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Research paper

Mix proportioning of M80 grade Self-Compacting Concrete based on Nan Su Mix design method principles

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Abstract

The quest for the development of high strength and high performance concretes has increased considerably in recent times because of the demands from the construction industry. High-performance concretes can be produced at lower water/powder ratios by incorporating these supplementary materials. Fly ash addition proves most economical among these choices, even though addition of fly ash may lead to slower concrete hardening. However, when high strength is desired, use of silica fume is more useful. This paper proposes a mix proportions for M80 grade Self-compacting concrete (SCC) based on Nan Su mix design principles. First, the amount of aggregates required is determined, and the paste of binders is then filled into the voids of aggregates to ensure that the concrete thus obtained has flowability, self-compacting ability and other desired SCC properties. The amount of aggregates, binders and mixing water, as well as type and dosage of superplasticizer (SP) to be used are the major factors influencing the properties of SCC. Slump flow, V-funnel, L-flow, U-box and compressive strength tests were carried out to examine the performance of SCC, and the results indicate that the Nan Su method could produce successfully SCC of high strength. Based on Nan Su mix design method, material quantities such as powder content (Cement + Pozzolan), fine aggregate, coarse aggregate, water and dosages of SP and VMA, required for 1 cu.m, are evaluated for High strength grade (M80) of Self Compacting Concrete (SCC) are estimated. Final quantities, of M80 grade SCC mix, is assumed after several trial mixes on material quantities computed using Nan Su mix design method subjected to satisfaction of EFNARC flow properties.

1. Introduction

Self-compacting concrete (SCC) is a new kind of high performance concrete (HPC) with excellent deformability and segregation resistance. It is a special concrete that can flow through and fill the gaps of reinforcement and corners of moulds without any need for vibration and compaction during the placing process. To produce SCC, the major step is designing an appropriate mix proportion and evaluating the properties of the concrete thus obtained. In 1993, Okamura proposed a mix design method for SCC. The major advantage of this method is that it avoids having to repeat the same kind of quality control test on concrete, which consumes both time and labor. However, the drawbacks of Okamura's method are that (1) it requires quality control of paste and mortar prior to SCC mixing, while many ready-mixed concrete producers do not have the necessary facilities for conducting such tests and (2) the mix design method and procedures are too complicated for practical implementation. The ''Standardized mix design method of SCC'' proposed by the JRMCA is a simplified version of Okamura's method. This method can be employed to produce SCC with a large amount of powder materials, and a water/binder ratio of < 0.30. On the other hand, the Laboratory Central DesPontset Chausses (LCPC), the Swedish Cement and Concrete Research Institute (CBI), research groups in both Mainland China and Taiwan all have proposed different mix design methods of HPC. The LCPC's approach is developed on the basis of the BTRHEOM rheometer and RENE LCPC software. It is difficult for others to adopt their method without purchasing the software. CBI's approach makes use of the relationship between the blocking volume ratio and clear reinforcement spacing to fraction particle diameter ratio. However, it is not clear how to carry out the critical tests because concrete mixed with coarse aggregates and paste only is susceptible to severe segregation. In Taiwan, the method proposed by Hwang et al. involves a densified mixture design algorithm, which is derived from the maximum density theory and excess paste theory. Nevertheless, there is no information yet concerning the relationship between their method and the ability of concrete passing through reinforcement or its segregation resistance. Hon's group of Mainland China has not disclosed their mix design procedures, but just offered some useful principles. They have also shown that too low a paste volume not only impairs the passing ability of concrete, but also reduces its compression strength if no vibration is used in the mixing process. Hence forth this study tried to utilize Nan Su mix design procedure for SCC. The procedures are given below.

