Self Compacting Concrete (SCC). Durable Construction with:

Hathi Cement

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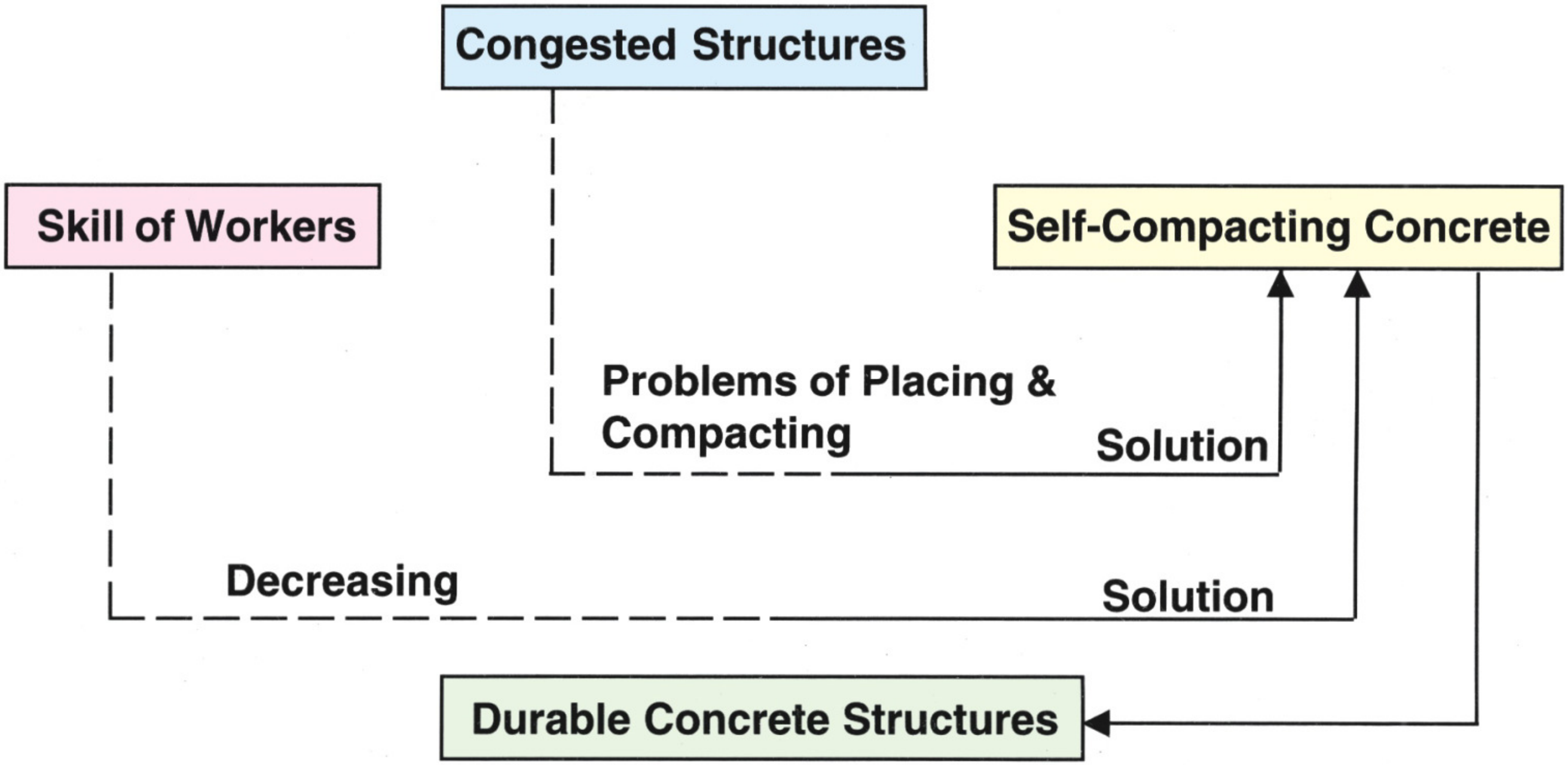
The designs are indicative and based on a trial model, please review and conduct necessary trials / tests for an appropriate mix design prior to implementing the same.

Self Compacting Concrete (SCC): Index

Necessity


Congested Structures
Skill of Workers
Self-Compacting Concrete
Problems of Placing &
Compacting
Solution
Decreasing
Solution
Durable Concrete Structures

