Experimental Studies on M30 Grade Self Compacting Concrete

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***Abstract*— Self-compacting concrete (SCC) becomes a very popular choice in concrete industry because of its easy replacement in highly congested reinforcement structures without undergoing any consolidation, reduced labours, non-segregation property and smooth finishing. In this paper, experimental study has been carried out to achieve target compressive strength and durability requirements for M30 grade SCC. Nan-Su mix design method was used by changing the Nan-Su coefficient and water cement ratio by keeping all other parameters constant. In this work SCC trial mixes developed by using fly ash as filler material, Auromix-400 as super plasticizer and ordinary Portland cement of 43 grade. The workability tests like Slump flow, V-funnel, L-box and U-box tests were carried out to determine its fresh properties and checked against EFNARC specifications. At the age of 7 and 28-days of curing of cubes, compressive strength properties were obtained. Finally for Nan-Su coefficient 11 i.e. C=11fc' and water cement ratio 0.5, both strength and durability criteria were achieved by satisfying all the requirements given by EFNARC guidelines.**

***Index Terms*— Self compacting concrete, Nan-Su coefficient, water-cement ratio, fly ash, Auromix-400 super plasticizer, compressive strength.**

I. INTRODUCTION

Self-Compacting Concrete (SCC) is a special kind of innovative concrete, which is exceedingly flowable and non-segregating concrete, and can be easily placed and compacted under its own self weight need not requiring any mechanical vibration due to its good deformability nature and also as it acquire a property called capability of flowing through thin openings or extremely congested reinforcement structures. Self-compacting concrete is world widely abbreviated by an acronym SCC. SCC is also otherwise called as High-Fluidity Concrete, Self-Leveling Concrete and Self- Consolidating Concrete.

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SCC was developed first in Japan in the late 1980s to be mainly used for highly congested reinforced structures in seismic regions. As the durability of concrete structures became an important issue in Japan, an adequate compaction by skilled labours was required to obtain durable concrete structures. However, the gradual reduction in the number of skilled workers in Japan's construction industry has led to a similar reduction in the quality of construction work. This requirement lead to the development of SCC and its development was first reported in 1989. SCC is another sort of High Performance Concrete (HPC). It has got an excellent capability to fill up formwork and encapsulated congested reinforced steel bars by the effect of gravitational force and de-aerates completely in formwork while flowing with maintained homogeneity. The necessity of this type of concrete was proposed by Okamura in 1986. Studies to develop self-compacting concrete, including a fundamental study on the workability of concrete, were carried out by Ozawa and Maekawa at the University of Tokyo.

Fresh properties of SCC and their requirements

A concrete mix can only be classified as SCC if the requirements for all the following three workability properties in fresh state are fulfilled (EFNARC, 2002):

a) Filling ability: It is the property that characterizes the ability of the SCC of flowing into formwork and filling all space under its own weight, guaranteeing total covering of the reinforcement.

b) Passing ability: It is the property that characterizes the ability of the SCC to pass between obstacles gaps between reinforcement, holes and narrow sections, without blocking.

c) High resistance to segregation: it is the properly that characterizes the ability of the SCC to avoid the segregation of its components, such as the coarse aggregates. Such a property provides uniformity of the mixture during transport, placement and consolidation.

Based on the EFNARC guidelines some of the available fresh property tests such as slump flow, V-funnel, L-box and U-box tests were conducted to evaluate the fresh properties. EFNARC specifications for SCC workability tests requirements in fresh state are given below in table 1.

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Table 1: Requirements of SCC given by EFNARC Guidelines

Workability Test	Units	EFNARC Guidelines
Slump flow(dia)	mm	650-800
U-Box(h2-h1)	mm	0-30
L box(H2/H1)		0.8-1
V funnel (time of flow)	Sec	8-12

II. LITERATURE REVIEW

A. In 2001, Nan-Su e al conducted experimental studies and tests on concrete for achieving self-compacting property and finally given a simplest procedure called Nan-Su method of mix design for self-compacting concrete.

B. In 2011, B Mahalingam et al carried out an experimental work on SCC using fly ash as partial replacement material for cement, at replacement levels of 30%, 40% and 50% respectively and also using suitable super plasticizer. Finally SC with 30% replacement of fly ash gives better results for fresh and hardened properties of concrete.

C. In 2012, Navaneethakrishnan et al did an investigation study on SCC using Nan-Su method of mix design with silica fume as a partial replacement material, at various replacement levels of 0%, 10%, 15% and 20% for cement. Finally SCC with 15% replacement of silica fume gives maximum compressive strength values compared to other replacements.

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III. METHODOLOGY

Nan-Su mix design method: It is considered to be the very simple and easy method and therefore is utilized for designing SCC mix of M30 grade in this experimental work. This mix design method was invented in Taiwan by0Nan-Su.

The step by stop procedure is represented as below in flow chat.

