Low Fines, Low Viscosity, Self-Consolidating Concrete for Better Impact on CO_2 Emissions

Production of low fines SCC with increased robustness in a highly flowable, less viscous condition meeting true SCC specifications is now a reality to help realise the architect's and engineer's dream of various complex profiles and shapes in various structures across sectors. ***Nilotpol KAR, Managing Director, Master Builders Solutions, South Asia, and Amol Patil, Sr. Specialist- General Manager (Admixture and Specialty Products) Master Builders Solutions, India****, present the concept, which has been validated through a few case studies where huge possibilities of its application exist in various civil engineering sectors.*

Classical Self-Consolidating Concrete (SCC) has its pitfalls in stability and rheology with high cementitious content in the mix owing to the ever-changing concrete constituents. In grades of concrete around the 35 – 50 MPa, the cementitious content and the costs thereof are highly uneconomical to sustain.

In developing economies of Asia Pacific, use of classical self-consolidating concrete is still low and comprised in terms of evaluation. Also, nearly 75% of concrete is still below 40 MPa. Any SCC supplied by a concrete producer for these grades leads to an over design.

For the last decade, low fines SCC has evolved with special tailor-made Poly Carboxylate Ether (PCE) based hyperplasticizer coupled with special focus on the mix design to give a stable and fluid mix to conform to SCC specifications and is referred to as Smart Dynamic Concrete. With the further innovation and evolution of chemistry, tailor-made formulations incorporating special polymers aid in significant improvement in rheology to give better passing ability and segregation resistance. With the climate change policies, this enables better binary and ternary binder compositions to reduce CO_2 emissions and result in improved durability. It is thus a dream come true of a higher performing and versatile concrete – in terms of Ecology, Ergonomy, Efficiency, and Economy.

Introduction

Use of high slump mixes as well as high flowable mixes existed since the 1980s. To activate dispersion in concrete, apart from focus on concrete mix design, optimum water binder ratio, powder type and content optimisation, a suitable comb type polymer – poly carboxylate ether (PCE) – based chemistry to maximise dispersion has been used.

While introduction of flowable mixes changed the dimension in concrete, it did not impact the construction industry in concrete pours except for dense / congested reinforcement. So, while we traverse from 1990s to 2010s less than an estimate of 2 – 4% of all ready mixed or site mixed concrete as an average is used as flowable mixes which typically fulfil all properties of Self Consolidating Concrete (SCC) as per

1. The European Guidelines for Self-Compacting Concrete - Specification, Production and Use.
2. ASTM C1611, the Slump Flow of Self-Consolidating Concrete; ASTM C1621, the Passing Ability of Self-Consolidating Concrete by J-Ring; and ASTM C1610.

Surprisingly, in Japan where the invention of SCC took place, the use is still < 20%.

Figure 1 provides an idea of the self consolidating concrete volume as a part of the total concrete volumes done in that country.

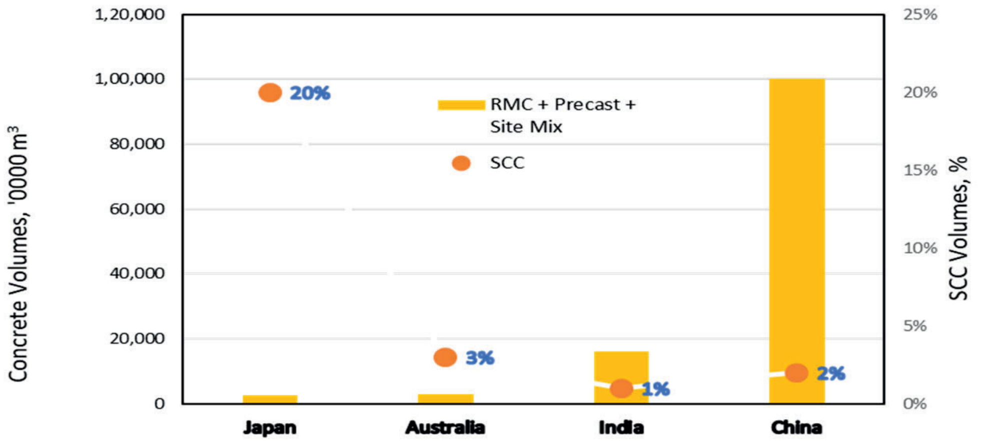

Figure 1: Estimated total concrete volumes and % of Self Consolidating Concrete (SCC) as % of total concrete volumes

