Discussion Forum

Self-compacting concrete

The Special Issue on self-compacting concrete (SCC) published in June 2004, Vol 78, No 6, has opened a window to another new and relevant technology to compact concrete — without vibration — which is so very necessary in sections of structures with congested reinforcement.

The Nuclear Power Corporation has kept up its reputation of being in the forefront of every new technology in its sphere of engineering activities by already experimenting and using this technology in pump house construction at the Tarapur and Kaiga power plants. Congratulations to Mr A. Mittal *et al* and S.G. Bapat *et al* for their very informative two papers published in this regard[1,2]. A close reading of these two papers along with the one by Praveen Kumar *et al* brings out a few questions posed below, clarification of which will go a long way in expanding knowledge in this important subject[3].

Mr A.K. Mittal has cast a pump house wall — partly submerged in sea water (Tarapur cooling water) using SCC of 40 MPa grade, with water/powder ratio 0.8 to 1.00 (by volume) and total powder content – 160 to 240 l/m^3. Other constituents are 300 kg cement, 200 kg fly ash, 25 kg micro-silica, 175 kg water, 664 kg coarse aggregate, 976 kg fine aggregate, 12.60 kg (2.4 percent by weight of cementitious material) superplasticiser, presumably of the sulphonated naphthalene type, and viscosity modifying agent (VMA) powder – 52.3 g (0.03 percent by weight of water). He has not stated which type of VMA has been used – diutan gum or polyacrylic based. The use of SNF-type superplasticiser instead of poly carboxylic type used by his colleague, Mr Bapat has no doubt made the mix economical, the use of silica fume has however offset this economy. Further, since he has used silica fume which, at a high superplasticiser dosage, could act as a viscosity modifier by micro-filler effect and restraining segregation and bleeding, could he not have eliminated VMA totally? Did he make any experiment in this regard without VMA? In the same issue, there is a paper by Praveen Kumar *et al* where the authors have obtained 45-47 MPa SCC without VMA, consisting of 300-300 kg/m^3 cement, 350-400 kg fly ash, 22.5-22.5 kg micro silica (7.5 percent by weight of cement — less than that of Mittal), 174.9-137.9 *l* of water, 6.00-34.8 kg of modified PCE as superplasticiser, 441-415 kg of 10 mm nominal CA and 147-138 kg of 20 mm nominal CA and 883-830 kg of FA. As these mixes also performed satisfactorily in laboratory, there is perhaps scope for economy in Mr Mittal's mix. Is it that the shape and size of Mittal's aggregates being more angular and harsh, the mix was prone to segregation and therefore mix designed was the optimum? Any views in this regard would be welcome. Further, he has defined powder content as the sum of cement, pozzolanic material and sand particles finer than 125 micron, whereas Praveen Kumar *et al* have only added up the cementitious material quantities to arrive at the total powder content. He may please clarify the correct definition of total powder.

One more point, it has been reported elsewhere that some portion of this cooling water structure has rebar coating as additional corrosion protection. If so, the addition of silica fume, (having seven days pozzolanic activity index almost same as that of fly ash) for the purpose of durability alone, is a matter of opinion. He may also throw some light here. In fact J. Annie Peter *et al* has not used either silica fume or VMA and achieved the strength with good ductility index by using only 0.4 percent by weight of binder as superplasticiser.

Mr Bapat's paper also requires few clarifications.[2] His finally adopted mix given in *Table* 3 of his paper is more or less same as that of 450 F50 given in *Table* 2, excepting the superplasticiser and VMA dosage. In fact, the mix adopted is apparently much costlier with 1.80 kg/m^3 of polycarboxylic superplasticiser (as against 0.4 kg/m^3 of the trial mix) and 1.35 kg of VMA/m^3 (as against only 0.3 kg/m^3 of the trial mix) compared to the trial mix which had 28-day compressive strength of 37.97 MPa as against the target mean of 38.25 N/mm^2 – and a small fine tuning here could have achieved the desired goal. In fact, he has not reported the 28-day strength actually obtained though he has reported the 56-day strength as 50 MPa, which none of the trial mixes of *Table* 4 have achieved. It is not also understood why instead of cost effectiveness he discontinued the use of the much-cheaper SNF-based superplasticiser with VMA.

The surface of the core sample with conventional concrete as shown in *Fig* 10

has come out quite all right and F-3 finish could have been achieved on such concrete surface in the normal manner. The reported cement content of 325 kg/m^3 and w/c ratio of 0.48 have resulted in M30 grade concrete, apparently without use of any plasticiser (w/c ratio being quite high) as also without any need of strengthening the form work. Under the circumstances does he think SCC would be still cheaper than normal strength concrete? His clarification is sought in this regard. Further, the discusser feels that looking to the reinforcement arrangement and the strength requirement, conventional concrete would have been a better option here.

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References

1. Mittal, Amit, Kaisare, M.B. and Shetti, R.G. Use of SCC in a pump house at TAPP 3&4, Tarapur, *The Indian Concrete Journal*, June 2004, Vol. 78, No. 6, pp. 30-34.

