STUDY ON MECHANICAL CHARACTERISTICS OF SELF COMPACTING CONCRETE WITH FLYASH

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Abstract

This project investigates the study of workability and durability characteristics of Self-Compacting Concrete (SCC) with Viscosity Modifying Admixture (VMA), and containing Class F fly ash. The mix design for SCC was arrived as per the Guidelines of European Federation of National Associations Representing for Concrete (EFNARC). In this investigation, SCC was made by usual ingredients such as cement, fine aggregate, coarse aggregate, water and mineral admixture fly ash. The experiments are carried out by adopting a water-powder ratio of 0.40. Workability of the fresh concrete is determined by using tests such as: slump flow, T50, V-funnel, L-Box and U-box tests. The mechanical properties of concrete such as Cube compression, Cylinder compression, Split tensile strength and Flexural strength were performed. M30 Grade of concrete was opted. Four mixes were prepared varying aggregate ratios from 51% to 54%.

The Cube compressive strength at the age of 28 days, the ranges for Mix 1 was 28.65 and for Mix 4 we observed it having highest of all compressive strengths 39.41 and later on the other mixes compressive strength was decreased. The split tensile strength at the age of 28 days, Mix-4 exhibited maximum strength. But for Flexural strength it is observed that Mix- 4 resulted in higher strength.

Keywords: Axial compressive strength, Tensile load, Flexural Strength, Mechanical Properties and Self-compacting concrete

1. INTRODUCTION

One of the basic infrastructural facilities that man needs for good living is shelter. The development of technology in materials and construction has made it possible to build even skyscrapers. However, the increasing cost of conventional construction materials has made it difficult to meet the shelter requirements of the teeming population of developing countries. Fast expansion in the construction industry brought forth with it associated problems

Due to its versatility and easy mould ability, worldwide concrete is recognized as a premier construction material. It is the material of choice for a variety of applications such as housing, bridges, highway pavements, industrial structures, water-carrying and retaining structures, etc., The credit for this achievement goes to well-known advantages of concrete such as easy availability of ingredients, adequate engineering properties for a variety of structural applications, adaptability, versatility, relative low cost, etc.,

One of the major factors that influence the strength and durability of concrete structures is the degree and quality of consolidation and effective curing of concrete. The lack of uniform, and complete compaction and curing had been identified as the primary factor responsible for poor performance of concrete structure.

2. LITERATURE REVIEW

Present-day self-compacting concrete had been classified as “the most sought development in construction industry due to its numerous inherited benefits." As the name itself reflects, vibration is not required for achieving full compaction. This kind of concrete offers many benefits and advantages over conventional concrete. These include an improved quality of concrete and reduction of on-site repairs, lowers overall costs, faster construction times, and facilitation of introduction of the automation into the concrete construction. A crucial improvement in health and safety is achieved through terminating the handling of the vibrators and a significant reduction in the environmental noise loading on and around the construction site. The composition of SCC mixes includes substantial proportions of fine-grained inorganic materials and this gives possibilities for utilization of mineral admixtures, which are currently waste products with no practical applications and are costly to dispose off

Hajime Okamura: Okamura proposed that this is a new type of concrete, which doesn't require compaction and by its own weight it flows into every corner of the formwork completely. In year 1986, Okamura started a research on flowing ability and workability of this special kind of concrete, later he called it as self-compacting concrete. The property of Self-Comp actability in this concrete, largely influenced by the essential properties of materials used and mix proportions. Okamura in his study, in the year 1997 he had fixed the content of coarse aggregate to 50% of the total solid volume and the content of fine aggregate to 40% of the total mortar volume, so that he justified the Self-Compactability could be achieved easily, by adjusting the water to powder ratio and by addition of superplasticizers only

After Okamura began his research in 1986, other researchers of Japan had started investigations on SCC, to look forward in improving its characteristics. One of those was Ozawa who has done some research independently from Okamura, and in the summer of 1988, he succeeded in developing self-compacting concrete for the first time. The year after that, an open experiment on the new type of concrete was held at the University of Tokyo, in front of more than 100 researchers and engineers. As a result, intensive research has been begun in many areas, particularly in the research centers of large construction companies and at the University of Tokyo.