Amongst the challenges to produce a perfect SCC in practice, it is designed for its rheology. It is important to have a perfect balance and homogeneity between flow and cohesion to avoid segregation and bleeding, so the placement and self consolidation happens perfectly in tune inside the confines of the structural sections especially in conditions of dense or congested reinforcement. In normal SCC mixes anything in excess of 500 kg/m^3 is required where no less than 450kg is made up of cementitious content. The resultant mix is that the compressive strength is very high in the order to 60 to 75MPa. In many cases, this is an over design especially in the Indian context. Majority of concrete class required is less than 40 MPa and nearly more than 75% is between 30 – 45 MPa for the most commonly used grades of concrete in construction practice.

To make a justifiable point here is a case of a concrete structure falling in the category of R2 reinforcement (as per JASS) and strength class 30 MPa requiring joint-less concrete. The viable option here is SCC; however, the binder or cementitious fines to have a classical slump flow (spread) of > 600 mm and other limits of T500, L-Box, J-ring values would require somewhere to the tune of 450 kg/m^3 of cementitious fines with standard poly carboxylate ether based admixtures. This would result in "overkill" in the concrete mix design – this is probably one of the biggest reasons why such a concrete, despite the immense benefits never grew popular across India owing to exorbitant costs.

Relevance of Self Consolidating Concrete and the path to low cementitious fines self consolidating concrete in India

Post two waves of Covid and the recovery in infrastructure and other sectors, the construction boom in India provides an opportunity for clients, developers, contractors, ready mix concrete and precast concrete companies to higher output without

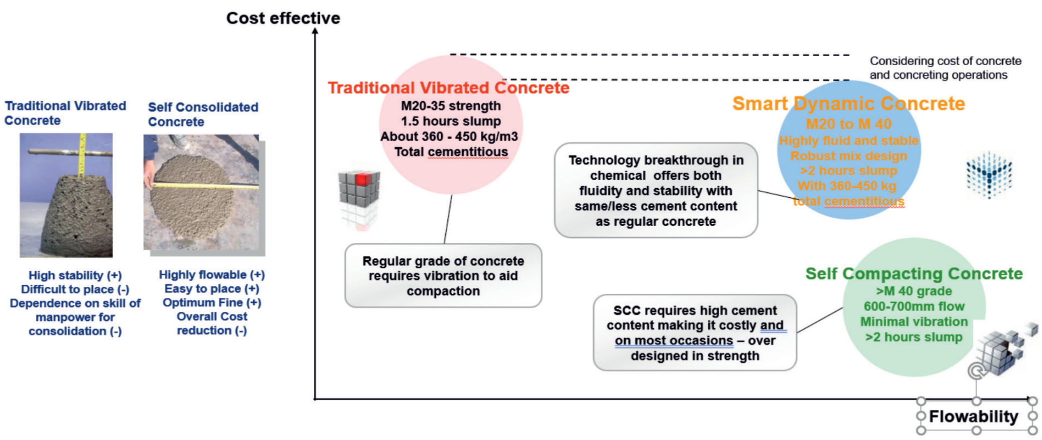

Figure 2: Smart Dynamic Concrete (SDC) incorporates the economics of regular ready-mix concrete and high performance of SCC

compromising on durability aspects of concrete (matrix, pore structure, permeability, water absorption, shrinkage, modulus of elasticity, recued cracking). For the popular grades of concrete a novel type of a tailor-made PCE based hyperplasticizer enables a practical on-site stable low fines self consolidation concrete (referred to as Smart Dynamic Concrete) taking care of Ecology, Efficiency and Ergonomy in the drive for some key aspects on the balance between "Environmental, Economic and Social" indicators. Fig 2 represents the balance between cost effective and flowability where low cementitious fines self consolidating concrete (also known as Smart Dynamic Concrete or SDC) establishes a definite path to achieving self consolidation in normal grades of concrete with all properties of traditional properties of SCC intact.

