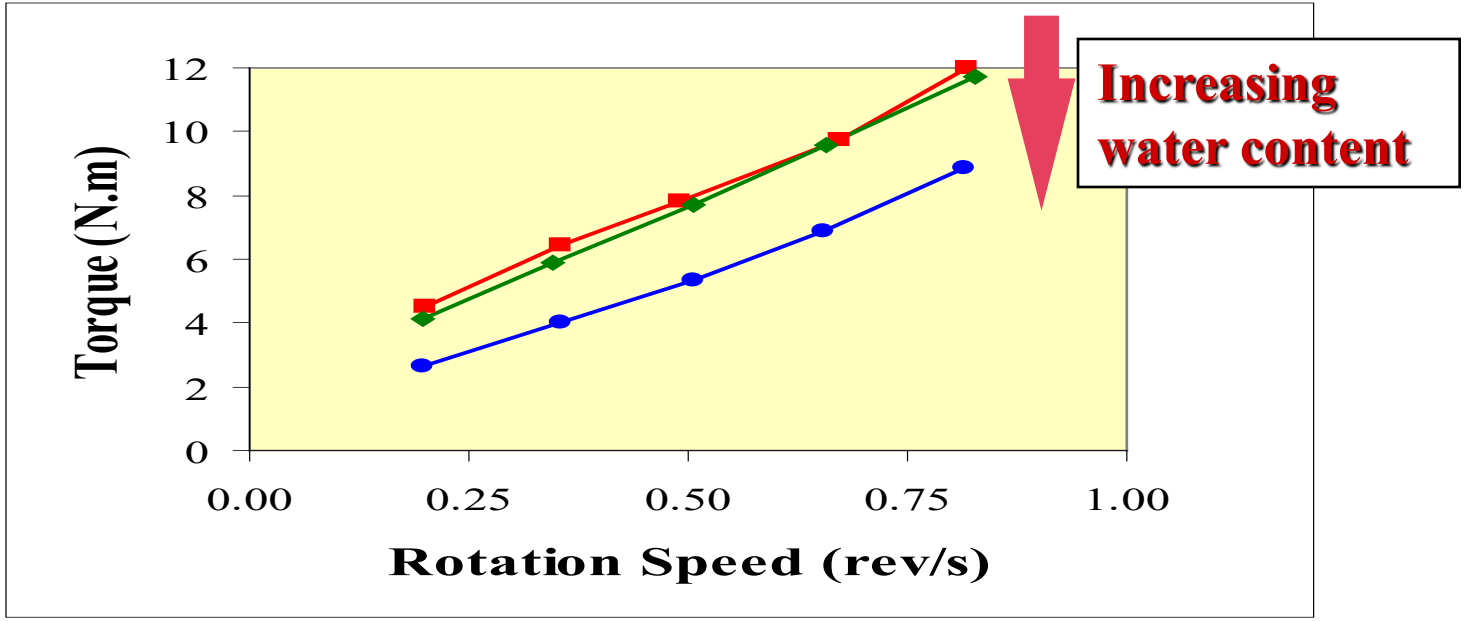


Same Yield Stress
BUT
Different Plastic Viscosity



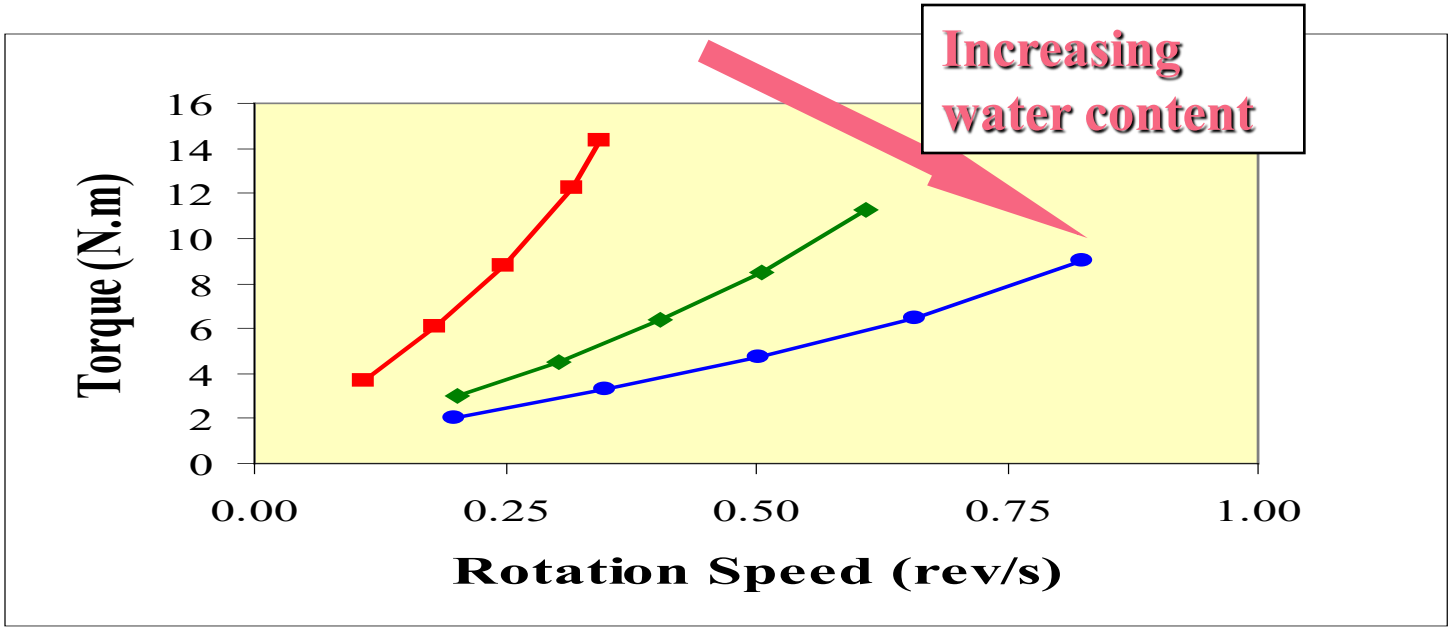
Same Plastic Viscosity
BUT
Different Yield Stress

Normal Concrete



Ferraris, de Larrard , 1998

Self-compacting concrete



Ferraris, de Larrard , 1998

Shear yield stress

Minimum stress needed for flow to initiate; function of the intergranular friction between the aggregate particles

Will depend on the volumetric fraction of aggregate particles, and the fluidity of the paste