Ozawa completed the first prototype of self-compacting concrete using materials already on the market. By using different types of superplasticizers, he studied the workability of concrete and developed a concrete which was very workable. It was suitable for rapid placement and had a very good permeability. The viscosity of the concrete was measured using the V-funnel test. Further, more experiments were carried out by Ozawa aiming on the influence of mineral admixtures, like blast furnace slag and fly ash, on the properties of segregation resistance and flowing ability of self-compacting concrete. He observed that flowing ability of the concrete improved remarkably when Portland cement was partially replaced with blast furnace slag and fly ash. By investigating with different proportions of the admixtures, he finally concluded that 25-45% of slag and 10-20% of fly ash, by mass, showed best flowing ability in concrete and strength characteristics.

Subramanian and Chattopadhyay are research and development engineers at the ECC Division of Larsen & Toubro Ltd (L&T), Chennai, India. They have over 10 years of experience on development of self-compacting concrete, underwater concrete with anti washout admixtures and proportioning of special concrete mixtures. Their research was concentrated on several trials carried out to arrive at an approximate mix proportion of self-compacting concrete, which would give the procedure for the selection of a viscosity modifying agent, a compatible super plasticizer and the determination of their dosages. The Portland cement was partially replaced with fly ash and blast furnace slag, in the same percentages as done by Ozawa (1989) before and maximum size of coarse aggregate did not exceed 25mm.

The two researchers were trying to determine different coarse and fine aggregate contents from those developed by Okamura. The coarse aggregate content was varied, along with water-powder (cement, fly ash and slag) ratio, being 50%, 48% and 46% of the solid volume. The U-tube trials were repeated for different water-powder ratios ranging from 0.3 to 0.7 in steps of 0.10. On the basis of these trials, it was discovered that self-Compactability could be achieved when the coarse aggregate content was restricted to 46 percent instead of 50 percent tried by Okamura (1997)

3 MATERIALS AND PROPERTIES

3.1 Cement

Cement plays vital role in concrete. One of the important criteria tricalcium aluminate (C_3A) content, tricalcium silicate (C_3S) content, dicalcium silicate (C_2S) content etc. It is also necessary to ensure the compatibility of chemical and mineral admixtures with cement.

In this study, Zuari Cement of 53 grade Ordinary Portland Cement conforming to IS: 12269–1987 was used for the entire work. The cement was purchased from single source and was used for casting of all specimens. The physical properties of cement are furnished in Table No.1

Table 1 physical properties of cement

S.No	Characteristics	Test Results	Requirements as per IS 12269 - 1987
1	Fineness (retained on 90-µm sieve)	6%	<10%
2	Normal Consistency	33%	--
3	Initial setting time of cement	90 min's	30 minutes (minimum)
4	Final setting time of cement	340 min's	600 minutes (maximum)
5	Expansion in Le-chatelier's method	4 mm	10 mm (maximum)
6	Specific gravity	3.15	3.10 – 3.25

3.2 FINE AGGREGATE

The natural sand taken for this investigation is the locally available natural river sand. It was collected and cleaned for impurities, so that it is free from clayey matter, salt and organic impurities. Particles passing through IS sieve of 4.75 mm conforming to grading zone-II of IS: 383-1970 were used in this work. Properties such as gradation, specific gravity, fineness modulus, bulking, and bulk density had been assessed. The physical properties of sand are furnished in Table 2.

