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Determination of Mechanical Properties of Fibre Reinforced Concrete with Mineral Admixtures

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ABSTRACT: In this project cement was partially replaced by fly ash and silica fume. A mix design was done for M₄₀ grade of concrete by using IS method. The utilization of fly-ash and silica fume in concrete as partial substitute of cement. 53 grade cement is used in this project. This paper reports comparative study on effects of concrete properties by partial substitute of OPC of 53 grade with fly ash and silica fume. Super plasticizer was used in the concrete mixes, which plays an important role for the production of high strength concrete. Steel fibre in different percentage i.e. 0.5%, 1% and 1.5% to that of total weight of concrete and casting was done. Different percentages of silica fume were used. The concretes thus produced were tested for compression, tension and flexure. The result show that with the addition of silica fume and fibres the properties of concrete improve.

KEYWORDS: Fly ash, silica fume, steel fibres, super plasticizer.

I. INTRODUCTION

Fiber reinforced concrete (FRC) is Portland cement concrete reinforced with more or less randomly distributed fibers. In FRC, thousands of little fibers are dispersed and distributed at random in the concrete during mixing, and thus get better concrete properties in all directions.

FRC is cement- based compound material that has been developed in recent years. It has been effectively used in construction with its excellent flexural-tensile strength, resistance to spitting, impact resistance and excellent permeability and frost resistance. It is a successful way to raise toughness, shock resistance and resistance to plastic shrinkage cracking of the mortar. Fiber is a small part of reinforcing material possessing certain characteristics properties. They can be rounding, triangular or flat in cross-section. The fire is often described by a convenient parameter called —aspect ratio. The characteristic ratio of the fiber is the ratio of its span to its diameter. The principle reason for incorporating fibers into a cement matrix is to raise the toughness and tensile strength and improve the cracking deformation characteristics of the resultant compound. For FRC to be a viable construction material, it must be able to complete cheaply with existing reinforced system.

When steel fibers are added to high strength concrete, the raise in fiber volumetric ratio results in a raise in the compressive strength of the concrete and a considerable amount of raise in the tensile strength of the fiber reinforced specimens is observed in split cylinder tests (Mukesh Shukla (2011) Okay and Engin, (2012). However, when this addition exceeds a certain volumetric level, the raise in the strength becomes less (Song and Hwang, 2004; Mohammadi *et al.*, 2008). Volumetric ratio of fiber also raises energy captivating capacity in bending (Gao *et al.*, 1997). Wang and Lee (2007) experimentally confirmed that steel fiber reinforced concrete. As the volume comfortable of the fiber raises, ductility under steady load raises in the diagrams. In other words, no difference is observed up to crack, but ductility rises afterwards with the raise in volume content of steel fibers (Rao and Seshu, 2005, Amithrana). In a research study, the effect of steel fibers on cracks in reinforced concrete beams was investigated and it was concluded

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Vol. 6, Issue 11, November 2017

that a steel fiber dosage of 30-40 kg/m³ was appropriate to have an appreciable improvement on cracks (AlterNet *et al.*, 2007). DuPont and Vandwalle (2002) and Paine *et al.* (2002) studied the donation of steel fibers of reinforced concrete beams and resolute that a steel fiber dosage of 1-2% by complete volume was ideal from that aspect. After having performed experiments

II. MATERIALS AND MIX PROPORTIONS

2. MATERIALS

The materials used in this present investigation are Normal Portland cement (53 grade), water, coarse aggregates, fine aggregates (sand, sag). In recent years, improvements in concrete properties have been achieved by blending cements with cementations admixtures such as fly ash (FA), granulated blast furnace slag (GBFS). Incorporation of these materials in concrete mixes improves the durability concrete. The movement of aggressive substances such as chloride ions and carbon dioxide into concrete which are the main causes of deterioration of concrete structures that affect their integrity and long term serviceability life, is thus very much reduced. The deterioration of concrete is not a result of only aggressive agents, but the overall quality of concrete and also plays a major role. In view of this problem, a growing number of concrete structures are constructed or under construction with the use of cement substitution materials. Therefore any attempt to alleviate the deterioration-risk implies producing good performance concrete capable of withstanding the harsh environmental conditions. In this chapter, the materials and methods described together with their properties. In this the tests carried out on different concrete mixes, curative regimes, mix proportions and casting of specimens is discussed.