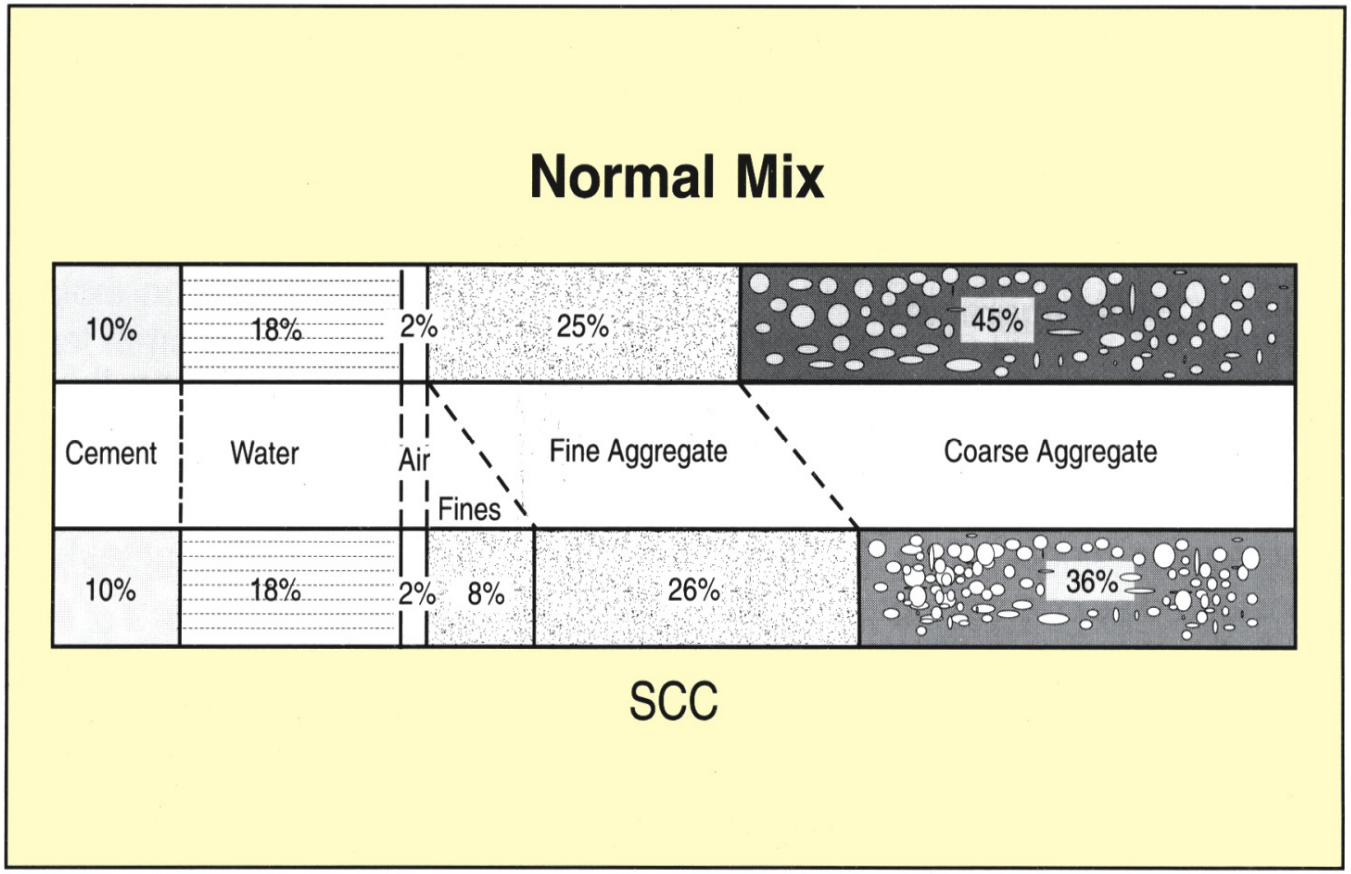
Meaning and Definition

- **Developed in 1980**
- **Concrete which flows to a virtually uniform level under the influence of gravity without segregation, during which it de-aerates and completely fills the formwork and spaces between the reinforcement without any need for induced compactions**
- **Obtained by,**
  - **limiting the w/c ratio**
  - **adding an effective plasticizer**
  - **Increasing sand-aggregate ratio**
  - **Adding viscosity enhancing admixtures**

Mix Design

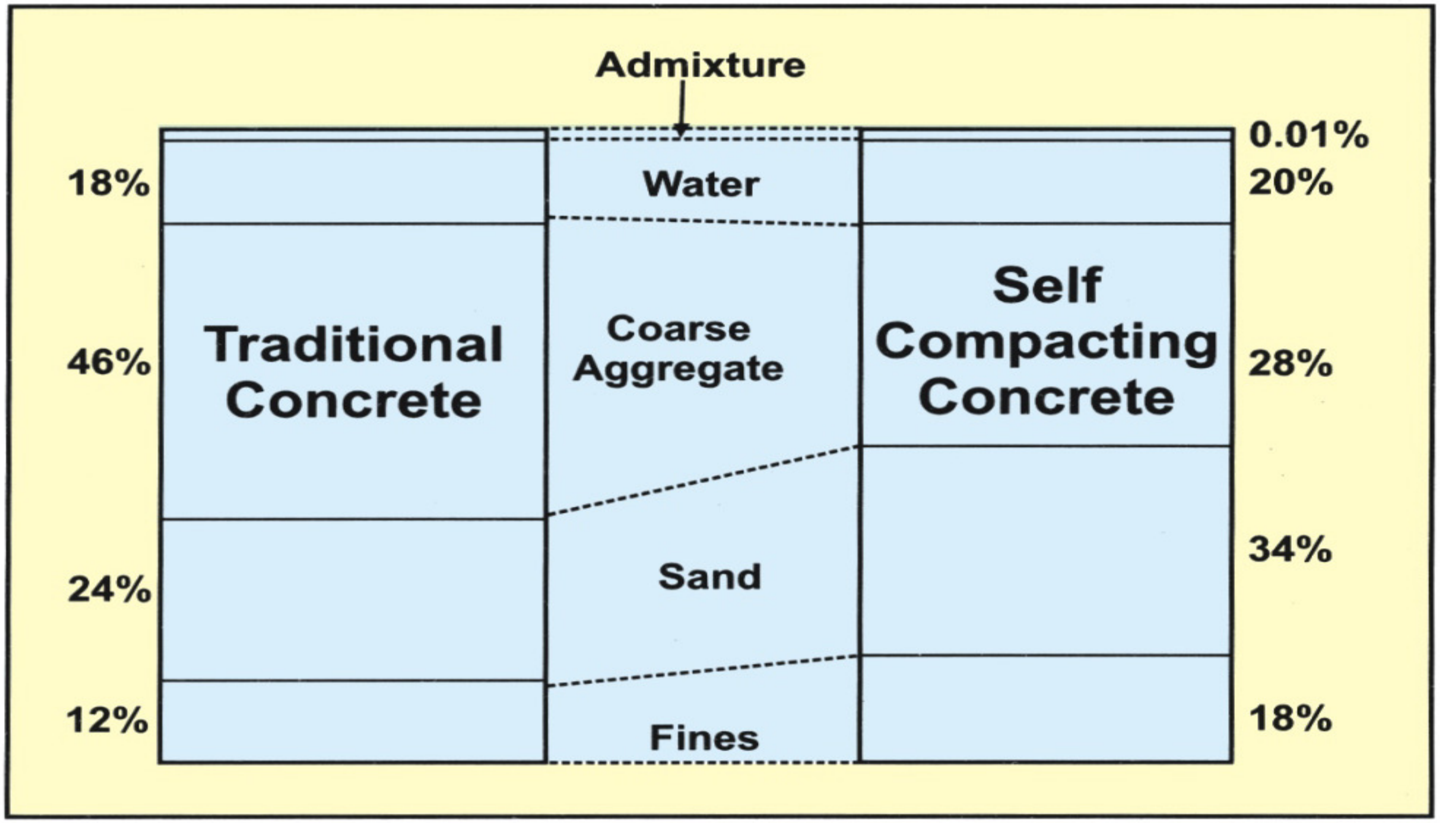
- To be designed in such a way to have high fluidity, least or no segregation, and low risk of blocking
- High cement paste volume, low coarse aggregate and water content, and proper dosage of super-plasticizer
- The sand/coarse aggregate ratio is about 1, which is slightly higher than that used for control concrete
- Refer Specification and Guidelines for Self-Compacting Concrete-EFNARC for more details

Mix Design



Constituents of Normal v/s Self Compacted Concrete

Mix Design



Constituents of Normal v/s Self Compacted Concrete

Mix Design

1. Coarse Aggregate

- Size is limited to 20 mm
- Crushed aggregates tend to improve the strength due to interlocking angular particles, also, reduce the flow-ability
- Rounded aggregates improve the flow due to less internal friction and less surface area per mass
- Gap graded aggregates better than well graded aggregates
- Amount less than 50% by weight of total aggregates (C.A. + F.A.)
- Normal range is 700-800 kg/m^3 of concrete
- By volume, content is 50-60% of the total aggregate volume

