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Study of Behaviour of Self Compacting Concrete

Monika Dhakla, Dr S K Verma

Abstract—Self compacting concrete (SCC), a new kind of concrete has been first developed in Japan. Fresh self compacting concrete flows into formwork and around obstructions under its own weight to fill it completely and self compact (without any need for vibration), without any segregation and blocking. The elimination of the need for compaction leads to better quality concrete and substantial improvement of working conditions. The three properties that characterize a concrete as self compacting are flowing ability, passing ability & resistance to segregation, these properties must all be satisfied in order to design adequate SCC, together with other requirements including those for hardened performance. Strength & Durability properties play an important role in concrete structures.The durability of concrete structures is closely related to the nature and severity of the environment in which they are located, as well as the nature of the concrete construction. The destructive stresses directly or indirectly can deteriorate concrete and lead to a reduction in service life or premature failure. Therefore, the durability must be given high priority in order to extend the lifespan of concrete. Unfortunately, the concrete industry achieved higher and higher strength but neglected the durability of concrete. Nonetheless, the durability issue has eventually gained attention, and therefore today more focus is on highly durable concrete, which would be able to sustain severe environments. This research is consists of the experimental studies of SCC :(i) development of a suitable mix for SCC that would satisfy the requirements of the plastic state (ii) casting of concrete specimens of standard shape and sizes are prescribed in the relevant Indian standards for determining the properties of concrete and testing them for compressive strength and water absorption (iii) cyclic exposure tests for duration of one month involving wet-dry and heat-cool cycles to observe the degradation of the prepared SCC samples are given before testing. The test results revealed that the compressive strength of SCC specimens increased with the time of curing. After giving exposure conditions of one month i.e. Heat-cool (Heating at 60^{0}C for a period of 4 hour in 1day and then cooling at room temperature for 1day), Wet-dry (Wetting for 1 day and drying for 1day at normal temperature) and Control(Lab environment).

Index Terms— Durability, Permeability, Self compacting concrete, water absorption

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1 Introduction

ONE of the important aspects for concrete buildings domain is self compacting concrete (SCC). SCC has a special composition with no necessity of compacting and it is able to flow under its own weight.

Nowadays, performance required for concrete structure is more complicated and diversified. The concrete is required to have high fluidity, high strength, self compatibility, and long service life concrete structures. SCC is highly engineered concrete that addresses these requirements.

Strength and durability properties of concrete play an important role in concrete structures. In the past, only strength of concrete was considered in the concrete mix design procedure assuming strength of concrete is an all pervading factor for all other desirable properties of concrete including durability. Later, this pious opinion was proved wrong. Although compressive strength is a measure of durability to a great extent it is not true that the strong concrete is always durable concrete. It is now recognized that the strength of concrete alone is not sufficient, the degree of harshness of the environmental condition to which concrete is exposed over its entire life is equally important. Therefore, both strength and durability have to be considered explicitly at the design stage.

Durability of concrete is defined as ability of concrete to resist weathering action, chemical attack and abrasion while maintaining its desired engineering properties. Different concretes require different degree of durability depending on the exposure environment and properties desired. Concrete ingredients, their proportioning, interaction between them, placing and curing practices and the service environment determine the ultimate durability and life of concrete. As a result of environmental interactions the microstructure and consequently the properties changes with time. A material is assumed to reach the end of service life when its properties, under given conditions of use have deteriorated to such an extent that its continued use is ruled out either unsafe or uneconomical .There are various tests which can be conducted on specimens to check these properties. Rapid chloride permeability, water absorption, water permeability, drying shrinkage are some of the test which can be done to measure durability whereas compressive strength, flexural strength, split tensile strength and bond strength are used for the evaluation of strength of concrete.

The present study comprises of development of a suitable mix for SCC that would satisfy the requirements of the plastic state, casting of concrete samples and testing them for strength tests and durability tests i.e. Water absorption test after giving cyclic exposures which consists of wet-dry cycles, heat-cool cycles to observe the degradation of SCC samples.