2.1. Fly ash (FA)

Fly ash is a by-product of the combustion of pulverized coal in power stations. It is a solid material extracted by electrostatic and mechanical means from the flue gases of furnaces fired with pulverized bituminous coal. During production of FA, the coal passes through the high temperature zone in the furnace and the carbon and volatile matter are burned off, whereas most of the mineral impurities, such as clays, quartz, and feldspar melt at high temperature. The fused matter is quickly transported to low-temperature zones, where it solidifies as spherical particles of glass. Some of the mineral substance agglomerates forming bottom ash, but most of it flies out with the flue gas stream and is called "fly ash". This ash is subsequently removed from the gas by mechanical separator, electrostatic precipitators. Its main constituents are SiO₂, AL₂O₃ and Fe₂O₃ with smaller quantities of other metal oxides, the chemical composition of fly ash..

The physical properties of fly ash are shown in the following table No.1

Table 1 Physical properties of fly ash

S.NO	DESCRIPTION	
1	Specific Gravity	2.5
2	Physical Form	Powder
3	Colour	Dark grey

2.3. Silica fume

Silica fume is a by-product of silicon or Ferro-Silica industry and is 100 times finer than cement. A silica fume is also referred to as micro silica or strong silica fumes. It consists of amorphous silica and has high reactivity towards lime. The substitute level of silica fume is generally low at about 10%. When SF is used in concrete mix, its beginning affects the physical understanding of the system, particularly near the aggregate surface where porosity exists. Silica

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 11, November 2017

fume starts reacting at the early stage of hydration procedure. The pozzolanic action of silica fume reduces considerably the quantity and size of “CH” crystals in hydrated cement paste. This phenomenon along with low W/C ratio reduces the thickness of conversion zones and thus the preferential orientation of CH crystals is significantly reduced. All these result in more uniform, stronger conversion zone potential of micro cracking. The silica fume used in all concrete mixes was obtained from Elkem Materials Limited. The chemical composition information is given in Table 3. It can be seen that the silica fume contains 85% silicon dioxide. The physical properties of Silica fume are shown in the following table no 2

Table No: 2 Physical properties of Silica fume

S.NO	DESCRIPTION	
1	Specific Gravity	2.2
2	Physical Form	Powder
3	Colour	Grey

The comparison of chemical composition of cement and mineral admixtures are shown in the table no 3

Table no: 3 Chemical compositions of cement and mineral admixtures (unit: %)

Chemical Composition	Cement and mineral admixtures		
	OPC	FA	SF
CaO	63	1.71	0.27
SiO ₂	22	60.48	85
Al ₂ O ₃	4	23	0.28
Fe ₂ O ₃	3.2	11	0.58
MgO	3	1.62	0.25
SO	3	-	-
K ₂ O	0.79	1.41	0.58
Na ₂ O	0.30	0.14	-

2.4. Water

Water is important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to structure the strength giving cement gel, the quantity and quality of water is essential to be looked into very carefully. Water presented in the Laboratory is used for mixing and curing. The locally available potable water, which is free from concentration of acid and organic substances, is used for mixing the concrete. The specific gravity of water is taken as 1.00.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 6, Issue 11, November 2017

2.5. Cement

Cement may be described as a material with adhesive and cohesive properties that make it capable of bonding, mineral fragments into a compact whole. It is usually manufactured from limestone mixed with shale, clay. Properly proportioned raw materials are pulverized into kilns where they are heated to a temperature of 1300 to 1500°C. The clinker is cooled and ground to fine powder with addition of about 3 to 5% of gypsum. The OPC (53 grade) used in the present work is of Zuari cement.