Table 2 physical properties of Fine Aggregate

S.No.	Tests Conducted	Results Obtained		Permissible Limits as per IS 383-1970
1	Specific gravity	2.65		2.5 to 3.0
2	Fineness modulus	3.05		--
3	Bulk density	**Loose State**	1415 kg/m3	
		Compacted State	1525 kg/m3	1400 to 1750 kg/m3
4	Water absorption (%)	1.09		Max 3%
5	Sieve Analysis	Zone – II		--

3.3 COARSE AGGREGATE

Locally available machine Crushed angular granite, retained on 4.75mmI.S. sieve of maximum size of 20mm confirming to I.S: 383-1970 was used in the present experimental investigation. It is free from impurities such as dust, clay particles and organic matter etc. The coarse aggregate is tested for its various properties such as specific gravity, fineness modulus, elongation test, flakiness test, sieve analysis, bulk density in accordance with in IS 2386 – 1963. The physical properties of Coarse aggreagte are furnished in Table 3.

Table 3 physical properties of Coarse Aggregate

S.No.	Tests Conducted	Results Obtained		Permissible Limits as per IS 383-1970
1	Specific gravity	2.73		2.5 to 3.0
2	Fineness modulus	7.52		--
3	Bulk density	**Loose State**	1480 kg/m^3	1400 to 1750 kg/m3
		Compacted State	1560 kg/m^3	
4	Water absorption (%)	1..20		Max 3%
5	Flakiness Index	21%		Max 25%
6	Elongation Index	23%		Max 25%

3.4 WATER

Water used for mixing and curing shall be clean and free from injurious quantities of alkalies, acids, oils, salts, sugar, organic materials, vegetable growth (or) other substance that may be deleterious to bricks, stone, concrete, or steel. Potable water is generally considered satisfactory for mixing.

Water acts as a lubricant for the fine and coarse aggregates and acts chemically with cement to form the binding paste for the aggregate and reinforcement. Less water in the cement paste will yield a stronger, more durable concrete; adding too much water will reduce the strength of concrete and can cause bleeding. Impure water in concrete, effects the setting time and causing premature failure of the structure.

To avoid these problems quality (potable) water must be proffered in construction works and PH value of water should be not less than 6. And also Quantity of water to be taken is important

3.5 FLY ASH:

Fly ash, one of the most widely utilized by-product in the construction industry resembling the Portland cement. In order to utilize fly ash for various applications, most of the thermal power stations had established a dry fly ash evacuation and storage system. Class F fly ash produced from Rayalaseema Thermal Power Plant (RTPP), Muddanur, A.P is used as an additive used as a filler material. The physical and as obtained by RTPP are presented in the Table – 4

Table 4 Physical properties of chemical admixture

Characteristics	Test Results
Specific gravity	2.12
Fineness (Kg/m2)	360

3.6 SUPER PLASTICIZER

In the present work, water-reducing admixture Master Glenium SKY 8630 which is an inbuilt Viscosity Modifying Agent conforming to ASTM C494 Type G, EN 934-2 T3.1/3.2 and IS 9103: 1999 is used. Master Glenium SKY 8630 is an admixture of a new generation based on modified polycarboxylic ether. The product has been primarily developed for applications in high performance concrete where the highest durability and performance is required. The physical properties of chemical admixture are furnished in table –5.

Table 5 Physical properties of chemical admixture

S.No	Characteristics	Test Results
1	Aspect	Light brown liquid
2	Relative Density	0.08+/- 0.01 at 250°C
3	Ph	≥6
4	Chloride ion Content	<0.2%

3.7 MIX PROPORTIONS

The mix proportions of M30 Grade Concrete Shows in table 6.

Table 6 Quantities of Ingredients per Cum of M30 Grade Concrete

Grade of Concrete	Mix 1	Mix 2	Mix 3	Mix 4
Cement(Kg/m^3)	375	375	375	375
Fly Ash(kg/m^3)	136	136	136	136
Fine Aggregate(kg/m^3)	779	795	810	825
12 mm Coarse Aggregate(kg/m^3)	746	731	716	700
Master Glenium SKY 8630 (Super Plasticizer)(lit)	3.88	3.88	3.88	3.88
Water(lit)	178	178	178	178

4 EXPERIMENTAL INVESTIGATION

4.1 CONCRETE MIX PREPARATION

Design of concrete mix requires complete knowledge of various properties of the constituent materials. Initially the ingredients such as cement and fine aggregate were mixed, to which the coarse aggregate are added followed by addition of water and thoroughly mixed. Prior to casting of specimens workability is measured in accordance with the code IS 1199-1959 by slump cone test.

