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Self-Compacting Concrete

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Abstract : *Concrete occupies a unique position among the modern construction materials. It is the only material manufactured at construction sites. Of course, concrete has its limitations-it cannot, on its own, flow past obstructions in to nooks and crannies. Thorough compaction often using vibration is essential for achieving strength and durability. As concrete is produced and placed at construction sites, under conditions far from ideal, we do often end up with unpleasant results-rock pockets, sand streaks and a host of workmanship related problems. Repair bills may be staggering and the durability of the structure may be in doubt. Self-compacting concrete (SCC) provides remedies to these problems. In addition SCC is promising to bring revolutionary changes in concrete by reducing site man power, improving durability, easier placing, improved durability, greater freedom in design, thinner concrete sections, reduced noise levels, speed in construction, Etc., SCC is also paving a way to dispose fly ash.*

The paper incorporates almost everything one wants to know about SCC. Starting with the uses the making of SCC is discussed in depth. Specifications, characteristics and testing methods are outlined. The properties of SCC are compared with those of traditionally vibrated concrete (TVC). Monetary terms are eluded basing on research results. A sincere effort is done to wipe out the skepticism that SCC is costly. Major works carried out by SCC are listed out. The paper is written based on the stipulations given by EFNARC on the properties of SCC. In addition the annexure gives valuable information.

potential for the use of SCC in construction projects has been effectively demonstrated in some countries. However a number of issues need to be addressed further to make this a widely acceptable technology. These issues, along with the existing level of research about various aspects of self-compacting concrete, including materials and mix-design, test methods; construction related issues and properties are discussed in this paper.

I. INTRODUCTION

Though concrete is a boon to the modern construction world, the construction engineer is often subjected to some annoying problems.

1. Improper consolidation of inaccessible areas and we cannot ensure quality
2. Tremendous waste of energy in vibration based compaction
3. Vibration related hearing loses and other injuries to workers

So these necessities experienced acutely by Prof. Okhamura in early 90’s paved a way to the invention of an innovative technology, capable of achieving the status of being an outstanding advancement in the sphere of concrete technology and it is none other than the self-compacting concrete (SCC).

“Self-compacting concrete is defined as a flowing concrete mixture that is able to consolidate under its own weight.”

In India, during the last couple of years, a few attempts were made in laboratories and in the field, to develop and apply SCC. The development is still in nascent stage. Despite the pioneering effort of nuclear power Corporation of India ltd., (NPCIL) and a few large contractors, there has been no large-scale application of SCC.

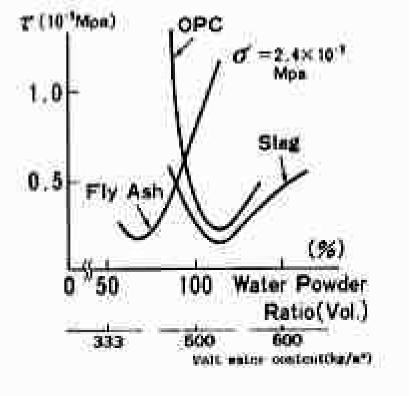
II. USES OF SCC

SCC has several advantages over traditionally vibrated concrete (TVC). They are:

1. Reduction in site manpower.
2. Better surface finishes.
3. Easier placing
4. Improved durability
5. Greater freedom in design
6. Thinner concrete sections
7. Reduced noise levels
8. Absence of vibration
9. Safer working environment
10. Speed in construction

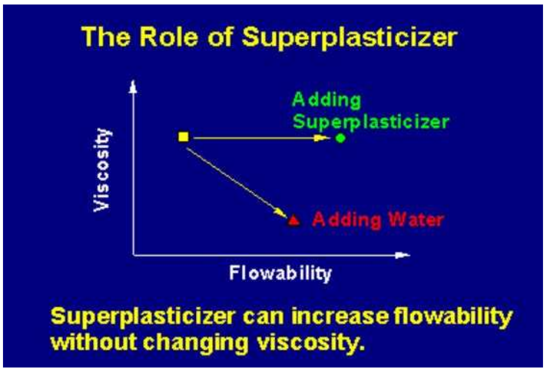
III. THE MAKING OF SCC

One of the main purposes of SCC is to have a better viscosity at a higher flow ability, which is inversely proportional to each other (fig1). By addition of some admixtures and choice of materials used we need to stabilize these properties at maximum level.



At first, it was thought it would be easy to create this new concrete because anti-washout concrete (awuwc) was already in practical use. Awuwc is cast under water and adding a large amount of a viscous agent made of water-soluble polymer strictly inhibits segregation. This prevents the cement particles from dissolving in surrounding water. However it was found that awuwc was not applicable for structures in air for two reasons.

1. Entrapped air bubbles cannot be eliminated due to high viscosity.
2. Compaction in the confined areas of reinforcing bars was difficult.


The Role of Superplasticizer

Superplasticizer can increase flowability without changing viscosity.

There are some changes made in TVC to get SCC. Mixture proportions for SCC differ from TVC. More over, SCC incorporates high range water reducers (HRWR, supper plasticizers).