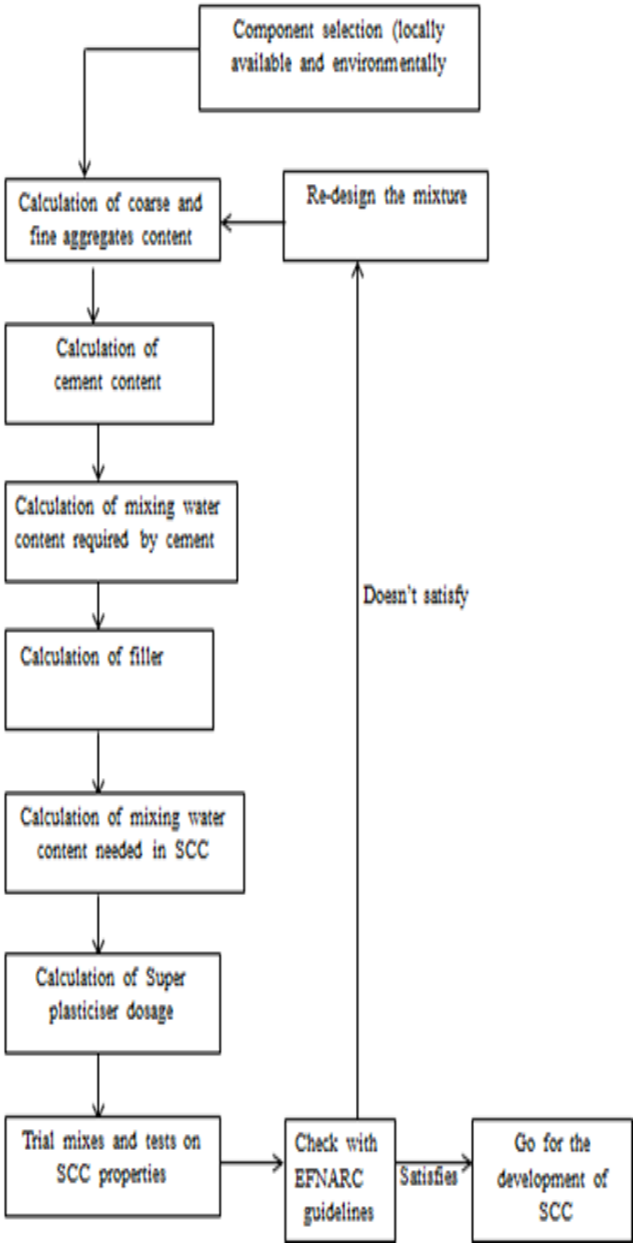

Fig 1: Flow chart for mix design procedure

Nan-Su mix design method was used to prepare trial mixes for M30 grade SCC for different Nan-Su coefficients like 7, 8, 9, 10, 11 and 12 to calculate cement content by varying water-cement ratio and keeping all other parameters like fine aggregates, coarse aggregates and dosage of super plasticizer were constant. Proportions of trial mixes were carried out using the absolute volume method. Each concrete mix was tested to achieve workability property then specimens of size 150mmx150mmx150mm cubes were casted for conducting compressive strength tests. Finally suitable concrete mix was

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selected based on the workability property in its fresh state, compressive strength and durability requirements.

Data's are obtained from experimental program

- Packing factor (PF)= 1.04
- Specific gravity of Cement (G_c) = 3.12
- Specific gravity of FA (G_{fa}) = 2.61
- Specific gravity of CA (G_{ca}) = 2.68
- Specific gravity of Fly ash (G_f) = 2.1
- Specific gravity of water (G_w) = 1.0
- Bulk density of FA (W_{fa}) = 1594 Kg / m3
- Bulk density of CA (W_{ca}) = 1264 Kg / m3
- The volume ratio of fine to total aggregate = 0.54
- Super Plasticizer (SP) dosage = 0.8%
- Air content (Va) = 1.5 %

IV. RESULTS AND DISCUSSION

The Workability test results with recommended limits of different Nan-Su coefficients 7, 8, 9, 10, 11 and 12 are tabulated in table 4.1 and compressive strength results corresponds to M30 grade of SCC for all Nan-Su coefficient are tabulated in table 4.2.

Table 2: Workability test results with recommended limits

Nan-Su Coefficient	W/C ratio	SP in (%)	Slump flow (mm)	V-funnel flow (sec)	U-Box test Results(mm)	L-box Ratio (h2/h)
7	0.36	0.8	680	10	25	0.84
8	0.4	0.8	692	9	20	0.82
9	0.44	0.8	705	11	26	0.9
10	0.47	0.8	718	8	22	0.87
11	0.5	0.8	726	10	24	0.85
12	0.52	0.8	738	11	21	0.92
Recommended limits		**_**	**650 – 800 mm**	**8 – 12 sec**	**0-30 mm**	**0.8 – 1**

Table 3: compressive strength test results

Nan-Su coefficients	7	8	9	10	11	12
7-days compressive strength (MPa)	8	13.48	17.63	21.63	27.85	30.51
28-days compressive strength (MPa)	19.41	24.14	28.59	33.62	39.56	42.96