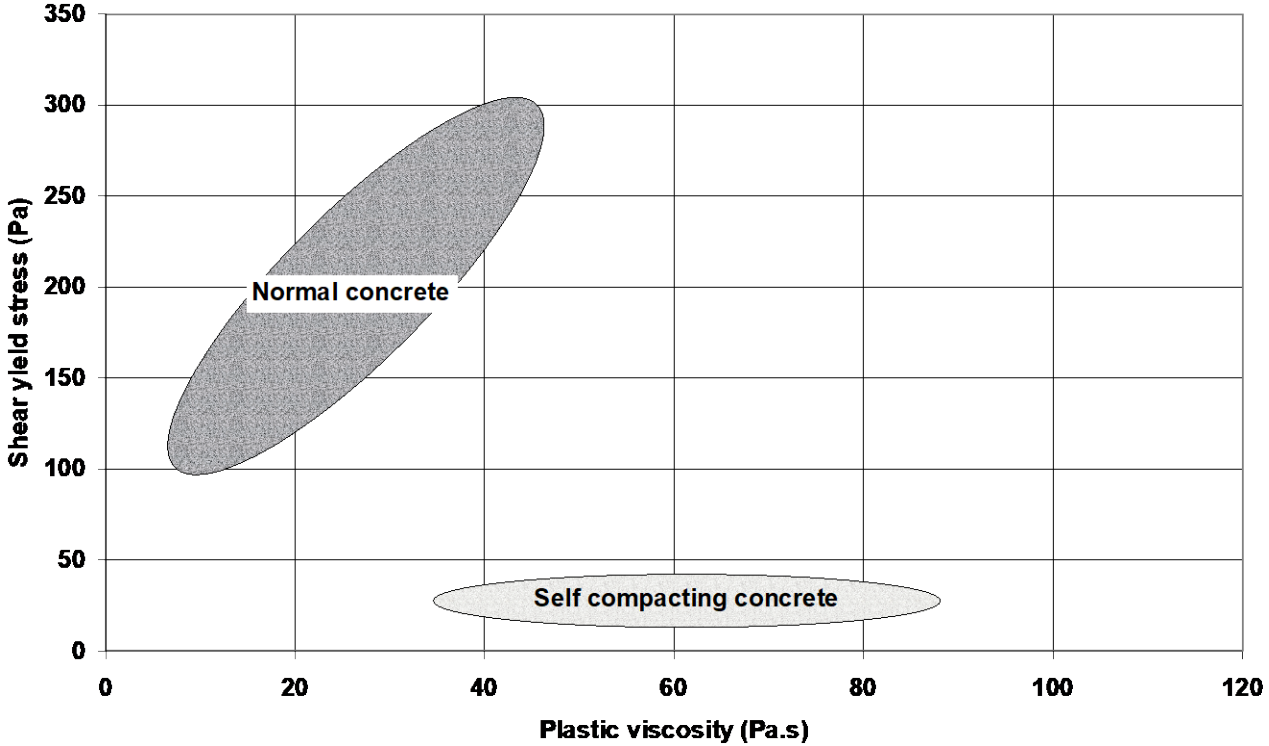
Plastic viscosity

If the fluid remains in the laminar regime while flowing between the solid particles, its contribution to the shear resistance will be proportional to the overall strain gradient

Plastic viscosity $\mu = \mu_o$ g(vol.fraction of aggregates)

Where μ_o is the plastic viscosity of the paste phase, and g is an increasing function of the aggregate volume fraction

Rheological control of SCC



Domone, 2010

Use of rheometers for assessment could be expensive → alternative methodologies can be used