2. Bapat, S.G., Kulkarni, S.B. and Bandekar, K.S. Using SCC in nuclear power plants — Laboratory and mock-up trials at Kaiga, *The Indian Concrete Journal*, June 2004, Vol. 78, No. 6, pp. 51-57.

3. Kumar, Praveen, Haq, Mohd. Ajazul, and Kaushik, S.K. Early age strength of SCC with large volumes of fly ash, *The Indian Concrete Journal*, June 2004, Vol. 78, No. 6, pp. 26-29.

Mr Mittal replies:

We are thankful to Mr P.K. Singha Roy for his comments. Our point wise response to his comments are as follows.

(i) While designing and using SCC mix for CCW pump house at TAPP-3&4 diutan gum VMA was used as it was found to be more cost effective as compared to polyacrylic-based VMA.

(ii) As per the specifications for CCW pump house all the structures below ground level are constructed using microsilica to improve the durability characteristics. A part of this pump house (W7 walls) was constructed using SCC. To maintain the same specifications microsilica was also used in SCC too. The use of microsilica also helped in improving the segregation resistance of concrete along with improved durability.

(iii) We also did a few trials without the use of VMA and got satisfactory results. But we observed that if VMA was not added in the mix then the SCC mix became very sensitive to any change in the total water content due to variation of moisture condition of coarse and fine aggregate. Therefore, although in the laboratory it was possible to get good SCC mix without any VMA, under actual field conditions it was quite difficult to maintain the proper segregation resistance of SCC. Therefore use of VMA was recommended.

(iv) If we compare the SCC mix of Mr Praveen Kumar *et al* with SCC mix of TAPP-3&4 there is a lot of similarity in cement content, microsilica content, ratio of fine aggregate to coarse aggregate as well as 28-day compressive strength. The only major difference is that Mr Praveen Kumar *et al* used 350 kg and 400 kg fly ash in mix 2 and mix 3, respectively while for TAPP-3&4 mix we used only 200 kg of fly ash. Therefore in overall cost TAPP-3&4 mix appears to be more economical. In our opinion, final proportioning of SCC depends largely on type and shape of coarse and fine aggregate and any change in the material characteristics optimum proportioning will also change.

(v) As per EFNARC, the powder is defined as material of particle size smaller than 125 micron. It also includes the quantity of sand below 125 micron. Since the EFNARC guidelines were used for designing the SCC mix, terminology as defined by these guidelines were also followed.

(vi) As already indicated, for CCW pump house all the structural elements below ground level were designed considering microsilica concrete, the same specification were is followed for SCC also. Since CCW pump house uses sea water therefore as an additional precaution the reinforcement was also epoxy coated. These specifications are given by the designer considering the criticality of the structure.

I hope that we have answered all the queries raised by Mr P.K. Singha Roy.

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Mr Bapat replies:

I would like to thank Mr Singha Roy for his comments pertaining to our paper. The response is as given below:

(i) VMA, mentioned in *Table* 2 is indicated as percentage of total powder content. This is clearly mentioned under 'Mixture design'. VMA mentioned in *Table* 3 is in terms of kg/m^3 and the value is correct.

(ii) Mixture proportioning is for M 30 grade concrete with target mean strength of 38.25 MPa. Results obtained in trial mix, as indicated in *Table* 4, shows that all values are above 38.25 MPa except one value, which is 37.97 MPa. As per acceptance criteria given in IS 456 : 2000, any individual strength can be (f_{ck}-4) MPa, which is (30-4) = 26 MPa. Also, in any group of four non-overlapping samples, strength should be (f_{ck} + 4) MPa, which is (30+4) = 34 MPa. The value 37.97 MPa meets the acceptance criteria.

(iii) The statement regarding the 56-day strength being 50 MPa was a generalised comment. Actual average 56-day strength achieved, as can be seen from *Table* 4, is 52.10 MPa.

(iv) As regards to use of polycarboxyl-based admixture, in place of SNF-based admixture, the reason for the adoption of the former is mentioned in the paper under 'Mixture design'. In addition, it was observed during trials that workability retention, when SNF admixture is used, was around one hour as against three hours in case of polycarboxyl-

Table 1: Comparison on the basis of trial mixes

	SNF + diatun gum			*Polycarboxylic + Acrylic based VMA*		
	Amount, kg	*Rate, Rs*	*Cost, Rs*	*Amount, kg*	*Rate, Rs*	*Cost, Rs*
Cost of admixture	9.9	35.00	346.50	1.8	115	207.00
Cost of VMA	0.035	1200	42.00	1.35	60	81.00
Total, Rs/m^3			388.50 /m^3			288.00 /m^3

based admixture. This was also one of the considerations in selection of admixture type. Also, the dosage of SNF-based admixture was 2.2 percent as against dosage of 0.4 percent in case of polycarboxyl-based admixture. Cost comparison, on the basis of trial mixes, is as given in *Table* 1.

- If we consider mixture design, given by Mr Amit Mittal in his paper based on TAPP-3&4 experience, the cost of admixture works out to Rs 441.00/m^3 of concrete for SNF-based admixture plus Rs 62.40/m^3 of concrete for VMA (diatun gum) that is, Rs 503.40/m^3 of concrete. In addition, 25 kg micro silica has been used with cement content of 300 kg/m^3.