2.5.1. Ordinary Portland Cement (53 grade)

Normal Portland Cement (OPC) is one of several types of cement being manufactured throughout the world, are some of the more commonly used. OPC is the general purpose cement used in concrete constructions. OPC is a compound of lime (CaO), silica (SiO₂), alumina (Al₂O₃), iron (Fe₂O₃) and sulphur trioxide (SO₃), Magnesium (MgO) is present in small quantities as an impurity associated with limestone. SO₃ is added at the grinding stage to retard the setting time of the finished cement. When cement raw materials containing the proper proportions of the essential oxides are ground to a suitable fineness and then burnt to incipient fusion in a kiln, chemical combination takes place, largely in the solid state resulting in a product aptly named clinker. This clinker, when ground to a suitable fineness, together with a small quantity of gypsum (SO₃) is Portland cement. In fact, cement powder is “nothing else” other than a combination of oxides of calcium, silicon, aluminum and iron. The cement used throughout the test program was Normal Portland Cement (OPC) of 53 grades conforming to IS 4031:1988 was used in the present study. The specific gravity of cement is taken as 3.0. The chemical and physical properties of cement are presented in following tables.

2.5.2. Chemical composition O.P.C

Although Portland cement consists essentially composed of four major oxides: lime (CaO), silica (SiO₂), alumina (Al₂O₃), and iron (Fe₂O₃) and also Portland cement contains small amount of magnesia (MgO), alkalies (Na₂O and K₂O), and sulfuric anhydrite (SO₃).

2.6. AGGREGATES

The material which is combined with cement and water to make concrete is called aggregate. Aggregate makes 60 to 80 percent of concrete volume. It raises the strength of concrete, reducing the shrinking tendencies of cement and is used as economical filler. Aggregates are divided into fine and coarse categories.

2.6.1. Fine Aggregates

2.6.1.1. Sand

Naturally available sand is used as fine aggregate in the present work. The most common constituent of sand is silica, usually in the form of quartz, which is chemical inert and hard. The sand is free from clayey matter, silt and organic impurities etc. Hence used as a fine aggregate in concrete. The size of sand is that passing through 4.75 and retained on 150 micron IS sieve. The specific gravity of Sand is taken as 2.62. Sand is tested for specific gravity, in accordance with IS: 2386-1963.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 6, Issue 11, November 2017

Grain Size Distribution of Fine Aggregate-Sand

Table 4: Sieve analysis of Fine Aggregate-Sand

S.NO.	Sieve Size	Percentage passing (100-F)
1	4.75mm	98.5
2	2.36mm	88.5
3	1.18mm	56.9
4	600µm	36.35
5	300µm	6.7
6	150µm	0.5
7	Pan	0

2.6.2. Coarse aggregates

The coarse aggregate is free from clayey matter, silt and organic impurities etc. The specific gravity of Sand is taken as 2.65. Coarse aggregate is tested for specific gravity, in accordance with IS: 2386-1963. The maximum size of 20 mm is used as a coarse aggregate in concrete. For most of building constructions, the coarse aggregate consists of gravel or crushed stone up to 20mm size. However, in massive structures, such as dams, the coarse aggregate may include natural stones or rock.

2.6.2.1 Grain Size Distribution of Coarse Aggregate

Table 5: Sieve Analysis of Coarse Aggregate

S. No	Sieve Size	% passing (100-F)
1	20mm	80.92
2	16mm	24.63
3	12.5mm	2.56
4	10mm	0.53
5	4.75mm	0.32

2.7. DETAILS OF MIXES

Concrete mix design in this experiment was designed as per the guidelines specified in by IS10262-1982 and ACI committee. All the samples were prepared based on the design trail mix of M20 grade of concrete was used in the present investigation. In this the mineral admixtures were used to substitute cement by various percentages such as (10, 20, and 30) of cement weight and the percentage of aggregates was kept constant for all mixes.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 6, Issue 11, November 2017

III. EXPERIMENTAL RESULTS

RESULTS OF NORMAL CONSISTENCY TEST

3.1. Normal consistency of cement with replacement of fly ash

The variation of normal consistency of cement paste with addition of fly ash is shown in the table 5.1. The normal consistency test shows a very slight increase with the partial replacement of cement by fly ash at different dosages of 5, 10, 15, and 20 % in ordinary Portland cement which are 2% respectively.