Mix Design

2. Fine Aggregate

- Size is smaller than 4.75 mm and up to 0.075 mm
- Finer than in normal concrete
- Weight of sand to that of coarse aggregates in range of 1.1 to 1.6
- Ratio may be less if filler dust is used
- Volume should be 40-50% of the mortar/paste volume

3. Dust/Fines

- Size is smaller than 0.075 mm
- Decided to be used in absence of use of various SCMs
- Amount in absence of SCMs to be used is 400-600 kg/m^3 of concrete

Mix Design

4. Cement

- Amount same as to be used for normal concrete
- Use of fly ash, slag, silica fume is very essential

5. Water

- w/c ratio to be less than 0.4 for durability considerations
- Free water should be less than 200 L per m^3 of concrete
- Amount in absence of SCMs to be used is 400-600 kg/m^3 of concrete
- Water powder ratio by volume is generally 0.8-1.1

Mix Design

6. Chemical Admixtures

- Super-plasticizers promote workability retention with a mechanism of electrostatic repulsion and steric hindrance
- Viscosity modifiers increase resistance to segregation while still maintaining high fluidity, allowing concrete to flow through narrow space

Mix Design Approach

1. Evaluate the water demand and optimise the flow and stability of the paste
2. Determine the proportion of sand and the dose of admixture to give the required robustness
3. Test the sensitivity for small variations in quantities (the robustness)
4. Add an appropriate amount of coarse aggregate
5. Produce the fresh SCC in the laboratory mixer, perform the required tests
6. Test the properties of the SCC in the hardened state
7. Produce trial mixes in the plant mixer.

HATHI CEMENT

Mix Proportioning and Properties of Self Compacting Concrete

M-30	
Cement (kg/m^3)	270
Fly Ash (kg/m^3)	180
20mm (kg/m^3)	395
10mm (kg/m^3)	590
Reg. Natural (kg/m^3)	800
Fine Natural	0
Est Water (w/c) (kg/m^3)	180
	2415

M-35				
Cement (kg/m^3)	315	315	262	315
Fly Ash (kg/m^3)	210	210	262	170
20mm (kg/m^3)	420	370	522	500
10mm (kg/m^3)	420	370	522	500
Reg. Natural (kg/m^3)	500	700	394	300
Fine Natural (kg/m^3)	300	205	200	400
Est Water (w/c) (kg/m^3)	200	195	188	180
	2365	2365	2350	2365

Mix Proportioning and Properties of Self Compacting Concrete

M-50		
Cement	370	420
Fly ash	150	130
20mm	430	385
10mm	515	574
M. Silica	0	0
Reg. Natural	816	400
Fine Natural	0	348
Est Water (w/c)	180	171
	2461	2428

M-60	
Cement	420
Fly ash	130
20mm	385
10mm	574
M. Silica	50
Reg. Natural	400
Fine Natural	348
Est Water (w/c)	171
	2478

All quantities are in kg/m^3

SCC For RMC and Site-mixed Concrete

- Properties of Fresh SCC
  - Flow-ability is obtained by using proper admixture
  - Stability or resistance to segregation of plastic concrete is achieved by increasing the total fines content in concrete or by modifying viscosity
  - Proper grading of materials helps in reducing cement and admixture quantities in concrete

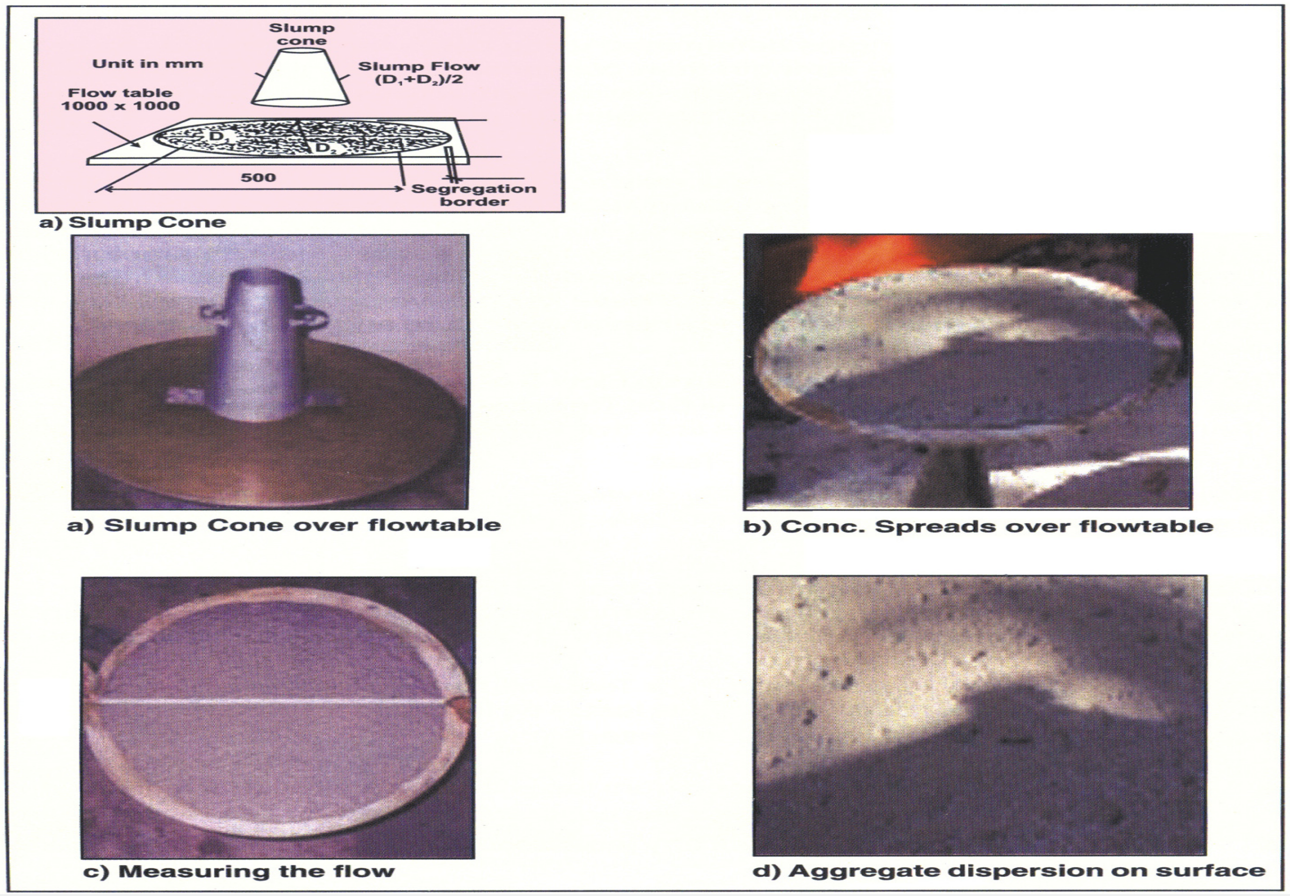
SCC For RMC and Site-mixed Concrete

The filling ability and stability of self-compacting concrete in the fresh state can be defined by four key characteristics. Each characteristic can be addressed by one or more test methods:

Characteristic	Preferred test method(s)
Flow-ability	Slump-flow test
Viscosity (assessed by rate of flow)	T^{500} Slump-flow test or V-funnel test
Passing ability	L-box test
Segregation	Segregation resistance (sieve) test

Evaluating Self-compatibility of Fresh Concrete

1. Slump Flow Test (along with T_{500} time Test)



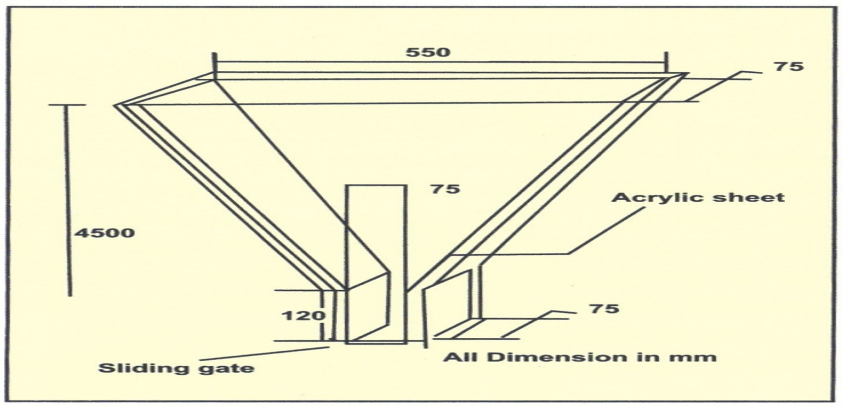
Tests for Evaluating Self-compatibility of Fresh Concrete

1. Slump Flow Test (along with T_{500} time Test)

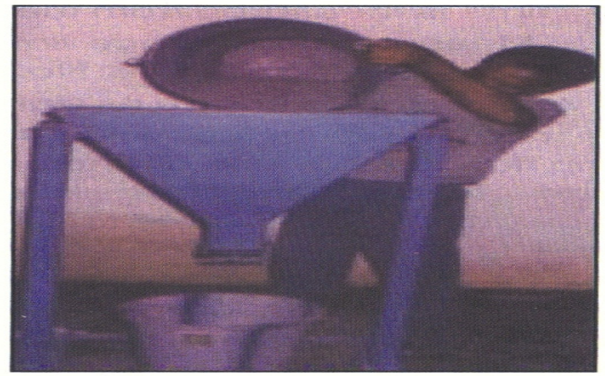
- Assesses filling ability of SCC
- Slump flow is the mean diameter in mm in two perpendicular directions of the concrete spread, after the concrete had stopped flowing.
- T_{500} mm slump flow time is the time taken for the concrete in sec to spread by 500 mm
- Good flowable concrete, permissible range of values for slump flow are 650 to 800 mm and $T_{500\ mm}$ test time are 2-5 seconds.

Tests for Evaluating Self-compatibility of Fresh Concrete

2. V-Funnel Test

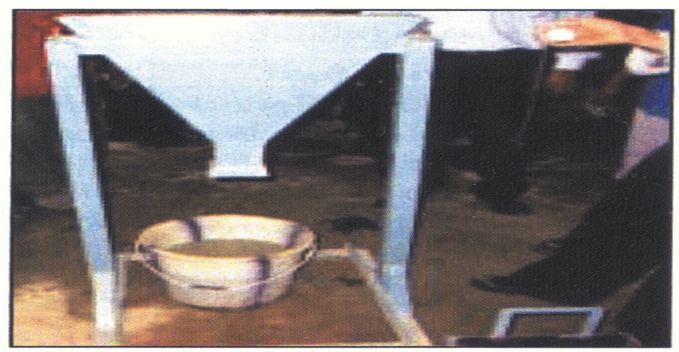


a) V - Funnel



b) SCC being poured into the funnel

c) Time of flow being recorded



d) Final time recorded as SCC's flow stops

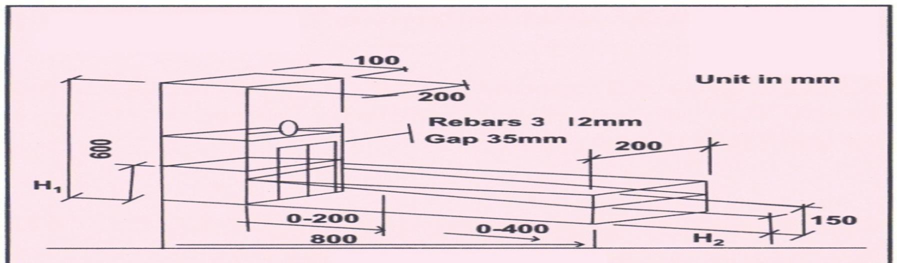
Tests for Evaluating Self-compatibility of Fresh Concrete

2. V-Funnel Test

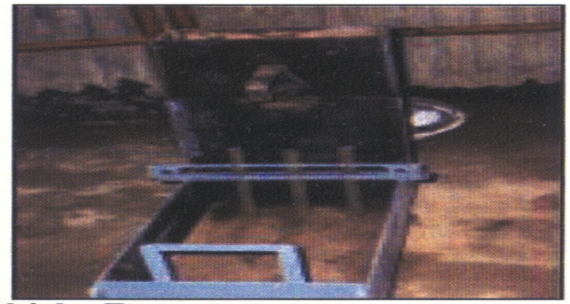
- Assesses flowing ability and segregation resistance
- Evaluate the time required to empty the funnel completely in seconds, i.e. T_0
- T_5 is the time required to empty the funnel completely in seconds after 5 minutes of filling the funnel completely
- T_0 from the test should be in the range of 8-12 seconds and T5 should be less than 3 seconds over T_0.
- If T_5 is more than 3 seconds over T_0, there are chances that SCC mix will segregate.