- Statement made under 'Mixture design', namely, "if compatible SNF-based admixture is developed, the use of diatun gum as VMA may be cost effective", is of general nature.

(v) Getting good finish is one of the advantages of using SCC. Basically, vibrating efforts are not required, which eliminates possible human error. It enhances impermeability characteristics of concrete (durability aspects). Photographs of core samples of conventional concrete and SCC, clearly indicate that the core of SCC is superior in appearance. The statement that conventional concrete is apparently without admixture, is not correct. Admixture was used to get the required workability. Also, we do not agree that by merely giving closer consideration to the reinforcement arrangement and the strength requirement, conventional concrete would have been a better option. We would like to state that without taking two additional construction joints, one at bottom of the tie beam and one at top of tie beam, it was impossible to cast this column with defect-free conventional concrete.

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Summing up by Guest Editors

It is a matter of satisfaction that the Special Issue on "Self-compacting concrete" could attract contributions on various aspects of this new development. The Editorial team laid appropriate emphasis on field experience and we would like to place on record our appreciation of the efforts of the authors.

The comments by Mr Singha Roy and the responses from the authors give an opportunity to clarify some issues and elucidate a few points of practical interest.

One common feature of the SCC mixes in the two NPC projects is the low powder content, which is approaching that of conventional concrete. In the early days of development in Japan, the powder content was high and the question of autogeneous shrinkage of SCC was raised and addressed by some research workers in that context. Subsequent to the early developments using only powders, VMA has also been used to control the segregation tendency of highly flowable mixes. Now the mixes are classified into three categories:

(i) powder type

(ii) VMA type

(iii) combined type.

The last type uses both higher powder content and VMA to control the viscosity. One can view the Tarapur mix as a 'combined type' and the Kaiga mix as a 'VMA type'.

Mr Singha Roy has raised the possibility of proportioning SCC without using any VMA. It is possible to proportion such mixes using high powder content. However, practical considerations dictate otherwise. The first consideration is stated by Mittal: "… if VMA is not added, the SCC mix becomes very sensitive to any change in total water content due to variations in moisture content of aggregates…" The second consideration is the possibility of autogeneous shrinkage in concretes with high powder contents. A third one is the effectiveness of conventional superplasticisers in mixes with high powder content.

While reporting the investigations or applications, it is desirable to consider whether to give the dosage of VMA as a percentage of water content in the mix in contrast to superplasticisers, which are specified as a percentage of cement or powder content. In the case of polysaccharides (diutan), the manufacturer recommends the dosage as a percentage of water. The user should also check whether the VMA is compatible with the superplasticiser. VMAs based on polysaccharides are compatible with all superplasticisers currently in common use. However, those based on, say polyethylene glycols may work only with specific categories of superplasticisers. The admixture supplier should be consulted

regarding combinations of VMAs and superplasticisers. Sometimes, use of a retarded superplasticisers in combination with some VMAs may result in extended setting times.

The practice of assigning the proportions of materials in terms of weights seems to be getting extended to SCC mixes. SCC mixes may contain a variety of powders, differing in their densities; 300 kg of cement and 200 kg of fly ash is not the same as 300 kg of cement and 200 kg of slag powder, when we consider their solid volumes. It is time that the trend is halted. It will be helpful if additional information regarding solid volume is furnished whenever tests or applications are reported.

There is some debate on the definition of "powder". In SCC mixes the powder content is a critical parameter that controls flowability of the mix. There should be agreement regarding the definitions and Mr Mittal's use of EFNARC is appropriate.

Mr Singha Roy has raised a point whether one can dispense with the use of silica fume in SCC. It is possible to proportion SCC without using silica fume. However, if the specifications call for use of silica fume, one can as well take advantage of that. Generally, a lower powder content or VMA dosage and a higher superplasticiser dosage will be required, when silica fume is used.

A penchant for specifying high strengths and low water-cement ratios for SCC is discernible, even before large-scale applications have become common. While proportioning SCC, the focus should be on flowability and stability. It will be better to make a beginning with concretes of lower grades, say M20, which have the required characteristics of SCC and then move on to higher grades as one gains experience.

SCC is perceived to be a high cost proposition. Costs and specifications seem to be the barriers in the widespread use of SCC. Therefore a few remarks about the perception of high costs may be in order. Firstly, the cost of admixtures should not be viewed in isolation. A VMA costing say Rs 1200 per kg may be required only in a miniscule amount. It is also possible that a third generation plasticiser is recommended as an admixture for SCC, but it may not have a VMA in it. On some occasions low water cement ratios are taken for estimating purposes and this may result in high dosage of superplasticisers when an SCC mix is developed. A reasonable water content of say 175-185 l/m^3 and an equivalent powder volume may result in reasonable dosages for superplasticisers and VMA.

The advantages of using SCC have been listed in the *Editorial* in the Special Issue and we draw attention to the excellent durability and finishes obtained with SCC. It is evident that this Special Issue has created awareness and interest in SCC. The Editors look forward to publishing more about the actual use of SCC in future.

— On behalf of the Editorial Team

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