4.2 CUBE COMPRESSION STRENGTH TEST

Compression test is the most common test conducted on hardened concrete, because it is an easy test to perform, and most of the properties of concrete are qualitatively related to its compressive strength. Compression test is carried out on specimen of cubical or cylindrical in shape. Compression test is done confirming to IS: 516-1959. All the concrete specimens were tested in compression-testing machine. Concrete cubes of size 150mm × 150mm × 150mm were tested for Compressive Strength. Compressive Strength of concrete is determined by applying load at the rate of 140kg/sq.cm/minute till the specimens failed. The compressive strength for cubes were tested at the age of 3, 7, 14 and 28 days.

4.3 SPLIT TENSILE STRENGTH

Split Tensile Strength test was conducted on cylindrical specimens at 28days as per IS 5816-1999. Three cylindrical specimens of size 150 mm × 300 mm were casted. Split tensile strength

of concrete is determined by applying the load at the rate of 140kg/sq.cm/minute till the specimens failed. The maximum load applied was then noted.
The splitting tensile strength (Ft) was calculated as follows:

$$Ft = \frac{2P}{\pi DL}$$

Where, P = Compressive load
L = Length of the cylinder
D = Diameter of the cylinder

4.4 FLEXURAL STRENGTH TEST

Flexural strength is a measure of tensile strength of concrete of an unreinforced concrete beam to resist failure in bending. The flexural strength can be determined by Standard test method. In this study, three beams of size 100 mm × 100 mm × 500 mm were used to find flexural strength.

5 RESULTS AND DISCUSSIONS

5.1 COMPRESSIVE STRENGTH

The cast cubes of all four mixes were tested for cube compressive strength at 3, 7, 14 & 28 days for normal water curing. The variation of the cube compressive strength with the age prepared using the various Mixes (Mix 1, Mix 2, Mix 3 and Mix 4) is shown in Figure No. 1. It can be observed that the compressive strength of concrete of Mix 4 exhibits more Strength than the other Mix Proportions

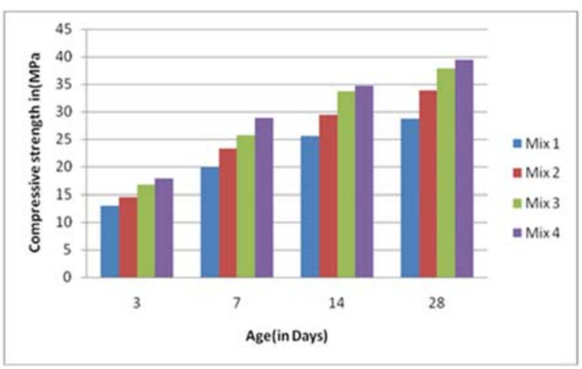
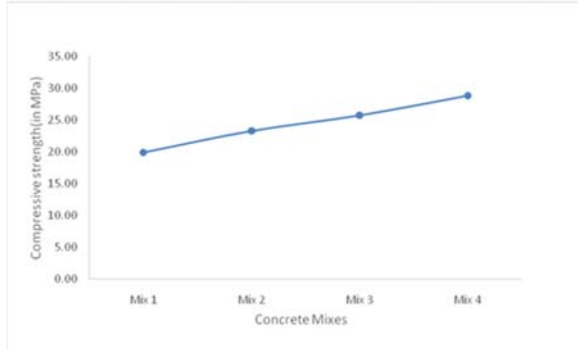
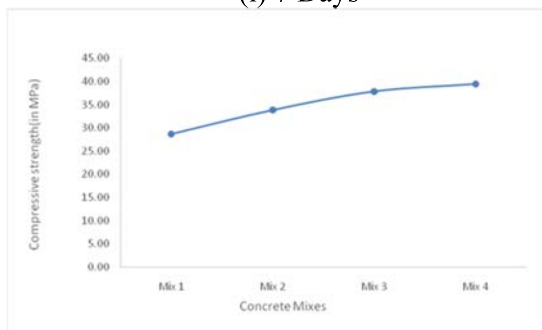


