COMPARISON OF COMPRESSIVE STRENGTH OF CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH SILICA FUME & FLY ASH

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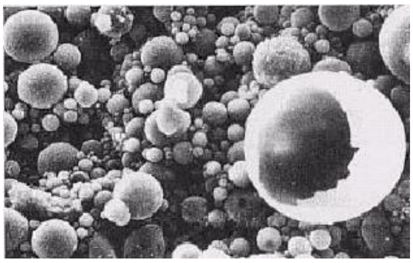
I. INTRODUCTION

CONCRETE:
Concrete is a manmade, marvelous outcome achieved on mixing mainly; cement, sand, gravel and water in a particular material proportions. Years ago, this manmade material concrete was mostly used in construction of buildings and it is expected to remain for coming years. It has been evolved into many different forms to satisfy the needs of developing world. Precast concrete components, prestressed concrete bridges, reinforced concrete buildings and Mass concrete damsare some typical examples. It is estimated that these forms of concrete are used in future development of the infrastructures.

HIGH STRENGTH CONCRETE
Concrete is always the key to develop stable and reliable infrastructure ever since the age of Greek and Roman. The compressive strength of the concrete has improved rapidly from 13.8 Mpa to the range of 41.4 Mpa within a short period of 1900's - 1960's. Poor performance, deterioration, long term durability and inadequate resistance are the major factors that demands for more architectural form, which has accelerated the research even into the microstructure of cements and concretes and more elaborate codes and standards. The outcomes of this research are new materials and composite with more improvement in the cement and the concrete properties. Today concrete strength is as good as 138 Mpa and even improving better, Research laboratories have even developed strength as high as 800 Mpa from research. High Strength Concrete is defined as a concrete which maintains desired properties like homogeneity, durability, highly dense in nature. Concrete of such kind cannot be obtained routinely using only traditional constituents and traditional mixing methodology. For example, these properties may include:
- Long life in service environment
- Compaction without segregation
- Volume stability
- Enhanced long term mechanical properties
- High toughness

COMPOSTION OF ULTRA HIGH STRENGTH CONCRETE:
The Ultra High Strength Concrete is the new generation on High Strength Concrete with concepts of particle packing taken one step further. Ultra High Strength Concrete is characterized by:

Large quantity of fine particles (typically silica fume)
High dose of high-range water reducing agents.
Low water-binder ratio
SELECTED ADMIXTURES FOR DEVELOPMENT HIGH STRENGTH CONCRETE:
(a) FLY ASH:
Fly ash is by product of pulverizing coal which comes out of the thermal power plant after it is used as a fuel, it is a consequence of the ignition of compressed coal in electric power production plants.. During combustion, the coal's mineral impurities fuse in suspension and are carried away from the combustion chamber by the exhaust gases. As on processes goes on, the fused material cools and solidifies into spherical glassy particles called fly ash.
Role of fly ash:-
When sufficient lime has been liberated from fly ash, it reacts with cementitious properties under water and leads to a pozzolanic action. There onwards, the strength increases rapidly and equality can be attained after 1-3 months. After the liberation of lime the pozzolanic action continues at a higher stage than cement hydration. So that high strength is obtained.



ASTM has classified the fly ash in to two cases
Class -- C
Fly ash normally produced by burning of sub bituminous coal in addition to the pozzolonic it is also having cementitious properties also. Properties of fly ash, particle size and shape characteristics dependent upon the source and uniformity of the coal, degree of pulverization etc. The majority of fly ash particles are glassy solid and spherical in shape.
Class –F
Fly ash normally produced from the burning of bituminous coal usually has less than 5% Cao class F fly ash has pozzolonic properties only.
(b) SILICA FUME
The use of pozzolanic materials is an old as that of the art of concrete construction. It was recognized long time ago, that the suitable pozzolans used in appropriate amount, modify certain properties of fresh and hardened mortars and concretes.

It has been amply demonstrated that the best pozzolans in optimum proportions mixed with Portland cement improves many qualities of concrete, such as

- Lower the heat of hydration and thermal shrinkage,
- Increase the water tightness,
- Reduce the alkali- aggregate reaction,
- Improve resistance to attack by sulphate soils and sea water,
- Improve extensibility,
- Lower susceptibility to dissolution and leaching,
- Improve workability,
- Lower costs.