Tests for Evaluating Self-compatibility of Fresh Concrete

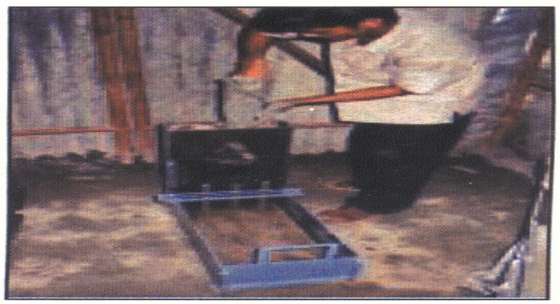
3. L-Box Test



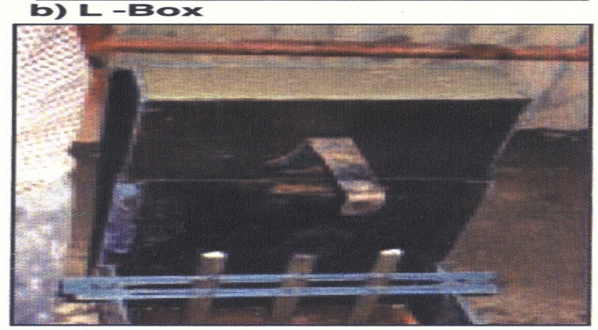
a) L -Box



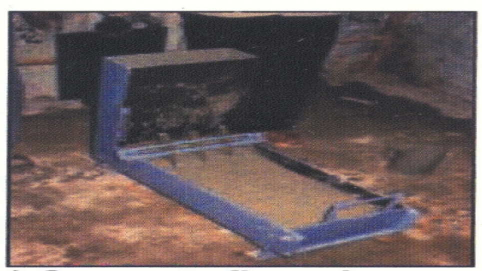
b) L -Box



c) Concrete being poured into the L - Box



d) Concrete filled into the L -Box



e) Concrete flows in the L-Box

Tests for Evaluating Self-compatibility of Fresh Concrete

3 L-Box Test

- Assesses passing and filling ability of concrete
- Gap between reinforcing bars should be between 35mm and 55mm for 10mm and 20mm coarse aggregates
- Height of concrete h_2 at the end of the flow is to be measured along with height h_1 in the vertical box next to obstruction
- Blocking ratio is equal to h2/h1 and is a measure of passing ability
- A blocking of 0.8 to 1 is expected for good flow able concrete

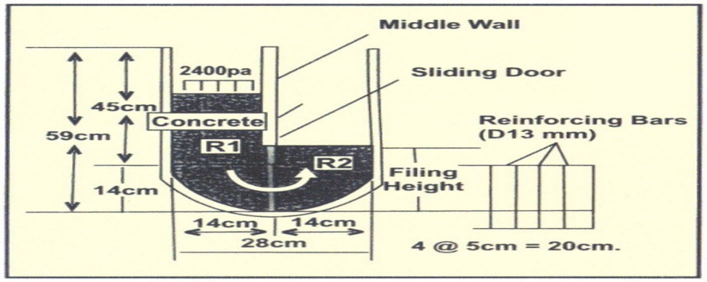
Tests for Evaluating Self-compatibility of Fresh Concrete

4 U-Box Test

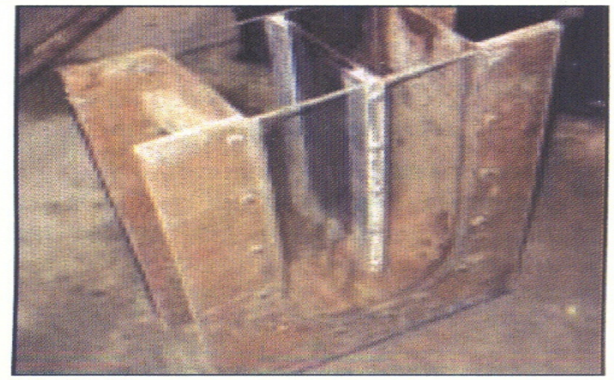
- Assesses the pass-ability of SCC
- Permissible range of difference h_1-h_2 = 300 mm
- A difference of more than 300 mm indicates possibility of blockage with viscosity being on the higher side.
- If $h_1 - h_2$ is close to zero, it indicates low viscosity and concrete could easily pass through.

Tests for Evaluating Self-compatibility of Fresh Concrete

4 U-Box Test

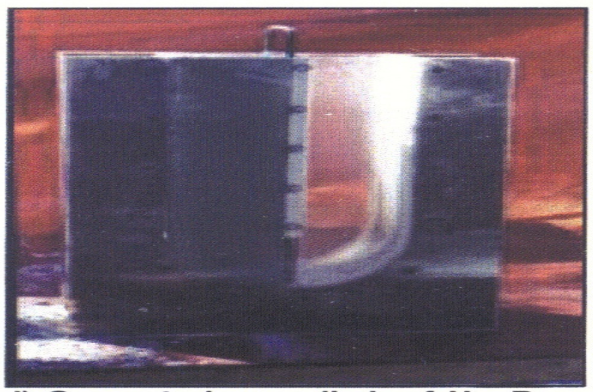


a) U - Box



b) U - Box

c) Concrete poured in the U - box



d) Concrete in one limb of U - Box

e) Height difference measured between 2 limbs of U - Box

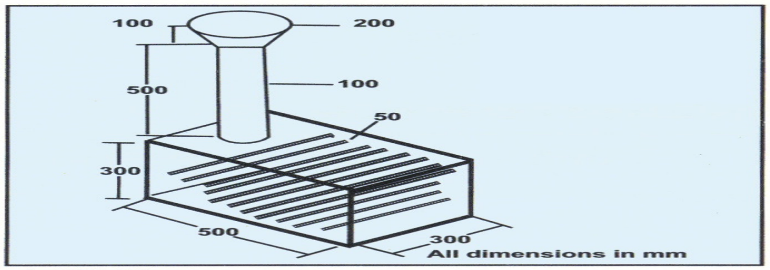
Tests for Evaluating Self-compatibility of Fresh Concrete

5 Fill Box Test

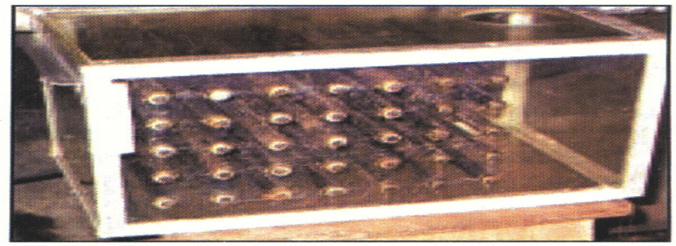
- ✓ **Assesses the filling of SCC**
- ✓ **Place the apparatus on a firm level support having a height of 1 m approximately**
- ✓ **Fill concrete in the box through the funnel provided at the top of the box until it covers the topmost obstacles at the far end of the box**
- ✓ **Compare the net volume of concrete filled with respect to the volume of the box upto the top of the top most obstacles, which gives the filling capacity of SCC.**