Fig. No.1 variation of Cube compressive strength of Different Mixes of concrete with Different Ages (3, 7, 14 & 28 Days)

The variation of 7 days and 28 days cube compressive strength of Different Mixes of Concrete is shown in Figure No. 2



(i) 7 Days



(ii) 28 Days

Fig No. 2 Variation of Cube compressive strength of Different Mixes of Concrete at Age of 28 – Days

5.2 SPLIT TENSILE STRENGTH

The variation of the Split Tensile with the age prepared using the various Mixes (Mix 1, Mix 2, Mix 3 & Mix 4) is shown in Figure No. 3. It can be observed that the Split Tensile strength of concrete of Mix 4 exhibits more Strength than the other Mix Proportions

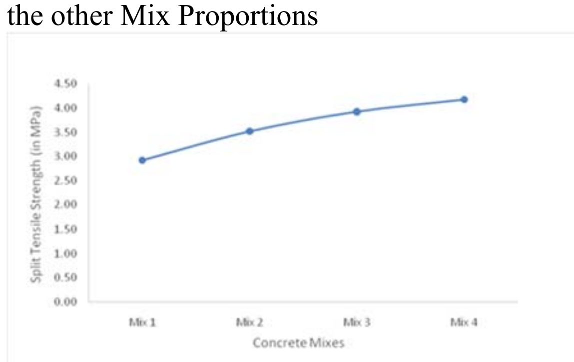


Fig No.3 Variation of Split Tensile Strength of Different Mixes of concrete

5.3 FLEXURAL STRENGTH

The variation of the Flexural Strength with the age prepared using the various Mixes (Mix 1, Mix 2, Mix 3 & Mix 4) is shown in Figure No. 4. It can be observed that the Flexural strength of concrete of Mix 4 exhibits more Strength than the other Mix Proportions

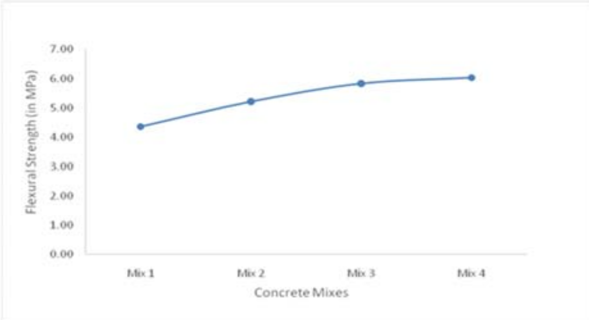


Fig No.4 Variation of Flexural Strength of Different Mixes of concrete

6 CONLUSIONS

1. It has been verified, by using the slump flow, V-funnel, L-box test and U-box test on fresh SCC that self-compacting concrete (SCC) achieved consistency and self- compact ability under its own weight, without any external vibration or compaction.
2. The Cube compressive strength at the age of 28 days, the ranges for Mix 1 was 28.65 and for Mix we observed it having highest of all compressive strengths 39.41 and later on the other mixes compressive strength was decreased.
3. It can be observed that maximum compressive strength was achieved for normal water curing method at 28 days of curing for Mix-4.
4. It is due to the optimum aggregates required for bonding is exactly at Mix proportion-4
5. The split tensile strength at the age of 28 days, Mix-4 exhibited maximum strength. But for Flexural strength it is observed that Mix- 4 resulted in higher strength.

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