II. LITERATURE REVIEW

ShwetaGoyal, Bhattacharjee. B and Maneek Kumar they investigated on the behavior of 28 and 90 days compressive strength of role of Fly Ash (FA), Silica Fume (SF) and Super plasticizer dosage. They concluded that in same workability the silica fume increased the Super plasticizer dosage on the other hand Fly Ash decreased the dosage of Super plasticizer. With low Super plasticizers the three components are design for high workability without impair in strength.

Murthi.P and Siva Kumar. V in their experimental study the behavior of the ternary blended concrete and identify the relationship between the compressive strength and split tensile strength. They used two kinds of binary materials like ASTM class Fly Ash (FA) and Rice Husk Ash (RHA), these two materials are optimum replacement of cement in binary blended concrete. By using the silica fume as a cement replacement in binary system to improve the ternary blended concrete. The total weight of cement content, the silica fume is replacement in binary system is suggested as 4%, 8% and 12%.

Tahir Kemal Erdem, OnderKircainvestigated on concrete, that one single replacement in cement is more benefit then the combinations of cement replacement. They studied; M80 high strength concretes containing several type replacements were produced. In the first stage, silica fume is replaced in binary blends material in high strength concrete, the amount of silica fume is replaced as 5%, 10% and 15% by weigh of cement. In the second stage a third binder material is replaced in high strength concrete (class F or class C Fly Ash or ground granulated blast furnace slag) was introduced in the amount of silica fume and Portland cement at the first stage. Results indicated that ternary blends almost made it possible to obtain higher strengths than binary blends provided that the replacement by additions was chosen properly. The performance of slag in the ternary blends was better than class F Fly Ash but worse than class C Fly Ash.

AdityaDhagat, Manav Mittal they discussed that in present studies, the silica fume and fly ash is partly replaced with cement, which are by-product of electric furnace and thermal power plant. These two materials are partly replaced with cement to economize the construction of concrete and increases it strength. This will also helps to reduce the environmental losses. They prepared this replacement at 0.45 water cement ratio and they concluded that at 5 % replacement of silica fume in cement, the compressive strength and flexure strength of concrete specimen increases.

Audinarayana. D, Sarika. P, Dr. SeshadriSekhar. T, Dr. Srinivasa Rao, Dr. Sravana. P, Apparao. G discussed optimization of a Ternary Blended Cementitious structure base on Ordinary Portland Cement (OPC)/ Fly Ash / Micro Silica for the advance of high- performance concrete. Compressive Strength of Ternary Blended Concrete at the ages of 28, 90, 180 days for various combination of Fly Ash and Micro Silica mixes were investigated. Fly Ash was replaced by 0%, 15% and 20% along with Micro Silica of 0%, 5%, and 10%. All the mixes were studied at three water binder ratios of 0.55, 0.45 and 0.35.

Deepa A Sinha Discussed Extensive research work for decades also is in development throughout the world in concrete technology in discovery another material which can partly or completely replace ordinary Portland cement (OPC) and which can also get together the requirements of strength and durability aspects. Along with the xmany another materials try as incomplete cement replacement materials, the strength, workability and durability performance of industrial by products like fly ash, blast furnace slag, silica fume, met kaolin, rice husk ash, etc., now termed as complimentary cementitious materials (CCM) are relatively promising. Subsequently, these have led to the improvement of binary, ternary and tertiary blended concretes depending on the amount of CCM and their combination use as partial cement alternate materials. The use of suitably proportioned ternary blended allows the produce of one SCM to recompense for the inbuilt reduction of another. The main objective of this perform research was to investigate the properties of ternary blended concrete incorporate silica fume, met kaolin, and GGBS. The properties investigated comprise workability, compressive strength and. flexural strength. In this project, we have replaced cement by ternary blend of Fly ash, met kaolin, silica fume, GGBS up to 30% to determine the workability, compressive strength and flexural strength.

III. METHODOLOGY

TESTS CONDUCTED ON CEMENT

THE FOLLOWING ARE LABORATORY TESTS:

CONSISTENCY OF CEMENT:

Consistency is generally defined as degree of mobility or the degree of fluidity. The cement pastes consistency can be best defined by vicat plunger apparatus. A diameter of 10 mm and 50 mm length plunger penetrates to 5-7 mm depth from the bottom of the mould.