Tests for Evaluating Self-compatibility of Fresh Concrete

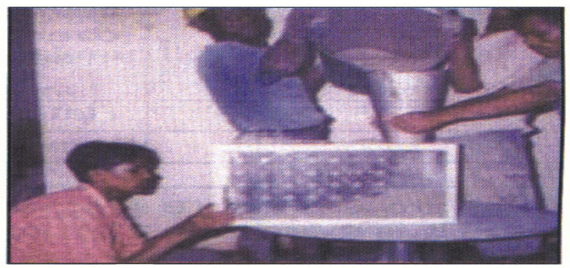
5 Fill Box Test



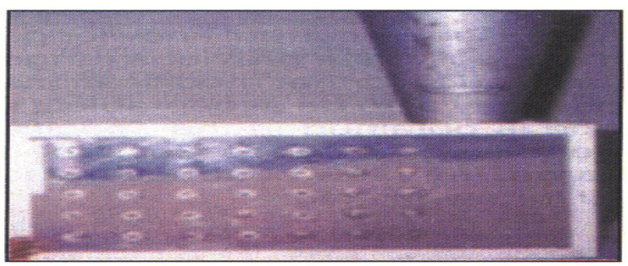
a) Fill Box



b) A view of Fill Box



c) Concrete being poured in the Fill Box



d) Concrete is getting filled in the Fill Box

e) Concrete flows through the obstructions

SCC Acceptance Criteria

Range of Test Values Considered Acceptable

S.No.	Test	Unit	Acceptable Range of Values
1.	(a) Slump Flow (b) $T_{50\,cm}$ Slump Flow Time	mm sec.**	650-800 2-5
2.	a) V. Funnel - T_0 b) V Funnel - T_5	sec. Increase over (2a) in sec.	8-12* 0-3
3.	L Box (h_2/h_1)	Ratio	0.8-1.0
4.	U Box (h_1-h_2)	mm	<30
5.	Fill Box	%	Min 90 (90-100)

Note : * If V Funnel results are less than 8 sec,decrease the water/powder ratio in the mix. If it is more than 12 sec., increase water/powder ratio.

** It is the time needed in Slump Flow test for concrete to spread by 50 cm(mean diameter).

SCC Acceptance Criteria

Properties of SCC and Tests Proposed

Property	Test Methods Laboratory (Mix design)	Field (For Quality Control) Aggregate Size	Modification of Test According To Max.
Filling ability	• Slump flow • T_{50cm} slump flow • V funnel	• Slump flow • T_{50cm} slump flow • V funnel	None Max. 20 mm
Passing ability	• L box • U box • Fill box		Different openings in L-box & U-box.
Segregation resistance	• V funnel at $T_{5\ minutes}$	• V funnel at $T_{5\ minutes}$	None

SCC Acceptance Criteria: Gap analysis

S.No.	Test	Possible reasons for lower test results	Possible reasons for higher test results
1.	Slump Flow	**650mm** Viscosity too high Yield value too high	Viscosity too low Segregation
2.	T_{50cm} Slump Flow	**2 sec.** Viscosity too low.	**5 sec.** Viscosity too high Yield value too high
3.	'V' Funnel T_o	**8 sec.** Viscosity too low	**12 sec.** Viscosity too high Yield Value too high Possibilities of blockage
4.	Increase in 'V' Funnel T_5 Test	**'0' sec.** Doubtful results	**3 sec.** Segregation possibility, rapid loss in workability, probable blockage.
5.	'L' Box	**0.8** Viscosity too high Yield Value too high Possibility of blockage	
6.	Fill Box	**90%** Viscosity too high Yield value too high	**100%** False Results

Note : Yield value is the force (shear stress) that must be exerted on a material to initiate flow. Hence, high yield value means high viscosity.

SCC Acceptance Criteria: Corrective actions

S.No.	Identified Faults	Possible Corrective Action (One or more of the following)
1.	Viscosity is too high	Increase water content, increase paste volume, increase super plasticizer .
2.	Viscosity is too low	Reduce water content, reduce paste volume, reduce super plasticizer, increase viscosity modifying agent, use finer powder, use finer sand.
3.	Yield value is too high	Increase super plasticizer, increase paste volume, increase mortar volume
4.	Segregation	Increase paste volume, reduce water content, use finer powder.
5.	Rapid loss in workability	Increase retarder, use different super plasticizer, substitute filler for cement.
6.	Blockage	Reduce maximum aggregate size, increase paste/mortar volume.
7.	False Result	Check test procedure and other conditions.

ANNEX J

(Foreword)

SELF COMPACTING CONCRETE

J-1 GENERAL

Self compacting concrete is a concrete that fills uniformly and completely every corner of formwork by its own weight without application of any vibration, without segregation, whilst maintaining homogeneity.

J-2 APPLICATION AREA

Self compacting concrete may be used in precast concrete applications or for concrete placed on site. It may be manufactured in a site batching plant or in a ready-mixed concrete plant and delivered to site by truck mixer. It may then be placed either by pumping or pouring into horizontal or vertical forms.

J-3 FEATURES OF FRESH SELF COMPACTING CONCRETE

The following are some of the features of self compacting concrete:

a) Slump flow: 600 mm, *Min.*

b) Sufficient amount of fines (< 0.125 mm) preferably in the range of 400 kg/m^3 to 600 kg/m^3. This can be achieved by having sand content more than 38 percent and using mineral admixture to the order of 25 percent to 50 percent by mass of cementitious materials.

c) Use of high range water reducing (HRWR) admixture and viscosity modifying agent (VMA) in appropriate dosages.'

SCC Acceptance Criteria

IRC: 112 also recommend use of SCC in concrete bridges and the same is under draft stage to be put in rigid pavement and cell fill pavement by IRC.

Production, Placing and Quality Control

- Mixing of Concrete
  - Common Mixers, force action mixers are more preferred
    - Free fall plant and truck mounted mixers
    - Forced Action mixers
  - Mixing Time is longer as compared to control concrete
  - Super-plasticizers to be added towards the end of mixing to get better flow ability
  - Admixtures to be dispensed together with or in the mixing water

Production, Placing and Quality Control

- Transporting of Concrete
  - If produced at site, concrete distributions to be carried out using a concrete pump, skip or chute
  - Truck drum to be cleaned after every trip
  - During waiting time, drum to rotate at not less than one rotation per minute
  - Improper agitation may induce segregation
  - Before delivery, drum to be rotated at full speed of 10-20 rotations per minute for 3 minutes

Production, Placing and Quality Control

- Site acceptance in case of RMC
  - Recommended test for characterizing SCC on site is slump-flow test
  - Gives a good indication of uniformity of concrete supply

- Site requirements and preparation
  - Formwork design, including support and fixing systems, should normally assume that the full hydrostatic concrete pressure is applied to the formwork
  - Good formwork preparation is essential for optimizing surface finish