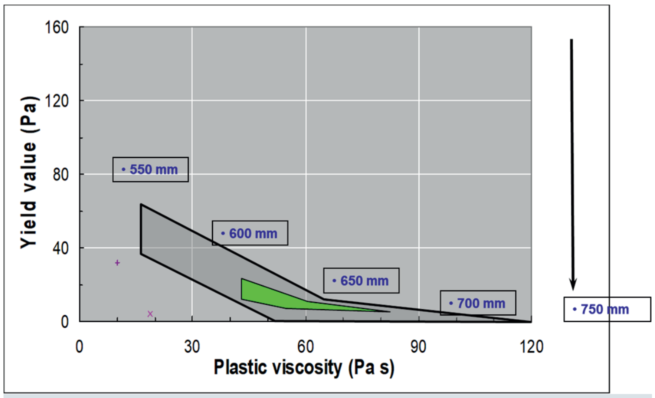

Figure 3: Correlation in flowable concrete like SCC and SDC between Yield Value and Plastic Viscosity.

Today, designers are also interested in making complex designs with ordinary concrete as we step into the age of differentiation. All the stake holders are looking for "differentiation" in the market to capture customers' attention and take a unique position whilst improving their service levels – value engineering. Concrete is a commodity and concrete producers endeavour to move away from the commoditisation of the second largest consumed material in the world (after water). In the quest for Value Added Concrete as a form of differentiation in the very competitive concrete market, there is immense possibility with a sustainable type in form of SDC.

A decade long innovation in making ordinary concrete, extraordinary

Smart Dynamic Concrete (SDC), a low-cementitious fines self consolidating concrete incorporates the ideal properties of cost effectiveness of regular ready-mix concrete and the flowability of conventional SCC as per the testing parameters laid in EFNARC / ASTM. The current challenges of energy efficiency, availability of labour, project delivery on time, speed and return on investment can be overcome with a sustainable and very dense matrix in the cover of concrete offering higher durability and flowable concrete (highly fluid) to save time and money. Reduced energy for consolidation of concrete, repair / rehabilitation issues, placement times and hence concrete placement times are reduced by at least 20 to 40%. Even SDC can flow without aid of vibration for 10 – 15 metres!

The role of construction chemicals gets pivotal here. The stability zone of self consolidating concrete is shown in Fig 3. The fluidity depends on a correlation between yield value and plastic viscosity which can be managed through the unique innovative concept of SDC. This is enabled with a unique PCE based hyperplasticizer tailor-made with a unique viscosity controlling agent to incorporate a perfect balance in a normal grade concrete without increasing cementitious fines and / or powder content. And yet achieve the entire SCC properties a required for an SDC.

Some other salient values include:

(i) Reduction in noise at site (1/5th to 1/10th) and minimal vibration to deliver improved health and safety at construction sites.

(ii) Reduced manpower up to 33% compared to conventional concrete

(iii) Higher levels of SCMs (supplementary cementitious materials) to delivery quantifiable sustainable benefits towards lower CO_2 emissions. EPDs are possible to support in Green Building Certifications.

(iv) The structural designer and architect can be emboldened to create more innovative, complex designs as well as exposed fair faced concrete.

(v) Owing to stability of the mix and its segregation resistance the resultant bleeding is lower than limits – this enables reduction of micro-cracking and the ITZ is benefited for a more durable and uniform concrete matrix.

(vi) For the same grades of concrete – SDC vs traditional vibratable concrete delivers lower chloride diffusion values and lower permeability values.

A few case studies over the last 10 years

a. Pashmina Waterfront: Bengaluru, Karnataka

This project in Bangalore had challenges of high-rise pumping, form finish concrete and cycle time of modular formwork. Approximately 60,000 m^3 of concrete was done with SDC concept with a reduction of cement content by 20 kg/m^3, enhanced surface finish and reduction in concrete placement time by 25% enabling better cycle of formwork.

Figure 4: Concrete Finish with SDC at a Pashmina Waterfront project

b. Kalinganagar Township Project: Jaipur, Odisha

The available aggregates for the grades of concrete posed a challenge for a sticky mix and SDC enabled a low viscosity concrete with a V Funnel time of less than 10 seconds creating a better placement situation which improved by 25%. Fig 5 below is a snapshot of the project.