STANDARD CONSISTENCY TEST:

Standard consistency is adopted by the following procedure, for the first trial 400g of cement and 24% of water for the cement weight is added and a paste is prepared. After adding water this paste must be filled in Vicatmould within 3-5 minutes. After completely filling the mould with the cement paste, shake the mould to expel air. For the second trail (with 25% of water) the depth of penetration is to be found.

Fig 3.1 Vicat's apparatus

Trials are conducted in a similar fashion, but with a higher water cement ratio till the plunger reaches to 5-7 mm depth from the mould.

TEST RESULTS:

Table 3.1 Standard Consistency Cement used for KCP 53 grade cement

Trial No	Cement content (gm)	% of water	Penetration from bottom (mm)
1	500	28	31
2	500	29	19
3	500	31	16
4	500	33	6

Consistency value should be between 5-7mm and hence 33% of water is selected as the percentage of water to produce a cement paste of standard consistency.

INITIAL SETTING TIME:

The moment at which the water is added to cement and where the cement paste losses its plasticity is defined as initial setting time.

As per the procedure done in laboratory it is define as the elapsed time at moment water is added to a cement, to the time at which the needle of Vicat apparatus reaches to the bottom of the mould at a measure of 5-7 mm.

Taking, cement of 400 gm is gauged with 0.85 times of water required to produce a cement paste of standard consistency. The paste is gauged and transferred into Vicatmould gently, quickly in 3-5 min. The moment at which the water is added to cement is recorded through stop watch. The room temperature and water temperature at the time of gauging should be around 27° C to 29° C.

The needle is lowered gently and brought into the contact of the test blocks surface and released quickly. The needle should be allowed to penetrate deep into the test block. Initially the needle completely pierces the block. But after certain time the needle penetrates to a depth of 5-7 mm from the bottom of mould, before the paste losses its plasticity. The initial setting time is taken when the elapsing time, is added the water in cement and the test block is penetrates by needle to a depth equal to 5-7mm from its bottom, at the time stop watch is stopped and taking as initial setting time.

TEST RESULTS:

Initial setting time of cement is 90 minutes.

FINAL SETTING TIME:

Final setting time is defined as losing its plasticity completely. In other words, the paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5 mm.

As per the procedure done in laboratory it is define as the elapsed time at moment water is added to a cement, to the time when only the needle of Vicat apparatus released the circle portion of that needle disappears, until the dot appears. After getting the impressing stop the stopwatch note down the final setting time.

Taking, Cement of 400 gm is gauged with 0.85 times of water required to produce a cement paste of standard consistency. The paste is gauged and transferred into Vicatmould gently, quickly in 3-5 min. The moment at which the water is added to cement is recorded in start stop watch. The room temperature and waters temperature at the time of gauging should be around 27° C to 29° C.

Replace the needle of the Vicat apparatus by a circular attachment. The cement shall be considered as finally set when, upon lowering the attachment gently cover the surface of test block, the centre needle makes an impression, while the circular cutting edge of the attachment fails to do so.

TEST RESULTS:

Final setting time of cement is found to be 305min.

COMPRESSIVE STRENGTH OF CEMENT:

The cement is always tested for strength at the laboratory before it is used for important works.

Strength tests are not made on neat cement paste because of difficulties of excessive shrinkages and subsequent cracking of neat cement. Strength of cement is found on a cube cast with using cement mortar, sand in specific proportions.

The standard sand is used for finding the strength of cement; it shall be confirmed to IS: 615-1991.

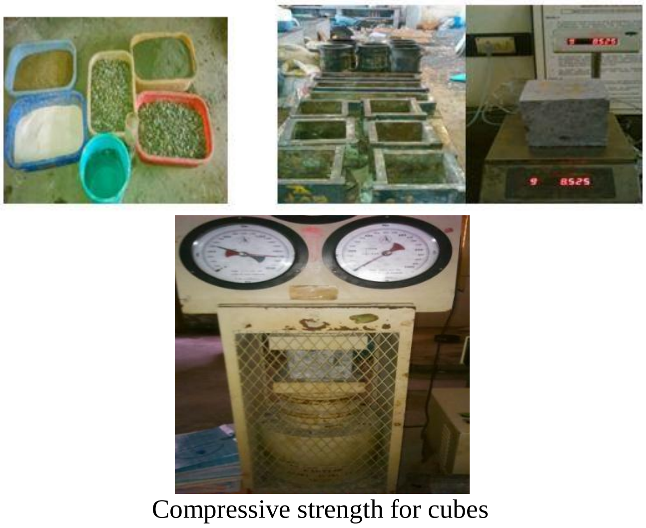
PREPARATION OF BEAM SPECIMENS

SPECIMEN

Total 9 prisms were casted and each prism size is 100 X 100 X 500 mm

MIXING

Mixing of the concrete is either done by hand or in a laboratory using batch mixer