In larger amounts and frequently a viscosity-modifying agent (vma) in small doses. On a whole the questions arising on materials for SCC are:

1. Water powder ratio
2. Limits on the amount of marginally unsuitable aggregates
3. Choice of HRWRA
4. Choice of VMA
5. Interaction and compatibility between cement HRWRA and VMA.

WATER – POWDER RATIO:

When concrete flows between reinforcement bars, the relative location of the coarse aggregate should be changed. This relative displacement causes shear stress in paste between the coarse aggregate, in addition to compressive stress. In order to assure smooth flow, shear stress should be minimum. Experimental results (1) indicate that the shear force required for relative displacement largely depends on water powder ratio of the paste. From the graph between shear stress and water powder ratio, the optimum water powder ratio is found.

AGGREGATES:

Among various properties of aggregates, the main one for SCC is the shape and gradation. For SCC, round aggregate would provide a better flow ability and less blocking potential for a given water powder ratio, compared to angular and semi rounded aggregates. Moreover, the presence of flaky and elongated particles may give rise to blocking problems in confined areas.

One deficiency in aggregates is poor gradation. Use of fillers (either reactive or inert) has been suggested as a means of overcoming this problem. At present, a trial and error approach is used to fix the type and amount of filler.

HRWR‘s:

HRWR‘s help in achieving excellent flow at low water contents. A number of studies (2,3,4,5) have been conducted on the use of different types of HRWR ‘s with or without vma's. These studies seem to indicate that acrylic co polymers (ac) and poly carboxylate ethers (PCE) are effective at lower dosages compared to sulfonated condensates of melamine (SMF) or naphthalene formaldehyde (SNF).

At present, SNF based admixture is priced lower (in India) than that based on ac and pcc.

Vma:

Vma reduces bleeding and improves the stability of the concrete mixture. An effective Vma can also bring down the powder requirement and still give the required stability.

Research shows that SCC produced with low powder ratio and Vma had similar fresh concrete properties as SCC with high powder content produced without Vma.

Most Vma’s have polysaccharides as active ingredients; however, some starches could also be appropriate for control of viscosity in SCC. Vma should be added after the super plasticizer has come in to contact with the cement particles due to swelling problems.

ADMIXTURE COMPATIBILITY:

There exists the problem of incompatibility between cement and HRWR. Jolicoeur and simard have studied the interaction between them and postulated that in concretes having low water content and high super plasticizer dosage, gypsum (in cement) may precipitate out, causing a premature stiffening of the paste and consequent loss of slump. However, SCC mixtures typically may have a water content of 170-200 l/m^3 and the compatibility problems associated with low water contents may not arise.

ROLE OF FLY ASH:

Now days, fly ash from thermal power stations is posing a problem about its disposal. So we have to explore all possible disposal methods for fly ash. Fly ash is known to enhance the flow ability of concrete. Studies (8, 9) of SCC using fly ash conclude that:

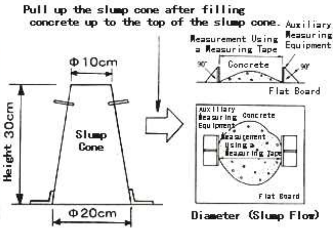
1. Fly ash from domestic coals is superior to other powders (blast furnace slag and lime stone powders) in its effects to enhance flow ability and control heat of hydration.
2. Air content necessary for securing resistance to freezing and thawing is found experimentally.
3. Change in quality of fly ash by type of coal is unavoidable and a mix design planning method is possible.

It is generally accepted that time of setting is retarded when fly ash is used in the concrete, especially class F fly ash. Class C fly ashes have shown both decreased and increased times of setting concrete depending up on the properties of fly ash.

IV. RECOMMENDED SPECIFICATIONS:

1. A good SCC shall normally reach a slump flow value exceeding 60 cm without segregation.

(a) Photo of Slump Flow Test



(b) Method of Slump Flow Test

2. If required, SCC shall remain flowable and self-compacting for atleast 90 minutes.
3. If required, SCC shall be able to with stand slope of 3 % in case of free horizontal surface.
4. If required, SCC shall be pump able for atleast 90 minutes and through pipes with a length of atleast 100 m.

V. MECHANICAL CHARACTERISTICS

1. Characteristic compressive strength at 28 days shall be 25-60 MPa.
2. Early age compressive strength shall be 5-20 MPa at 12-15 hrs (equivalent age at 20°)
3. Normal creep and shrinkage.
4. Although research tends to show that SCC ‘s viscosity varies with the shear rate and acts as a pseudo plastic material’s is often described as a Bingham fluid (viscoelastic) where the stress/shear ratio is linear and characterized by two constants- viscosity and yield stress.

VI. DEVISED TESTING METHODS

Many of the testing methods of ordinary concrete may not suit for SCC.So some testing methods are devised and still many are in constructive stages. These mainly aim at measuring the key properties of SCC.they are defined as:

Filling ability: this is the ability of SCC to flow in to all spaces within the formwork under its own weight.

Passing ability: this is the ability of the SCC to flow through tight openings such as spaces between steel reinforcing bars, under its own weight.

Segregation resistance: the SCC must meet the required levels of properties above whilst its composition remains uniform throughout the process of transport and placing.