3.1.1. Normal consistency of cement with replacement of silica fume

The variation of normal consistency of cement paste with addition of silica fume is shown in the table 5.2. The normal consistency test shows a very slight increase with the partial replacement of cement by silica fume at different dosages of 5, 10, 15, and 20 % in ordinary Portland cement which are 2% and 4% respectively.

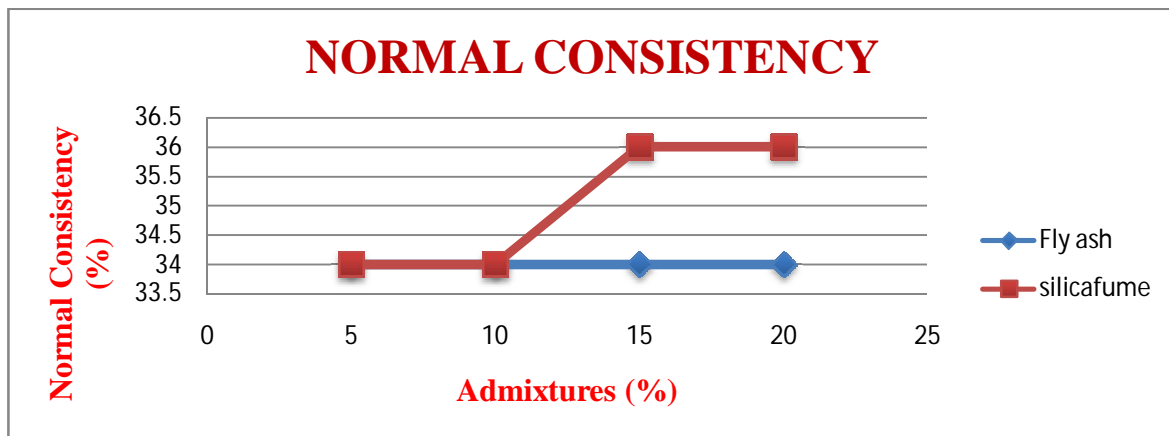


Figure 1: Effect on Normal Consistency for replacement of Cement with different admixtures

3.2. Initial and final Setting time of cement with replacement of silica fume

The variations in the initial and final setting times of cement with addition of silica fume. From table 5.4 it is observed that both the initial and final setting times got retarded and accelerated by replacement of silica fume in the ordinary Portland cement.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 6, Issue 11, November 2017

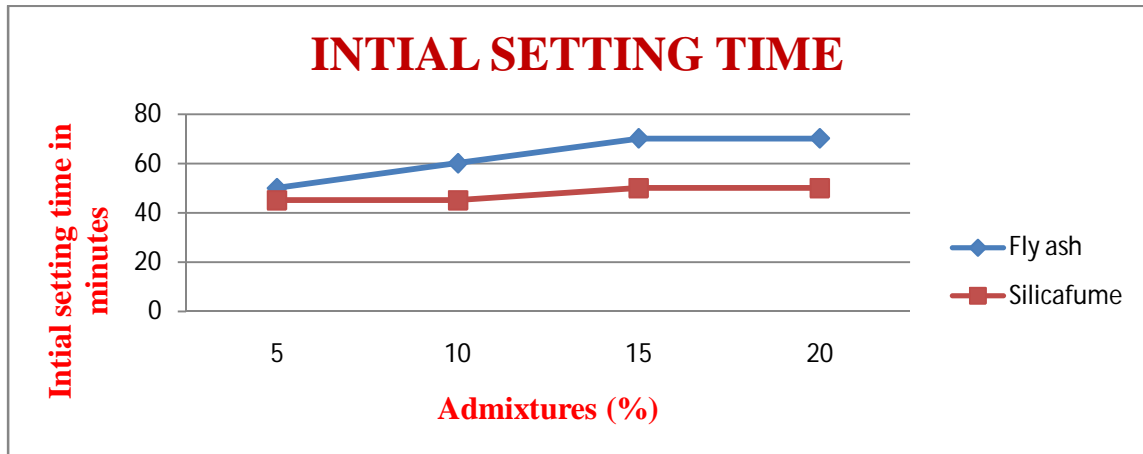


Figure 2: Effect on initial setting time for replacement of cement with different Admixtures

From above results it can be known that the initial setting time of normal cement paste is 45 minutes. From figure 5.2 the initial setting time was found to increase as the replacement percentage increases after the replacement of 5%. As per the Indian standards, the initial setting time should not be less than 30 minutes. Here all the replacement percentages satisfy this requirement.