Production, Placing and Quality Control

- Formwork release agents
  - Formwork used will be steel or resin surfaced plywood
  - Due to ability to achieve a very high quality of surface finish, heavy demands on type and application rate of mould releasing agent
- Formwork for Pumping Bottom up
  - Allows this method of placing concrete
  - Pump is to be connected via a special connector piece with slide valves into the formwork
  - Formwork to be designed to resist the hydrostatic concrete pressure

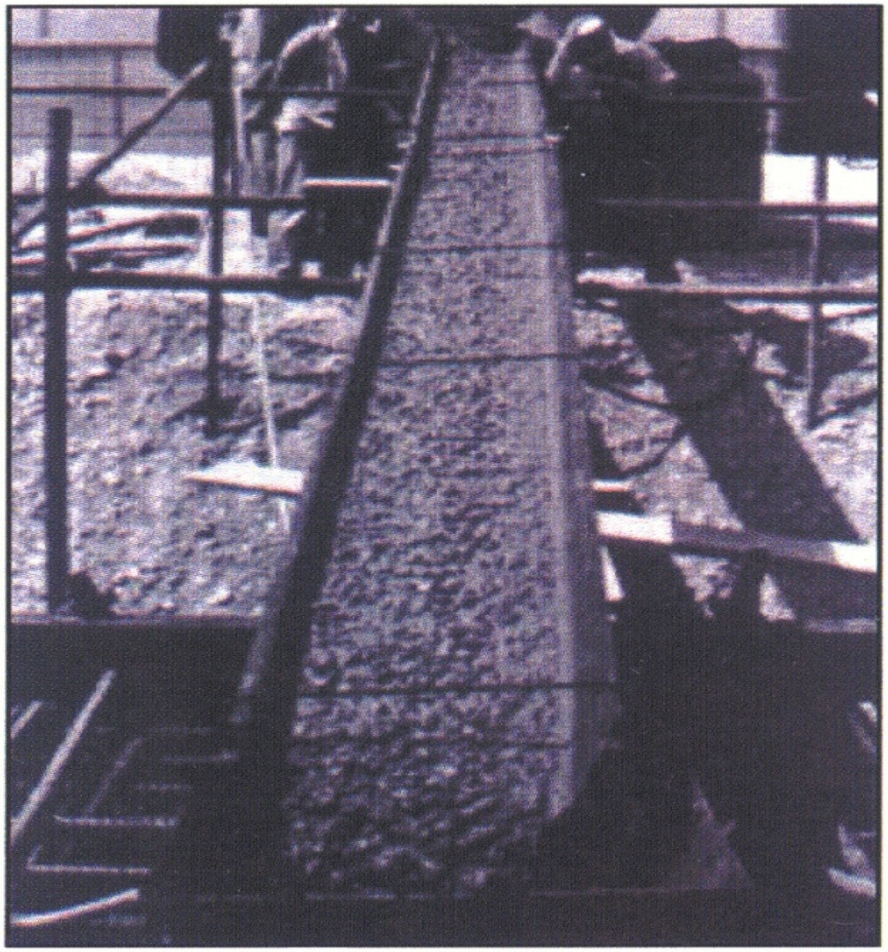
Production, Placing and Quality Control

- Placing by Pump
  - Most common method of placing
  - Suited to pumping through a valve from the bottom of the formwork
  - Method preferred when casting walls in buildings, with system formwork and also in tunnel linings and columns
  - Strengthening existing concrete or placing new concrete within existing structures

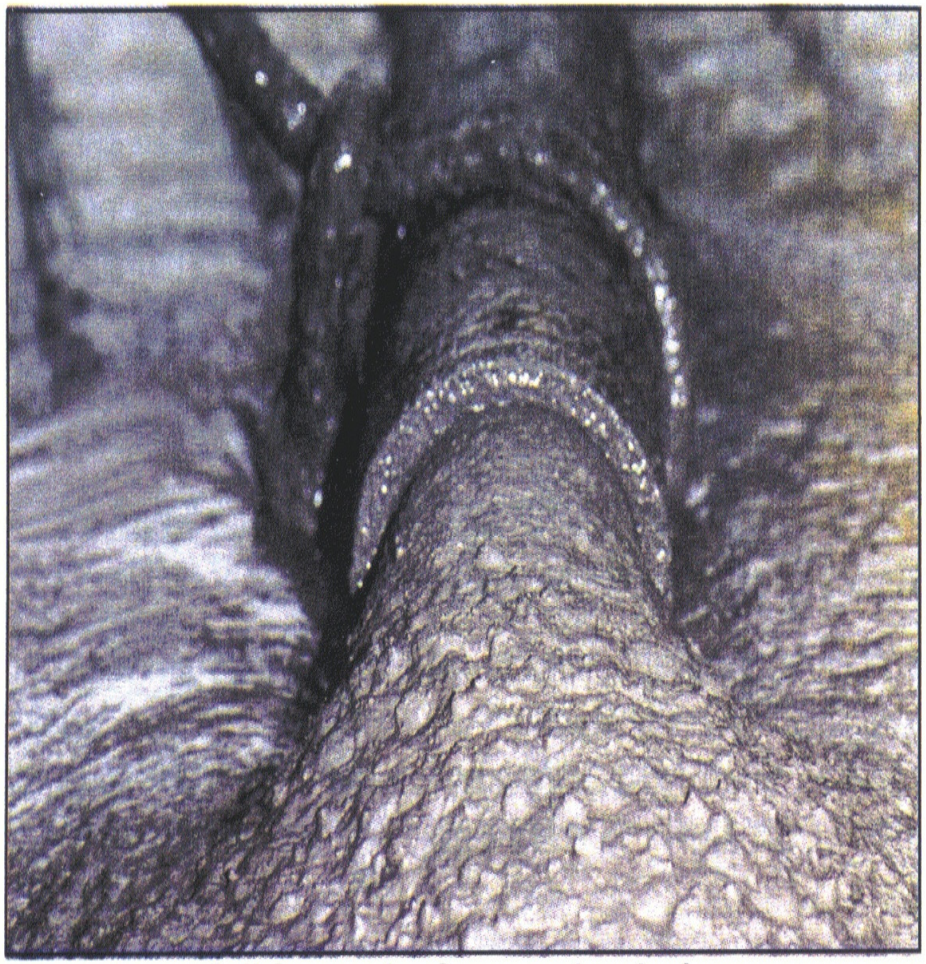
- Finishing Slabs
  - Require low slump flow than for walls and columns
  - Vibrating floats and light vibrating screeds are effective in scree ding of horizontal slab