2 Experimental Program

The experimental program included the following:

- Testing properties of materials used for making self com-

- *Monika Dhakla ,Department of civil engineering , Amity University, Haryaba, India, PH-8595332325. E-mail: monikadhakla@yahoo.com*
- *Dr S.K.Verma ,Department of civil engineering ,Pec university of technology,Chandigarh,India*

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pacting concrete
- Development of concrete mix of desired strength by making trials
- Testing slump flow, L-box, V-funnel and V-funnel at $T_{5minute}$ to assess workability
- Casting and curing of specimens.
- Compressive strength test on SCC samples
- Water absorption test on SCC samples.

2.1 Testing Of Materials

2.1.1 Test on cement

The cement use for the experimental studies was Ultratech 43 grade OPC as per the specifications of Indian Standard Code IS: 8112-1989.The various test performed on the cement and their values are shown in the Table 4.1

Table 1: Characteristics properties of Cement

Sr. No	Characteristics	Experimental value	Specified value as per IS:8112-1989
1	Consistency of cement (%)	32.5	---
2	Specific gravity	3.14	3.15
3	Initial setting time (minutes)	41	>30
4	Final setting time (minutes)	347	<600
5	Compressive strength (N/mm^2) (i) 3 days (ii) 7 days (iii)28days	 24.10 34.56 47.92	 >23 >33 >43
6	Soundness (mm)	1.00	10
7	Fineness of Cement (gm)	0.50	10

2.1.2 Test on fine and coarse aggregate

The physical properties of coarse aggregate and fine aggregate satisfied the requirement of IS: 383-1970 and the results are given in following tables

Table 2: Physical properties of fine aggregate

CONTENTS	COARSE-AGGREGATE	FINE-AGGREGATE
Specific Gravity	2.70	2.60
Free Moisture Content	Nil	2%
Water Absorption	0.15%	1.82%

2.1.3 Fly Ash

Fly ash used in the present work was procured from Guru Gobind Singh Thermal Power Plant, Ropar (Punjab). To assess the properties of fly ash, laboratory tests conducted by Central Soil and Material Research Station (CSMRS), New Delhi and CBRI-Roorkee are considered.

2.1.4 Stone Dust

The source of stone dust was from the stone crushers which are situated at the foot hills of Shivalik hills near the Gaggar River. Stone dust was very fine and it passed through a sieve of 150 micrometer. The specific gravity of stone dust is 2.50.

2.1.5 Superplasticizer

Structuro 202 has been used as a superplasticizer

Table 3: Technical data of superplasticizer

Form	Liquid
Color	Light yellow colored
Volumetric mass @20 degree Celsius	1.065 g/cc
Chloride content	Nil to IS: 456
pH Value	6.5
Alkali content	Typically less than 1.5g Na_2O equivalent

2.2 Self Compactibilty Tests On Trial Mixes

Four trial mixes were considered by varying the mix parameters such as quantity of filler, fine aggregate/coarse aggregate ratio while keeping the water powder ratio constant. Each mix was tested for compactability so as to decide about suitable SCC.

Table 4: Slump Flow Test Result on Trial Mixes

TR1	TR2	TR3	TR4
500	580	610	700
RANGE OF ACCEPTANCE GIVEN BY EFNARC 650 TO 800 (MM)			

Table 5: T_{50} Slump Flow Test Result on Trial Mixes

TR1	TR2	TR3	TR4
7.2	5.6	5	4
RANGE OF ACCEPTANCE GIVEN BY EFNARC 2 TO 5 (SECONDS)			

Table 6: V Funnel T_{5min} Test Result on Trial Mixes

TR1	TR2	TR3	TR4
2	4	4	3
RANGE OF ACCEPTANCE GIVEN BY EFNARC 0 TO 3 (SECONDS)			

Table 7: L-Box Test Result on Trial Mixes

TR1	TR2	TR3	TR4
0.7	0.8	0.8	0.9
RANGE OF ACCEPTANCE GIVEN BY EFNARC 0.8 TO 1 (SECONDS)			

Table 8: U Box Test Result On Trial Mixes

TR1	TR2	TR3	TR4
20	25	25	25

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RANGE OF ACCEPTANCE GIVEN BY EFNARC 0 TO 30 (MM)