Compressive strength for cubes

Split Tensile Test For Cylinder

IV. RESULTS

Compression Test for Silica Fume and Fly Ash:

Table Compressive strength by cubes for silica fume:

	7 days	28 days	56 days
M 0% replacement	57.86	78.06	80.79
M 2S% replacement	60.03	81.03	83.6
M 5S% replacement	61.97	81.52	83.85
M 7S% replacement	62.90	83.44	86.67
M 10S% replacement	61.69	80.56	82.92

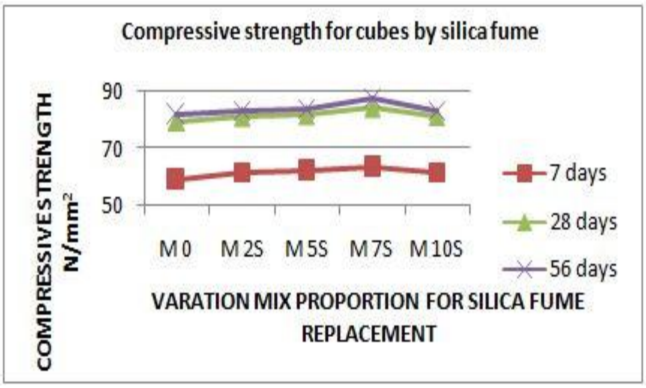


Fig Compressive strength for cubes by silica fume

Among all replacement variations M 7S i.e. 7% Silica Fume have shown maximum compressive strength results at 28 days curing and 56 curing periods.

Table Compressive strength by cubes for fly ash:

	7 days	28 days	56 days
M 0F% replacement	57.86	78.66	81.67
M 5F% replacement	58.85	78.77	80.8
M 15F% replacement	62.67	82.94	84.94
M 25F% replacement	61.13	80.68	82.86
M 35F% replacement	60.43	78.19	80.67
M 45F% replacement	56.98	77.43	78.8

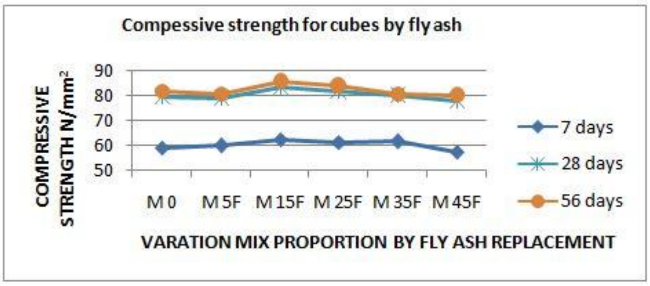


Fig Compressive strength for cubes by Fly Ash

Among all replacement variations M 15F i.e. 15% Fly Ash have shown maximum compressive strength results at 28 days curing and 56 curing periods.

Split Tension Test For Silica Fume And Fly Ash:

Table Split tensile strength for cylinder by silica fume:

	7 days	28 days	56 days
M 0% replacement	4.7	5.9	7.3
M 2S% replacement	5.07	6.13	8.1
M 5S% replacement	5.16	7.02	8.6
M 7S% replacement	5.78	7.75	9.15
M 10S% replacement	5.16	7.06	8.65

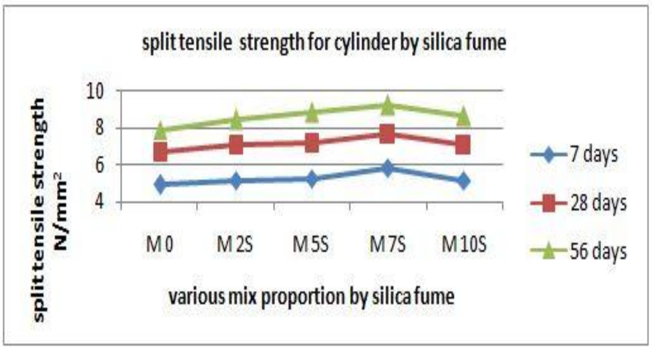


Fig Split tensile strength for cylinder by silica fume

Among all replacement variations M 7S i.e. 7% silica Fume have shown maximum split tensile results at 28 days curing and 56 curing periods.