Production, Placing and Quality Control

- Curing
  - Very crucial for top surface of elements cast using SCC
  - Top surface will dry quickly because of the increased quantity of the paste, the low water to fines ratio and the lack of bleed water at the surface.
  - Initial curing shall commence as soon as practicable after placing and finishing to minimize the risk of surface crusting and shrinkage cracks caused by early age water evaporation



SCC placed using a Chute



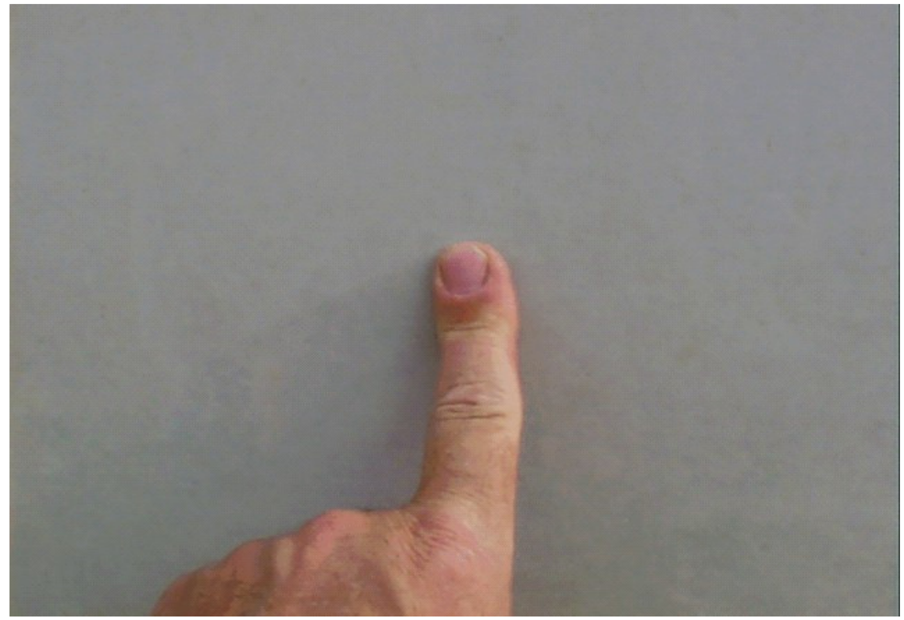
SCC placed using a Pump

Self Compacting Concrete

Casting a SCC Slab for a Commercial centre, Ferrara, Italy

Casting a SCC Slab for a Commercial centre, Ferrara, Italy

Levelling SCC with a Skip Float



On site surface finish at London Piccadilly, Lincoln and Loughborough UK

Properties of Hardened SCC and Durability

- Compressive Strength
  - ➢ Depends on mix design
  - ➢ Value and procedure are same as of control concrete
  - ➢ Self-compactibility has little effect on strength
- Tensile Strength
  - ➢ No major difference in value and procedure compared to control concrete
- Bond Strength
  - ➢ Superior compared to control concrete
- Coefficient of Thermal Expansion
  - ➢ Same as of control concrete

Properties of Hardened SCC and Durability

- Modulus of Elasticity

  Similar value compared to control concrete
- Shrinkage

  As concrete compressive strength is related to the water cement ratio, in SCC with a low water/cement ratio drying shrinkage reduces
- Creep

  Slightly higher compared to control concrete as SCC is more pasty

Properties of Hardened SCC and Durability

- **Shear force Capacity across Pour Planes**
  - **the shear force capacity between the first and second layer may be lower than for vibrated concrete**
  - **A surface treatment such as surface retarders, brushing or surface roughening should be sufficient**
- **Fire Resistance**
  - **The fire resistance of SCC is similar to normal concrete**
  - **a low permeability concrete may be more prone to spalling**
  - **The use of polypropylene fibres in concrete has been shown to be effective in improving its resistance to spalling**

Properties of Hardened SCC and Durability

- Durability

Self-compacting concrete with the right properties will be free from shortcomings and result in a material of consistently low and uniform permeability, offering less weak points for deleterious actions of the environment and, hence, better durability.

Practical Applications

- Reinforced concrete construction components as a load-bearing structure, where it is utilised in creating houses, halls, bridges, tunnels, pillars, roads, floors, foundations, girders, walls, etc.
- On account of its excellent appearance, SCC is also employed as architectural concrete in decorative walls, statues and visible walls as well as in components with filigree and complicated geometry.

Applications

- Complex formwork
- Difficult or restricted access areas
- Heavily reinforced members
- Slabs and floors
- High Walls
- Filling of structural steel pipes

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Case Studies: SCC Mixes at Various Projects

	Hotel	Hotel	Pwr Plant	Metro	Research Organization Building
Concrete Grade	M 50	M 40	M 30	M 35	M 35
Cement	600	400	225	330	470
Flyash	100	100	225	150	0
Binder	700	500	450	480	470
20 mm Agg	65%	420	354	455	432
10 mm Agg		420	354	309	352
N. Sand	35%	800	288	917	920
C. Dust		0	684	0	0
Water	189	174	165	163	194
PCE Admix	0.9%	0.5%	0.4%	0.8%	0.8%
VMA	Nil	0.15%	0.3%	0.2%	0.16%
Slump Flow	750	650	710	690	720
C. Strength					
7 Days	45	30	23.04	33.0	27.80
28 Days	70	65	40.42	46.0	44.50

Applications:**SCC for Rafts & Retaining Walls at Kesar Solitaire**

Materials	Kgs/M^3
OPC 53 grade	400
Flyash	175
"Corniche SF" Silica Fume	20
Binder	595
20 mm Agg	334
10 mm Agg	413
River Sand (Vaitarna)	396
Crusher Dust	432
Water	196
Glenium SKY 584	0.8%
Glenium Stream 2	0.15%
W/B Ratio	0.33
Slump Flow after 60 min	650 mm
V Funnel after 60 min	10 seconds
3 Days	27 MPa
7 Days	42 MPa
28 Days	54 MPa

Summary: Benefits of SCC

- A faster rate of placing, without vibration
- Uniform surface finish can be obtained with less remedial work
- Improved Pump-ability
- Improved consolidation around reinforcement
- Labour and Cost Saving
- Reduced construction period
- Improved overall construction quality
- Human errors (poor workmanship) can be avoided
- Reduced noise- improved health and safety at site
- Reduced equipment cost as no vibrators are required

Summary: Benefits of SCC

- Reduced manpower
- Early strength gain
- Reduced formwork costs as number of repetitive uses are more for SCC
- Denser reinforcement possible
- More innovative designs, more complex shapes, thinner sections, etc. are possible
- Reduced bleeding, proper compaction even in dense/congested reinforcement areas, no honeycombing, etc.
- Fewer defects & hence reduced remedial works
- Improved durability
- Easier placing, better surface finish

THANK YOU