Other additional properties, such as wash out resistance, finishability, may be significant.

Some of the tests are:

Sl. No.	Method	Property
1.	Slump flow - Abrams cone	Filling ability (F.A)
2.	T-50 slump flow	F.A.
3.	J-ring	Passing ability (P.A.)
4.	V-funnel	F.A.
5.	L-box	P.A.
6.	U-box	P.A.
7.	Fill box	P.A.
8.	GTM screen stability test	Segregation resistance
9.	Orimet	F.A.

VII. COMPARISON WITH TVC

Various properties of SCC are studied (10) in comparison with TVC and the results are:

a) **Compressive strength:** In all mixes compressive strengths of standard cube specimens were comparable to those of TVC made with similar w/c ratios. There is a little difficulty in producing SCC with characteristic cube strengths up to 60 MPa.

b) **Tensile strength:** This was assessed indirectly by the splitting test of cylinders. For SCC, both tensile strength and relation between tensile strength and compressive strength were of similar order as that of TVC.

Material	***Quantity***	***Rate, Rs***	***Quantity***	***Rate, Rs***	***Differentil***
Cement, Kg	395	3000/t	300	3000/t	-285
Fly ash, Kg	130	1500/t	170	1500/t	+60
20 mm aggregate, Kg	639	370/t	842	370/t	+75.11
10 mm aggregate, Kg	462	370/t	0.0	370/t	-170.94
Crushed sand, Kg	0.0	850/t	235	850/t	+199.75
Natural sand, kg	660	900/t	745	900/t	+76.5
Admixture PCE, l	---	140/l	4.23	140/l	+592.2
Admixture VMA, l	---	40/l	1.41	40/l	+56.4
Admixture SNF, l	5.25	33/l	---	33/l	-173.25

c) **Bond strength:** The strength of bond between concrete and reinforcement was assessed by pull out tests, using deformed reinforcing steel of two different Dias, embedded in concrete prisms for both civil engineering and housing categories. The SCC bond strengths, related to the standard compressive strengths, were higher than those of the TVC.

d) **Modulus of elasticity:** Results (10) available indicate that the relations between static modulus of elasticity and compressive strengths were similar for SCC and reference mixes (TVC) .a relation in the form E/(Fc)^0.5 has been widely reported, and all values of this ration were close to the one recommended by ACI for structural calculations for normal weight TVC.

e) **Freeze/thaw resistance:** This property was assessed by loss of ultrasonic pulse velocity (UPV) after daily cycles of 18 hours at -30° C, and 6 months at room temperature. No significant loss of UPV has been observed after 150 cycles for the SCC or reference higher strength concrete.

f) **Shrinkage and creep:** None of the results obtained indicate that the shrinkage and creep of SCC mixes were significantly greater than those of TVC.

g) **Durability:** Elements of all types of concrete have been left exposed for future assessment of durability but some preliminary tests have been carried out.

The permeability of concrete, a recognized indicator of likely durability, has been examined by measuring the water absorption of near surface concrete .the results suggest that in the SCC mixes; the near surface concrete was denser and more resistant to water ingress than in reference mixes.

A distinguishing of expectations and reality of the properties of concrete is furnished in annexure- 2 & 3.

VIII. HOW ECONOMIC IS SCC?

Many engineers are of the feeling that SCC is costlier than TVC.is it really so? The cost of the ingredients of TVC and SCC differ marginally-SCC materials cost just about 10-15% higher but if an in depth analysis of the other components of costs like the cost of consolidation, finishing, etc is carried out, one would realize that SCC is certainly not a costly concrete.

With a view to arrive at a proper comparison mix was proportional to make SCC have the same target strength as that of TVC. The cost analysis (11) is given as:

Net = +430.77

But that was not all. Let us examine the other cost factors in construction works.

Costing / cu.m	***Standard concrete***	***SCC***
Concrete	36.90	38.53
Admixture	3.53	8.38
Mould and assembly	5.04	5.04
Casting and compaction	8.40	3.03
Stripping	7.56	5.04
Finishing	18.48	0.0
Vibration maintenance	1.00	0.0
Total cost	**80.91**	**60.02**

Moreover men at work will reduce considerably saving their wages and hence it can be concluded that though the cost of materials of SCC may appear to be slightly more (say 15% or so), on a rational basis of total costs and future repairing costs, SCC just outweighs TVC.

IX. APPLICATIONS OF SCC

Use of SCC is being made here and there. However on a large scale basis's was successfully used at

1. Construction of two anchorages of akashi straights bridge opened in 1998,a suspension bridge with longest span in the world (1990 m)
2. Construction of wall of a large LNG tank belonging to Osaka Gas Company in 1998.
3. SCC has been used for the repair of a bridge built in 1960 in the Swiss Alps.

X. CONCLUSIONS

1. SCC is a recent development that shows potential for future applications.
2. SCC meets the demands placed by the requirements of speed and quality in construction.
3. There is non-accumulated evidence that properties of SCC in hardened state are similar to those of Conventional concrete.
4. As with any special concrete, exquisite care is necessary while handling, placing and curing to end up with the desired qualities.

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