Table Split tensile strength for cylinder by fly ash:

	7 days	28 days	56 days
M 0% replacement	4.89	6.69	7.85
M 5F% replacement	4.98	6.79	8.17
M 15F% replacement	5.68	7.59	8.89
M 25F% replacement	5.23	7.26	8.45
M 35F% replacement	5.33	7.29	7.78
M 45F% replacement	5.28	6.88	7.78

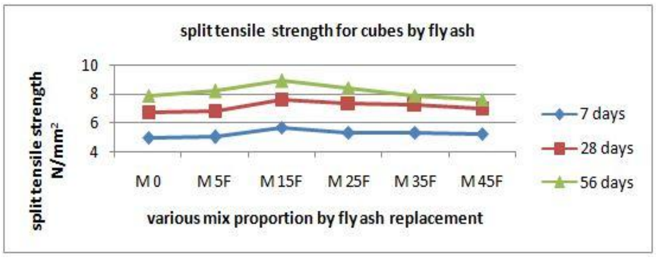


Fig Split tensile strength for cylinder by fly ash

Among all replacement variations M 15F i.e. 15% fly ash has shown maximum split tensile strength results at 28 days curing and 56 curing periods.

Flexural Strength Test for Silica Fume and Fly Ash:

Table flexure strength for prisms by silica fume:

	7 days	28 days	56 days
M 0S% replacement	4.55	7.35	8.35
M 2S% replacement	4.79	7.39	8.79
M 5S% replacement	5.05	7.49	8.85
M 7S% replacement	5.18	8.02	9.4
M 10S% replacement	4.76	7.12	8.16

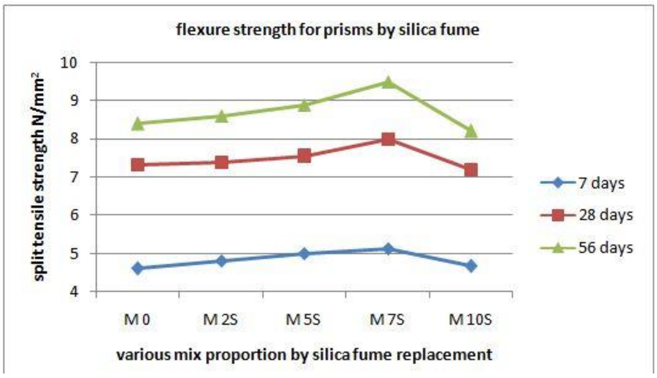


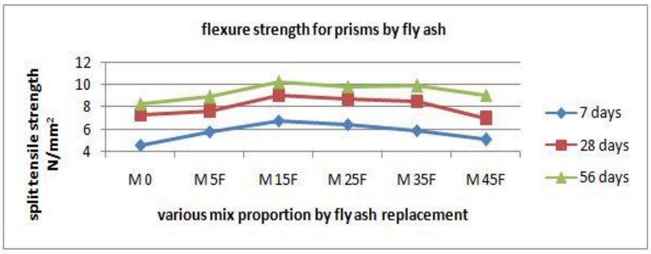
Fig 5.5 flexure strength for prisms by silica fume

Among all replacement variations M 7S i.e. 7% silica Fume have shown maximum flexure strength results at 28 days curing and 56 curing periods.

The flexure strengths for the Samples partially replaced with fly ash and Conventional concrete are compared and tested after curing of 7, 28 and 56 days. The results were plotted below.

Flexure strength for prisms by fly ash:

	7 days	28 days	56 days
M 0% replacement	4.7	7.28	8.25
M 5F% replacement	5.78	7.53	8.7
M 15F% replacement	6.75	9.1	10.3
M 25F% replacement	6.35	8.7	9.75
M 35F% replacement	5.7	8.45	9.76
M 45F% replacement	5.16	6.83	9.23



Flexure strength for prisms by fly ash

Among all replacement variations M 15F i.e. 15% fly ash has shown maximum flexure strength results at 28 days curing and 56 curing periods.