Finally, Trial Mix 4 was selected which fulfilled the criteria of self compactability checked by Slump flow test, V funnel test., L Box test and U Box test. After one month curing, the concrete was exposed to normal, heat-cool and wet-dry conditions for a period of one month and then they were tested for compressive strength and durability properties

3 Results

The experimental programme consisted of testing a total number of specimens for ascertaining various properties of concrete after exposure to different conditions. The specimens are tested for compressive strength and water absorption .The specimens after exposure of one month to various conditions i.e. normal lab environment, heat –cool cycles, wet –dry cycles are tested.

3.1 Compressive Strength

The compressive strength of SCC specimens is summarized in Table 9. The average compressive strength for all the specimens (7 days cured specimens, 28 days cured specimens, specimens subjected to normal, heat-cool and wet-dry exposures after 28 days curing) are tested. A 28-days average compressive strength of around 47 MPa, of the selected SCC mix, is quite satisfactory for the intended use of concrete in the local conditions. Further, the value of the compressive strength of the selected SCC mix is well within the range of 28-days compressive strength of SCC, as recently reported by various researchers (Zhu and Bartos, 2003; Bouzoubaa and Lachemi, 2001).

Table 9: Compressive Strength of SCC Specimens

Sample	Compressive strength(MPa)				
	7 Days Water Curing	28 Days Water Curing	1 Month Normal Exposure	1 Month Wet Dry Exposure	1 Month Heat Cool Exposure
1	32.01	48.16	51.77	54.44	56.44
2	31.77	46.33	50.51	57.1	59.64
3	32.27	47.82	53.50	56.44	57.53
Average	**32.01**	**47.43**	**51.92**	**55.99**	**57.87**

From Table 9 it can be noted that the compressive strengths of the specimens exposed to all the three exposures was more than 28 days compressive strength. Compared to 28 days compressive strength, the compressive strengths of specimens exposed to normal, wet-dry and heat-cool exposures are higher by about 10%, 18% and 22% respectively. Further compared to the compressive strengths of specimens exposed to wet-dry and heat-cool conditions are higher by about 7% and 11% respectively. The average compressive strength for all the specimens is plotted in Figure 1

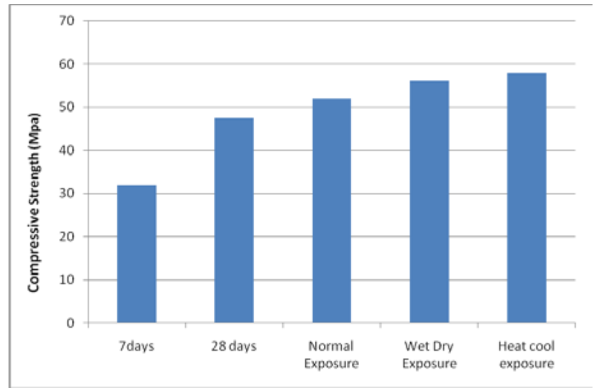

Fig.1. Average compressive strength of SCC specimens exposed to various exposures

The higher value of compressive strength of SCC specimens exposed to wet-dry conditions compared to those exposed to normal conditions may be attributed to increased hydration of cement. Similarly, the higher compressive strength of specimens exposed to heat-cool conditions compared to those exposed to normal conditions may be attributed to the accelerated hydration due to increase in the temperature. Temperature during the period of hydration that the influence the rate of gain of strength of concrete. Since the strength development depends upon the time and temperature. However, a decrease in the compressive strength due to wet-dry and heat-cool exposures may be expected after a long period of exposure. The effect of aggressive exposures on the compressive strengths within the duration of this study i.e. one month is not detrimental.