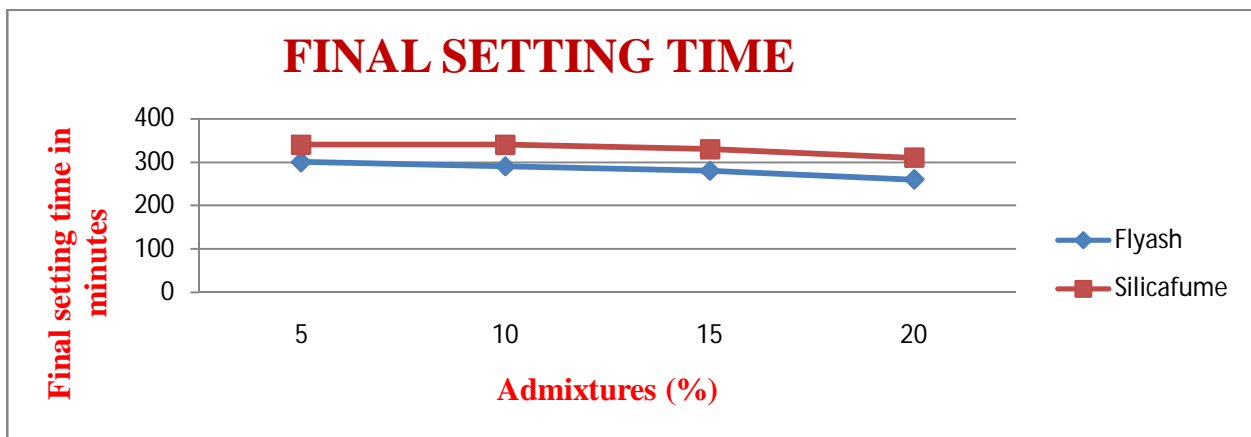


Figure 3: Effect on final setting time for replacement of cement with different Admixtures

3.3. FRESH CONCRETE TEST RESULTS

The properties of fresh concrete can be evaluated by slump cone test & compaction factor test with w/c ratio 0.4. The results of properties are given in table 6.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 6, Issue 11, November 2017

Table 6: Result of slump, compaction factor and density of fresh concrete

S.No.	Mix type (SF %,SF&FA%)	Slump value(mm)	compaction factor
01	MS0(0.0%,0.0%&0.0%)	72	0.952
02	MS1(0.5%,5%&5%)	20	0.820
03	MS2(0.5%,10%&10%)	35	0.810
04	MS3(0.5%,15%&15%)	48	0.902
05	MS4(1.0%,5%&5%)	15	0.801
06	MS5(1.0%,10%&10%)	16	0.786
07	MS6(1.0%,15%&15%)	31	0.802
08	MS7(1.5%,5%&5%)	12	0.740
09	MS8(1.5%,10%&10%)	13	0.792
10	MS9(1.5%,15%&15%)	15	0.810

3.4.HARDENED CONCRETE STRENGTH RESULTS

Result of compressive strength for M40 grade on concrete on cube. The specimens are separated by steel fibers, silica fume & fly ash with varying percentage. The table no 7 shows result of compressive strength at 7, 28& 45 days.

3.4.1COMPRESSIVE STRENGTH

The test results of compressive strength of M40 grade concrete with various proportions of fly ash, silica fume and steel fibers is shown in Table5.9.

The cube compressive strength indicates the average of three test results. It can be observed that the compressive strength of concrete prepared using fly ash and silica fume exhibits more strength than the control concrete.