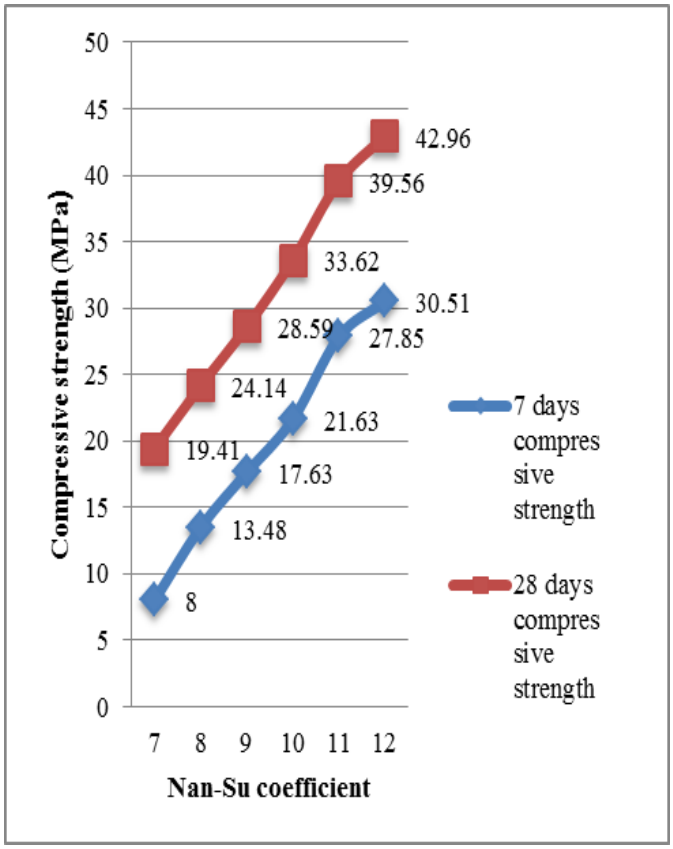

Fig 2: Graph between Nan-Su coefficient verses compressive strength

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By seeing above fig 4 it's easy to access that 28-days compressive strength of cubes is greater compare to 7-days compressive strength of cubes and also both 7 and 28-days compressive strength goes on increases as the Nan-Su coefficient goes on increasing because the content of cement required for m3 of concrete enhances.

Recommended Mix Design for M30 Grade SCC

For M30 grade of SCC as per IS 10262-2009 code target compressive strength is 38.25 MPa. In this present work, for Nan-Su coefficient 11 and water cement ratio 0.5 the obtained the compressive strength is 39.56 MPa and the cement content is 330 kg/m3 which fulfils the durability criteria as per IS 456-2000. Hence the following mix design is recommended for M30 grade SCC.

Table 4: The concrete mix proportions for coefficient 11

CEMENT (Kg)	F.A(Kg/m^3)	C.A (Kg/m^3)	FLY ASH (Kg/m^3)	WATER (Lit)	S.P (Kg/m^3)
330	895	605	158.93	234.93	3.91
1	2.71	1.83	0.48	0.71	0.012

Table 5: Recommended Mix Design test results for M30 grade SCC.

Nan Su coefficient		11
Water cement ratio		0.5
Super plasticizer dosage (%)		0.80
Quantity of concrete per m3	Cement (kg)	330
	Fine aggregate (kg)	895
	Coarse aggregate (kg)	605
	Fly ash (kg)	158.93
	Water (lit)	234.93
	Super plasticizer (kg)	3.91
7-days compressive strength (MPa)		27.85
28-days compressive strength (MPa)		39.56
Workability test results	Slump value (mm)	726
	V-funnel value (sec)	10
	L-box ratio	0.85
	U-box test value (mm)	24

V. CONCLUSIONS

a) In this dissertation study cubes were casted for Nan-Su coefficient 7,8,9,10,11 and 12 for M30 grade SCC and achieved expected results for 7-days & 28-days compressive0strength for Nan-Su coefficient 7,8,9,10,11 and 12. Finally got the required strength of about 39.56 MPa for M30 grade of self-compacting concrete for Nan-Su coefficient 11, with w/c ratio 0.5 and super plasticizer dosage 0.8 .

b) Finally based on the results what we got the following conclusions were discussed

- As the Nan-Su's co-efficient goes on increases the content of cement per m^3 also increases thus strength also get enhances ,where as the content of filler material per m^3 get decreases Since, the filler material do not participate in the strength parameter, as the filler material decreased, strength get increased.

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- As the Nan-Su's co-efficient increases, the water cement ratio gets increases, thus the flow ability of the concrete also increases. This we can observe in the test results of slump flow.
- In case of all the Nan-Su's co-efficient, the quantity of fine and coarse aggregate remains same since these are independent of Nan-Su's co-efficient and water cement ratio.
- In this SCC suggested mix design procedure gives higher fine aggregate content but smaller content of coarse0aggregate, hence the passing capacity along the voids of reinforcing bars could have been increases.

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