3.2 Water Absorption

The water absorption of the specimens exposed to three Conditions is summarized in Table 10, Table 11 & Table 12

Table 10: Water absorption of SCC specimens exposed to normal conditions

Sample	W_1 (Kg) Actual weight after drying	W_2 (Kg) Weight after water soaking	Absorption %
1	7.945	8.130	2.32
2	7.880	8.040	2.03
3	7.860	8.065	2.60
Average			**2.31**

Table 11: Water absorption of SCC specimens exposed to

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wet dry conditions

Sample	W_1 (Kg) Actual weight after drying	W_2 (Kg) Weight after water soaking	Absorption %
1	8.140	8.298	1.94
2	8.120	8.287	2.05
3	8.250	8.427	2.14
Average			**2.04**

Table 12: Water absorption of SCC specimens exposed to heat cool conditions

Sample	W_1 (Kg) Actual weight after drying	W_2 (Kg) Weight after water soaking	Absorption %
1	7.950	8.190	3.01
2	7.980	8.244	3.32
3	8.100	8.354	3.13
Average			**3.155**

The average water absorption in the SCC specimens exposed to all the three conditions is lower than that of conventional concrete. Water absorption test give description about total void space in concrete and it depends upon number of factors such as mix quality, degree of compaction and curing. Figure 2 depicts the average values of water absorption in the specimens exposed to three conditions. The water absorption in the specimens exposed to wet-dry conditions was less than that in the specimens exposed to normal conditions by about 11%.
The water absorption in the SCC specimens exposed to heat-cool conditions was more than that of specimens exposed to normal conditions, by about 26%.Reduction in the water absorption in the specimens exposed to wet-dry conditions may be attributed to intermittent curing during the entire period of exposure. It seems that the heat –cool exposure has resulted in an increase in the porosity of concrete.

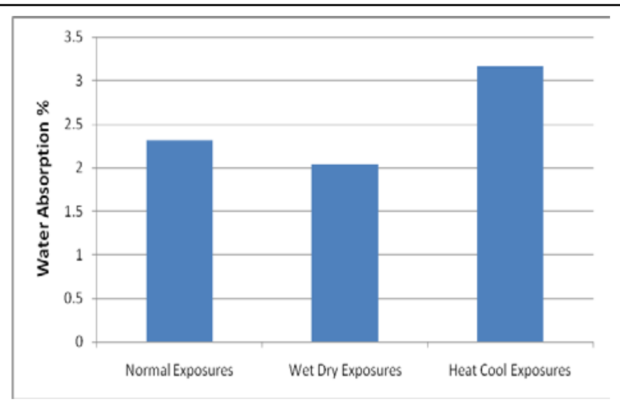

Fig.2. Average water absorption of SCC under various exposures

4 CONCLUSION

The main conclusions drawn from the investigation are summarized below:

1. When specimens subjected to different exposure conditions for one month and tested for compressive strength following conclusions were drawn.
   a) Considerable increase in the compressive strength of concrete specimens exposed to thermal variations was noted compared to specimens exposed to wet-dry and normal exposures.
   b) When compared to the compressive strength of specimens under normal exposure, the compressive strength of specimens under wet-dry was higher.
   c) Specimen exposed to heat-cool variations achieved a maximum strength of 57.87 N/mm^2, minimum strength was achieved by specimen exposed to normal conditions i.e. 51.92 N/mm^2, whereas wet dry gained a strength of 55.99 N/mm^2.

When concrete was subjected to limited number of cycles of heat-cool, wet-dry the compressive strength increased as compared to SCC under normal conditions. In the present study due to time constraint the number of cycles was less. However, it is expected that when SCC specimens subjected to 50 to 80 cycles (i.e. heating at 60^0 C and then cooling at room temperature on alternate days) then there will be decrease in strength due to thermal variations.

2. When SCC specimens were exposed to heat-cool, wet-dry and normal conditions and then tested for water absorption, following conclusions was obtained.
   a) When compared to the water absorption of specimens exposed to normal laboratory conditions, the water absorption of specimens exposed to heat-cool was higher.
   b) Specimens exposed to heat-cool variations achieved a maximum absorption of 3.15%, minimum absorption were achieved by specimens exposed to wet-dry conditions i.e. 2.01% whereas specimens exposed to normal conditions showed a 2.31% of water absorption.

The SCC specimens displayed better performances with regard to water absorption. However, number of cycles was less due to time constraint and hence no negative effect was observed in the present study.

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