Modified laboratory tests

- Slump flow test
- T_{50}
- V-funnel; Orimet

→ Flowability

- U-box test
- L-box test
- J-Ring test

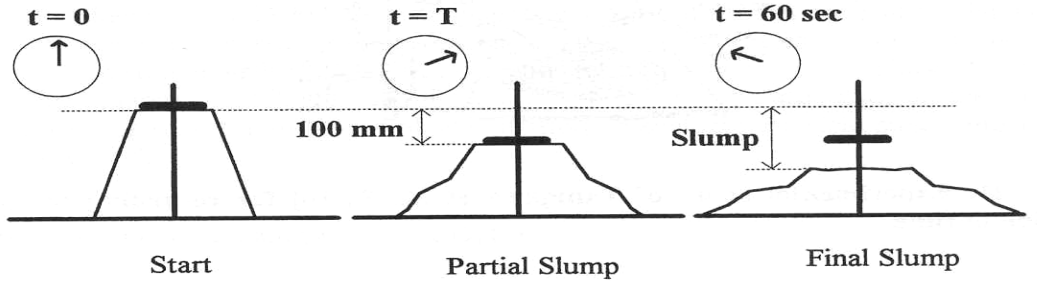
→ Passing ability

- Sieve stability test
- Settlement column test
- Penetration test

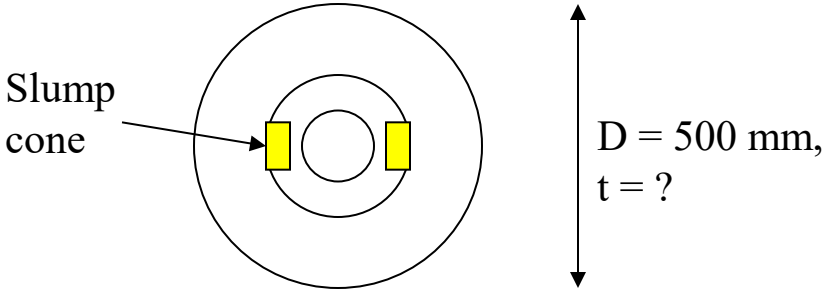
→ Segregation potential

Slump-based tests

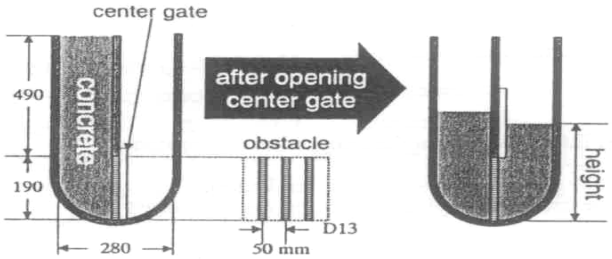
Modified slump test – (i) Overall slump, and (ii) Speed of slump



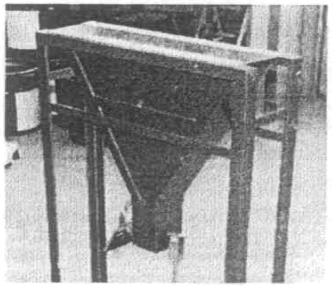
Slump flow test for SCC – (i) Overall spread, and (ii) time to spread 500 mm



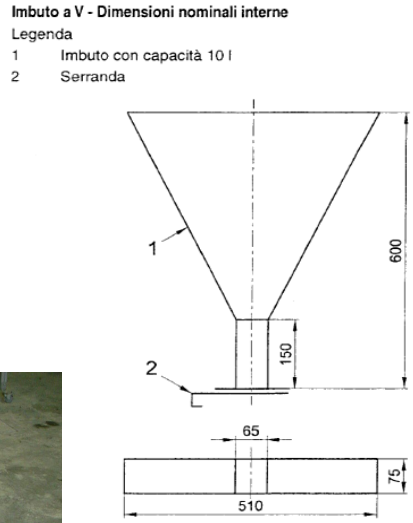
U-tube and V-funnel



U-tube test



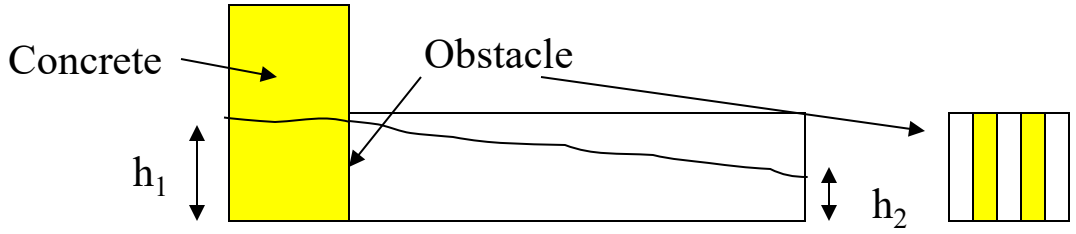
V-funnel test



U-tube test evaluates the potential of the SCC to overcome obstacles (in this case, the reinforcement gate); after flow, the height difference in the two limbs of the tube is measured (< 30 mm recommended)

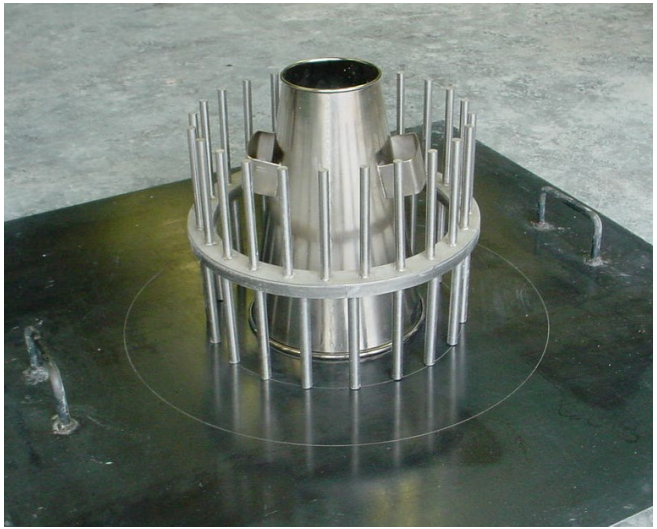
In V-funnel test, time taken to flow out of the funnel indicates the flowability of the SCC (6 – 12 sec recommended); also, a flow without break is considered satisfactory; test can be repeated at 5 minutes – to assess segregation impact