COST ANALYSIS:

Mix Proportion

Mix Proportion Of Concrete			
Cement	Fine Aggregate	Coarse Aggregate	W/C Ratio
1	0.62	1.64	0.3

Effective Cost analysis for 1M^3 with no binding material

Total Cost of concrete per 1 M^3 Meter when No binding material is Replaced	
Cement Cost	3360
Fine Aggregate Cost	621.7
Coarse Aggregate Cost	2209
Sp 430 Cost	1210
Total Cost of Concrete	Rs. 7,400.7

Effective Cost analysis for 1M^3 with silica fume

Total Cost of concrete per 1 M^3 Meter when optimum 7% Silica Fume Replaced in INR	
Cement Cost	3125
Silica Fume Cost	2822
Fine Aggregate Cost	621.7
Coarse Aggregate Cost	2209
Sp 430 Cost	1210
Total Cost of Concrete	Rs. 9,987.7
% increase in cost over ordinary concrete	34%
% increase in strength over ordinary concrete	9.94%

Effective Cost analysis for 1M^3 with fly ash

Total Cost of concrete per 1 M^3 when optimum 15% Fly Ash Replaced in INR	
Cement Cost	2856
Fly Ash Cost	50.4
Fine Aggregate Cost	621.7
Coarse Aggregate Cost	2209
Sp 430 Cost	1210
Total Cost of Concrete	Rs. 7,602.3
% decreases in cost over ordinary concrete	6.08 %
% increase in strength over ordinary concrete	5.27 %

V. CONCLUSION

- 7% replacements of binding material with Silica Fume in concrete have proven to achieve maximum strength than all replacement in range interval of Silica Fume Replacement for compressive strength.
- 15% replacement of binding material with Fly Ash has proven to achieve maximum strength in concrete for range interval of Fly Ash Replacement for compressive Strength.
- 7% replacements of binding material with Silica Fume in concrete have proven to achieve maximum strength than all replacement in range interval of Silica Fume Replacement for Split Tensile strength.
- 15% replacement of binding material with Fly Ash has proven to achieve maximum strength in concrete for range interval of Fly Ash Replacement for Split Tensile Strength.
- 7% replacements of binding material with Silica Fume in concrete have proven to achieve maximum strength than all replacement in range interval of Silica Fume Replacement for Flexural strength.
- 15% replacement of binding material with Fly Ash has proven to achieve maximum strength in concrete for range interval of Fly Ash Replacement for Flexural Strength.
- There was 34 % increase in initial cost of concrete for optimum replacement of 7% Silica Fume, the relative increase in strength was from 6% to 8% in compression, split and flexural properties.
- There was just 6.08% decrease in initial cost of concrete for optimum replacement of 15% Fly Ash, the relative increase in strength was from 5% to 6% increase in compression, split and flexural properties.
- Among the two mineral admixtures used Fly Ash turned out to be the best replacement to bring out good strength increment for properties of concrete in a more economic manner.

Future Scope of Project:
The research work was processed only for two mineral admixtures replacement in high strength concrete grade of M80. The replacements could be made with several other admixtures and at various Grade proportion Variations. The testing has been however executed in normal atmospheric conditions due to limitations but the tests can also be examined for critical acidic and hot temperature expose.

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Appendix I:
M80 Mix Design Procedure:
Design Stipulations:
Grade of concrete : M80
Size of aggregate :20 mm & 12.5mm
Degree of workability: 0.90 (compaction factor)
Degree of quality control: good
Type of exposure: moderate
Grade of cement: 53 grade ordinary Portland cement

Test Data for Materials
Specific gravity of cement: 3.15
Specific gravity of fine aggregate: 2.64
Specific gravity of coarse aggregate: 2.89
Water absorption of fine aggregate: 1%
Water absorption of coarse aggregate: 0.6%
Bulk Density of coarse aggregate: 1710 kg/m3
Aggregate Impact value: 8.2% (Exceptionally Strong)
Fine aggregate: Sand zone II according to IS: 383 - 1970
Coarse aggregate: Confirming to IS: 383 -1970

Mix Proportion Of Concrete			
Cement	Fine Aggregate	Coarse Aggregate	W/C Ratio
1	0.62	1.64	0.3