Figure 5: Concrete Finish with SDC at a township project in Eastern India

c. Kalpataru Crescendo: Pune, Maharashtra

The contractor had to deliver 35,000 m^3 and the challenges to have an economical SCC mix to deliver form finished concrete. SDC technology aided with a tailor made hyperplasticizer enabled a concrete which could be pumped at 25% lower pump operating pressure, including 3 slab cycles in a month compared to previous 2and 6 floors were completed in 2 months. Figure 6 provides a good glimpse of the surface finish.

Figure 6: Concrete Finish with SDC at a premier project in Pune

d. Shanghai Tower: Shanghai, China

Amidst a tight construction schedule for pouring > 60,000 m^3 of concrete in a huge raft in a single pour of 6 m thick raft. This was a mass concrete application requiring low cementitious content to control heat of hydration development as well as use of manufactured sand mandatorily due to limited availability of river sand. With a tailor-made PCE for SDC, an amazing record of nearly 60 hours over a weekend was the time taken with nearly 1,000 m^3 per hour concrete placement serviced by nearly 7 concrete plants and over 450 truck mixers. All fresh and hardened properties of concrete were maintained including the peak temperature < 65^{o}C in the core, whereas placement temperature was < 23^{o}C. Fig 7 below consist of a site photograph and Table 1 that is the strength progression chart.

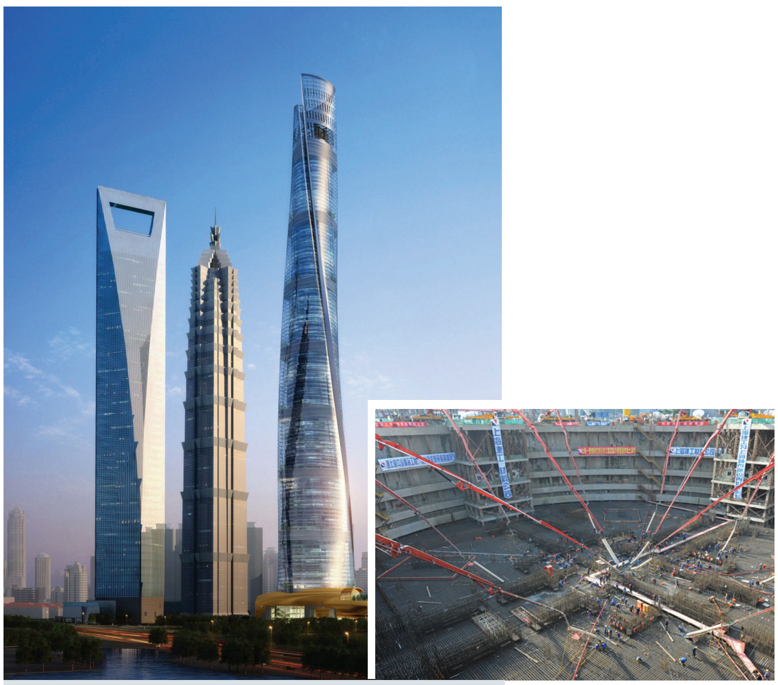

Figure 7: >60,000 m^3 of SDC for the raft foundation of Shanghai Tower in China

Table 1: 90 days strengths progression for specified C50 concrete				
Days	7d	28d	60d	90d
Average (MPa)	39.8	56.9	63.0	66.5

Conclusions

Low fines SCC (SDC) addresses the needs of the various stake holders across the construction industry and addresses the current challenges of speed, efficiency and durability of concrete structures especially in the common grades up to 40 MPa which constitutes more than 75% of the concrete in India. This type of concrete goes into structures that are not heavily reinforced (everyday RCC structures). This eliminates the extra costs related to fines (material, silos, handling, logistics, etc.) and reduces the binder content for the required strength class. This means less cement or more supplementary cement materials (SCM).

The innovative PCE based hyperplasticizer inbuilt with a special state of the art viscosity modifying admixture is now available in India and almost more than 5 mio cubic metres of concrete have been laid in India alone with this unique SDC concept. It is poised to make a breakthrough for increasing the use of self-compacting concrete in the construction industry as it offers multiple benefits to the various stake holders.

Acknowledgement

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