L-box test



The L-box test simulates a real life condition of filling up a formwork with concrete. Concrete flows through an obstacle (similar to the U-tube test) due to a potential energy gradient; the comparison of the final height h_2 to the initial height h_1 indicates the self-compacting and self-levelling nature of the SCC (0.8 – 1.0 recommended)

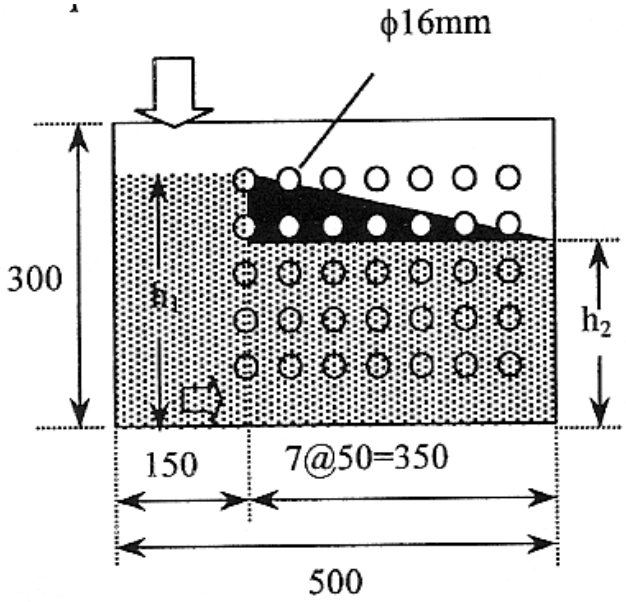
J-Ring with Slump Flow



Courtesy: Ravindra Gettu

A difference of 50 mm in the flow with and without J-ring indicates satisfactory performance