Table 7: compressive strength at 7, 28& 45 days

Mix. No.	Steel fibers%	Silica fume%	Fly ash%	Compressive strength(N/mm ²)		
				7 days	28 days	45 days
MS0	0.0%	00%	00%	33.320	48.328	48.328
MS1	0.5%	5%	5%	38.120	41.510	52.476
MS2	0.5%	10%	10%	30.128	37.435	44.954
MS3	0.5%	15%	15%	28.320	30.788	34.578
MS4	1.0%	5%	5%	39.182	44.938	58.120
MS5	1.0%	10%	10%	32.148	42.120	49.320
MS6	1.0%	15%	15%	34.540	39.435	46.542
MS7	1.5%	5%	5%	41.620	46.125	63.140
MS8	1.5%	10%	10%	31.492	43.986	55.130
MS9	1.5%	15%	15%	32.148	42.126	47.160

International Journal of Innovative Research in Science, Engineering and Technology

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Visit: www.ijirset.com

Vol. 6, Issue 11, November 2017

3.4.2. SPLIT TENSILE STRENGTH:

The test results of split tensile strength of M40 grade concrete with various proportions of fly ash, steel fibers and silica fume is shown in Table 5.10. The variation of split tensile strength of M40 grade concrete with different percentages of fly ash and varying percentages of silica fume is shown in table 8

Table 8: split tensile strength at 7 & 28 days

Mix. No.	Steel fibers%	Silica fume%	Fly ash%	Split tensile strength(N/mm ²)	
				7 days	28 days
MS0	0.0%	00%	00%	3.30	3.8
MS1	0.5%	5%	5%	2.84	3.2
MS2	0.5%	10%	10%	3.05	3.85
MS3	0.5%	15%	15%	3.57	3.75
MS4	1.0%	5%	5%	3.19	4.12
MS5	1.0%	10%	10%	2.64	4.26
MS6	1.0%	15%	15%	2.93	4.67
MS7	1.5%	5%	5%	3.12	3.89
MS8	1.5%	10%	10%	2.96	4.45
MS9	1.5%	15%	15%	3.28	3.98

3.4.5. FLEXURAL STRENGTH

The test results of flexural strength of M40 grade concrete with various proportions of fly ash, silica fume and steel fibers is shown in Table 5.11. The variation of flexural strength of M40 grade concrete with different percentages of fly ash and varying percentages of silica fume is shown in table no 9.

Table no.9: flexural strength (N/mm²) for 7 days.

mix. no	Steel fibers %	Silica fume%	Fly ash%	Flexural strength(N/mm ²) 7 Days
MS1	0.5%	5%	5%	4.712
MS2	0.5%	10%	10%	4.120
MS3	0.5%	15%	15%	4.182
MS4	1.0%	5%	5%	5.182
MS5	1.0%	10%	10%	4.320

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 6, Issue 11, November 2017

MS6	1.0%	15%	15%	4.896
MS7	1.5%	5%	5%	6.182
MS8	1.5%	10%	10%	5.920
MS9	1.5%	15%	15%	4.520

IV. CONCLUSION

The study on the effect of steel fibers with Fly Ash and silica fume can still be a promising work as there is always a need to overcome the problem of weakness of concrete. The following conclusions could be drawn from the present research.

1. Marginal raise is observed in the workability as percentage of Fly Ash and silica fume rises.
2. Density of concrete is more as the proportion of steel Fiber raises.
3. Compaction factor is raises as the Steel Fiber proportion decreases.
4. Higher percentage of Steel Fibers slump was down.
5. Water falling agent is required for workable mix as percentage of Steel Fiber raises.
6. Stiffness of specimens is raised because of Steel Fibers, Fly Ash and silica fume.
7. The strength of specimen is about 82% at 28th day and 95 to 100% at 45 days, because of steel fibers, Fly Ash and silica fume.
8. Specimen of MS1, MS4&MS7 having high Flexural strength as well as Compressive strength.
9. Specimen number MS4 having high split tensile strength compare to normal concrete.
10. For small quantity of Fly Ash and silica fume (10%&20%) Compressive Strength is more for 1.0% & 1.5% Steel Fibers.

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