2. SCC Mix design Calculations for High Strength (M80) Grade SCC using Nan Su Mix Design

The following is the mix design for high strength grade (M80) is based on Nan Su mix design method.
Characteristic strength MPa 80
Target mean strength MPa 80 + 1.65 X 6 = 89.9
Aggregate size mm 10
Specific gravity of coarse aggregate 2.6
Bulk density of loose coarse aggregate kg/m3 1434
Specific gravity of fine aggregate 2.57
Bulk density of fine aggregate kg/m3 1474
Volume of fine / coarse aggregate ratio 50 / 50
Volume ratio of fine aggregate to total aggregates (s/a) 50 / 100=0.50
Determination of fine aggregates kg/m3
Assume P.F = 1.10
Ws = content of fine aggregate in SCC (kg/m3)
Ws = P.F.X Wsl X (1 – s/a) = 1.10 x 1434 x 0.5 kg/m3 810
Determination of coarse aggregate kg/m3
Wg = content of coarse aggregate in SCC (kg/m3)
Wg = P.F. X Wgl x (1-s/a) = 1.10 x 1434 (1-0.50) = 788 788
Determination of cement content
C = 89.9/0.14 = 89.9 / 0.14 = 644 Kg/m3 644
Determination of the mixing water content require by cement
Wwc = 0.24 x 644 = 154.56 kg/m3 154.56 L
W/Fly ash = 0.22 W/MK = 0.22
Determination of total pozzolanic material(100% fly ash):
Vpf + Vpmk = 1 – [Wq/1000 x Gg + Ws/1000 x Gs + Wc / 1000 x Gc + Wwc/1000 x Gw + 0.015]

= 1 – [788/1000 x 2.6 + 810/1000 x 2.57 + 644/1000 x 3.15 + 154.5/1000 x 1 + 0.015] = 0.008 kg/m3

Total weight of pozzolanic material (100% fly ash) (Wpm)
Wpm = (Vpk + Vpmk) x 1000 x 2.15 / (1 + W/F)
= 0.008 x 1000 x 2.15/ (1 + 0.22) = 14 kg/m3
Determination water required for Fly ashWwf = W/F x Wpm
= 0.22 x 14 = 3.1 kg/m3
S.P dosage = 1.8 % (644 + 14) = 11.84 Kg/m3
Water content in S.P. = (1-0.4) x 11.84= 7.10 Kg/m3
Total Water content = 154.56 + 3.1-7.10= 150.56 kg/m3
Water Binder ratio (W/B) = 150.56/ (644 + 14)= 0.23

Based on calculations from Nan Su mix design method, quantities required for 1 cu.m are evaluated for high strength grade (M80) blended Self-Compacting Concrete (SCC) made with Fly Ash (FA), Microsilica (MS).

Table 1 Quantities per 1 cu.m for M80 grade SCC obtained using Nan Su method:

	Cement	Total Pozzolana	Fine Aggregate	Coarse Aggregate	S.P	Water
		Fly ash				
Quantity kg/m^3	644	14	810	788	11.84 L	150.56 L

Final quantities are assumed after several trial mixes on quantities computed using Nan Su mix design method subjected to satisfaction of EFNARC flow properties as shown in Table 2. The following are the quantities of materials calculated using Nan Su mix design method for High strength grade (M80) of fly ash based Self Compacting Concrete (SCC) and also presented are final quantities of materials after various trial mixes.

Table 2 Final quantities after different trial mixes of high strength M80 grade SCC mix

	Cement	Total Pozzolana	Fine Aggregate	Coarse Aggregate	S.P.	Water (water/powder =0.25)
		Fly ash				
Quantity kg/m^3	450	250	714	658	12.21 L	167L

The computed amount of total powder (i.e., OPC+FA) is 658 kg. For the above quantities flow properties are achieved conforming to EFNARC guidelines. But keeping in view, the high quantity of cement computed using Nan Su method , the maximum cement content is limited to 450 kg per cum of concrete as per clause 8.2.4.2 of IS 456-2000. After trail mixes, revised quantities in kg per cu.m for high strength grade (M80) SCC mix are arrived by increasing quantity of Pozzolan (fly ash) to maximum amount without compromising the EFNARC flow properties and desired strength property. For higher grades, Nan Su mix design method computations yield very less powder content. In fact, from the observations it may be stated that Nan Su method is very difficult to apply for higher grades of concrete to arrive at appropriate quantities of materials.

3. Conclusions

1. The aggregate Packing factor determines the aggregate content and influences the strength, flow ability and self-compacting ability.
2. SCC designed and produced with the Nan Su mix design method contains more sand but less coarse aggregates, thus the passing ability through gaps of reinforcement can be enhanced.
3. In the Nan Su mix design method, the volume of sand to mortar is in the range of 54–60%.
4. The water content of SCC prepared by the Nan Su mix design method is about 167 kg/m^{3}for the high strength compressive strength.
5. The amount of binders computed in the Nan Su mix design method can be less than that required by other mix design methods due to the increased sand content.
6. The Nan Su mix design mix design method is simpler, requires a smaller amount of binders, and saves cost.
7. The Packing Factor for M80 grade is 1.1
8. Because SCC produced with this method contains less coarse aggregates, further studies are needed to evaluate its effect on the elastic modulus of concrete.

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