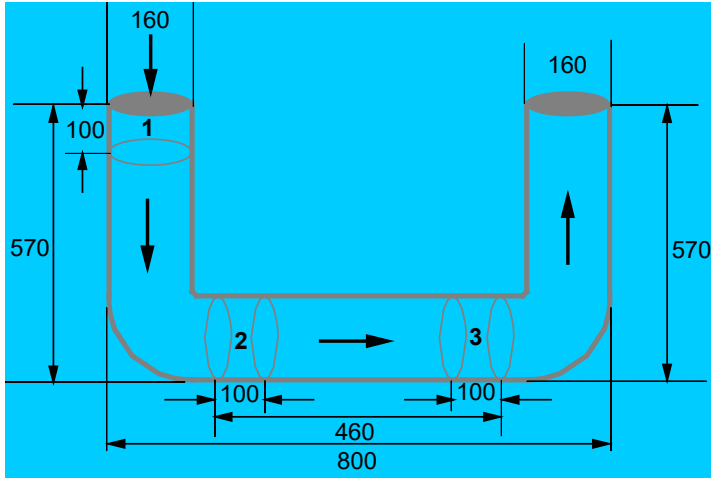
Box filling test



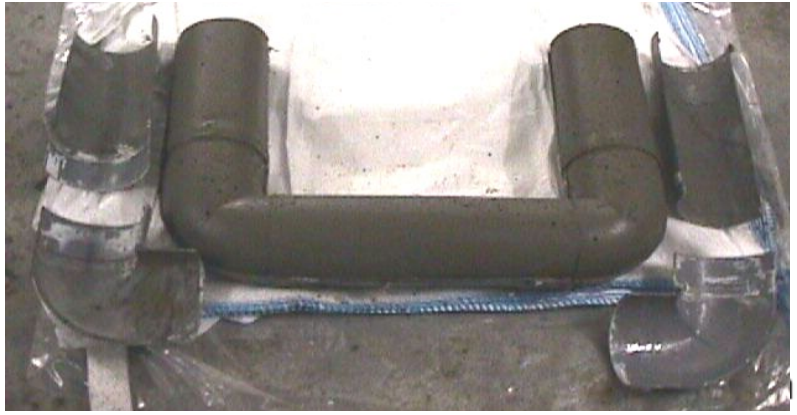
Blocking ratio, BR ≥ 0.8

Courtesy: Ravindra Gettu

Testing for segregation



Requirement: Segregation ratio (RS) ≥ 0.90

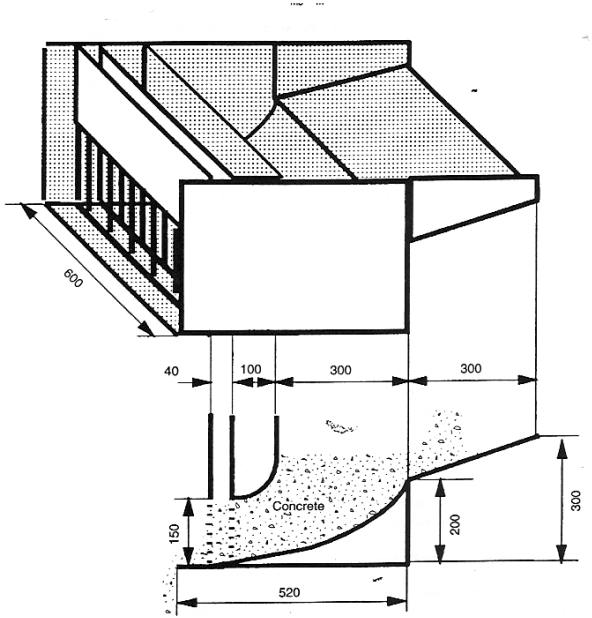


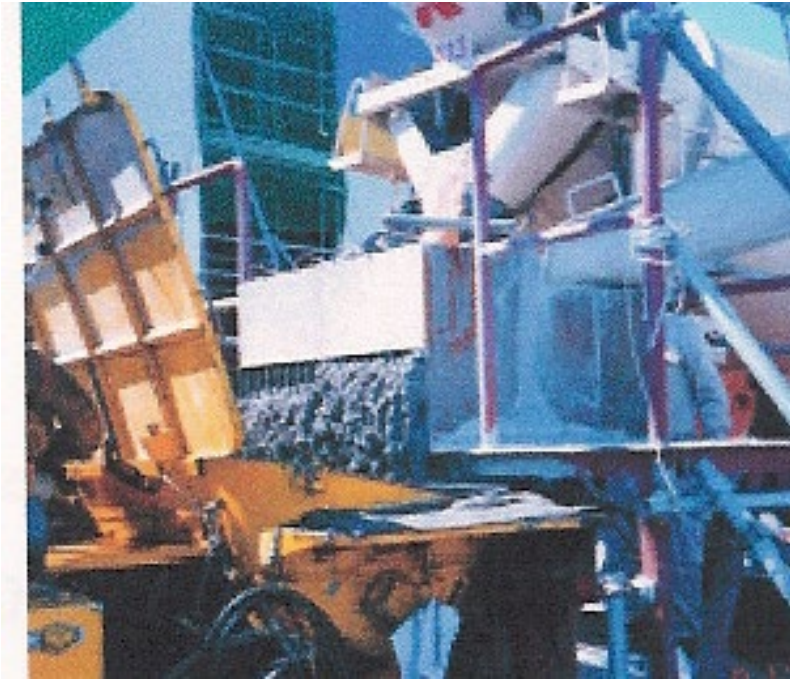
Courtesy: Ravindra Gettu

General remarks regarding tests

- Presence of obstacles (reinforcement cage) could cause blocking of flow if the mixture design is not proper (i.e. volume fraction of aggregates is high, or the maximum size of aggregate is large, etc.)
- Resistance to segregation can be checked by evaluating cut sections – or by settlement test

On-Site All Acceptance Test - Japan





All the concrete has to flow through the box without blocking for acceptance

Courtesy: Ravindra Gettu

EFNARC Classes for SCC

Type	Test	Classes
Filling ability	Slump flow (with or without J-Ring) V-funnel	SF1 – 550 – 650 mm SF2 – 660 – 750 mm SF3 – 760 – 850 mm VF1: $t \leq 8$ s VF2: $9 \leq t \leq 25$
Passing ability	Passing Ratio (height ratio) in L-box	PR1 ≥ 0.80 with 2 bars PR2 ≥ 0.80 with 3 bars
Flow rate	T500 in slump flow test Called 'Viscosity Class'	VS1 ≤ 2 s VS2 > 2 s
Segregation index	Sieve segregation – segregation index	SI1 ≤ 20 SI2 ≤ 15

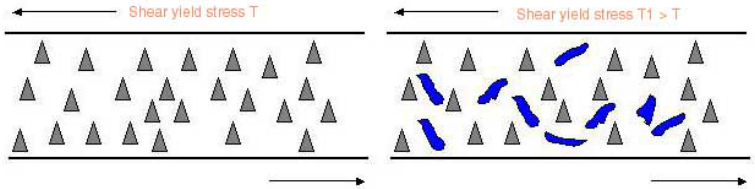
Issues with design of SCC

- Choice of mixture design approach – not standardized yet; EFNARC still preferred; rheology combined with particle packing used by many researchers
- Characterization of locally available materials, particularly aggregates

  - Accounting for aggregate shape

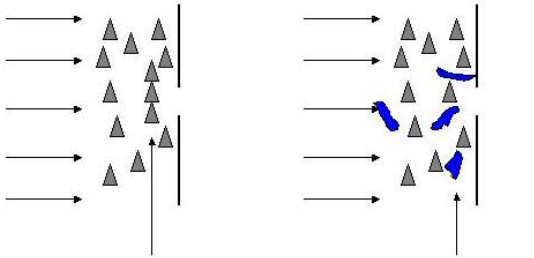
  - Alternative sources (manufactured sand)
- Correlating rheological properties with empirical measurements!!
- Application driven design of SCC

Possible effect of flaky and elongated aggregate



Conventional flow behaviour

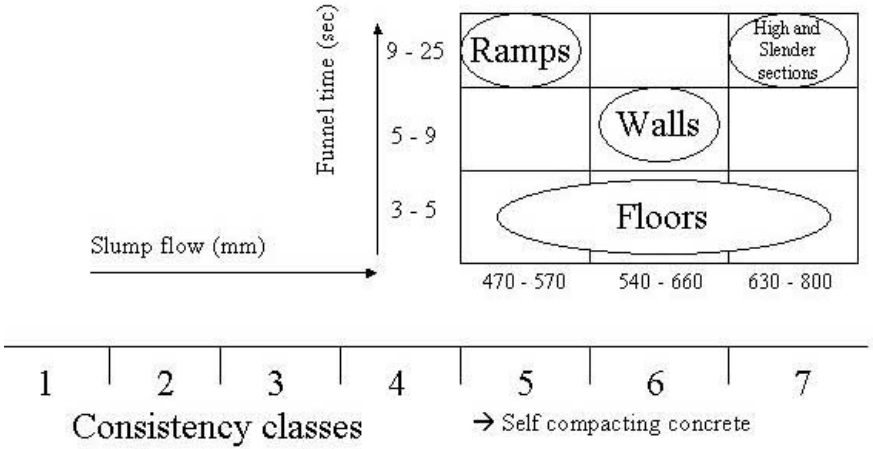
Flow behaviour in the presence of flaky and elongated particles – could increase yield stress



Conventional blocking due to 'arch' formation

Risk of blocking could increase in the presence of flaky and elongated particles

Application based design



Walraven (Netherlands)

Possibly tie up the consistency classes with the water content and/or powder content…

Issues with QC and on site process

- Tendency for higher early age shrinkage!!
- Hardened properties – Strength, creep, durability → research has shown that all these are equal to or better than conventional concrete!
- Pumping pressure – not much different from normal concrete except when casting rates are high

Summary

- Self compacting concrete presents clear advantages for construction of complex concrete structures
- Essential to control the rheology with a suitable choice of materials – several alternative test methods can be used for lab design and field quality assessment
- Potential QC issues during construction (specifically w.r.t. early age cracking) – adequate care needs to be exercised