International Journal of Research in Advent Technology, Vol.5, No.4, April 2017
E-ISSN: 2321-9637
Available online at www.ijrat.org

A Behavioural Study on Mechanical Properties of Concrete using Silica Fumes and Copper Slag as Partial Replacements for Cement and Fine aggregates with Additive Fibres

B.P.Sharath
Project Assistant (Part Time)
Dept. of Civil Engineering
National Institute of Technology, Suratkal, Karnataka, INDIA
Email: bpsharath1993@gmail.com

Abstract: Concrete is one of the versatile heterogeneous material. With the advent of concrete, Civil Engineering has touched the highest peak of technology. It is a material of choice where there is an at most necessity of its both physical as well mechanical parameters. The properties of concrete mainly depends upon on the constituents which are used in its making. Nowadays, consumption of industrial solid wastes in concrete production is considered to be environmental friendly, because it contributes in reducing the consumption of naturally available resources and these are abundantly available.
The mineral admixtures used in preparing the mix are Silica Fumes varied in only 5 % and Copper Slag varied in (0, 15, 20, 25, 30, 35, 40, 45) percent as partial replacements for cement and fine aggregates respectively along with Recron 3S fibers (0.325%) as additives for M 30 grade concrete. Prevailing results from are tabulated and compared with other for arriving at a final conclusion.

Index Terms: Silica Fumes, Copper Slag, GGBS, Recron 3 S Fibers

I. INTRODUCTION

'Cement', can be considered as globally sustained with very least effect upon the environment. The possibility of having the sustained energy as well as a reduction in the day to day cost expenses can happen only when the numerous left-out wastes from various industries are utilized in a proper manner as replacement additives for cement or aggregates or whatever it is. Therefore, among all that materials, GGBS, Micro silica, Copper Slag and so on, can find their utilization in concrete which are also known as artificially produced pozzolanic mineral admixtures **[1]**.

Enough research is in progress in our country and also in other foreign countries in order to get familiarized as well as to know the pros and cons towards the utilization of these admixing materials as replacement additives and considerably this whole work is getting encouraged day by day. These also states that by using Silica Fumes in concrete as partial replacement additive for cement has many added benefits as mentioned earlier in the introduction section **[2]**.

According to probable results obtained by the experimental investigation conducted by using this additive, the percentage limits of replacement of this material are between 10 to 20 percent for developing later age strengths of concrete. As per this research conducted, **[3]**, Silica Fumes was partly replaced in cement for the concrete grade of M-30 viz. 10 percent, have considerably lead to an appreciable increase in its compressive strength. Chemically speaking, when these types of materials are combined in it, the SiO_2 Fumes content gets reacted with $Ca(OH)_2$ (which is nothing but lime) to form Calcium Silicate Hydrates which is most commonly abbreviated as C-S-H, which have a real positive reflection of improvising the durability factor and also mechanical properties of concrete.

Copper Slag, which is considered to be a rubbish material and also a huge waste collected while conducting the procedure of extracting copper in various refineries, is very cheap and it can find its positive utilization in concrete when partly replaced for fines content and also if usage of such materials is encouraged considerably, a lot of problems related to their improper disposal can be solved and also steps can be taken to protect the environment effectively **[4]**. Copper Slag consists of various useful properties such as good soundness characteristics, stability, and excellent resistance to abrasion etc. which makes it suitable to be partly used for fines content in concrete **[5]**. Experimental studies were conducted in order to get familiarized with certain deciding parameters of concrete like mechanical and durability aspects by the usage of both silica fumes and copper slag as partial replacement additives for cement and fine aggregates respectively, and it was seen that among all the other mixes, the mix consisting of a maximum of 8 % of silica fumes and 40 % of copper slag has given high strengths and good durability results. It was also noticed that by using these two partial replacement additives, the compressive and flexural strengths were found to increase by about 29.9 % and 25.8 % respectively **[6]**. It was found that by the addition of Recron 3S fibers in a varying range starting from 0.2 % to 0.225 % with OPC, there was a drop in the compressive strength. Then by looking at this, the range of variation was slightly lifted up from 0.25 % to 0.35 %, which resulted an increase in the same. It is also mentioned that more and more increase in this varying addition of fibers will relatively drop the strength parameters. Therefore, it can be concluded that these fibers can be added upto 0.35 % in concrete for obtaining good results **[7]**.

II. OBJECTIVES OF STUDY

The main objectives of this thesis are listed as follows:

a) To investigate the behavioral study of the two mineral admixing materials i.e. Silica fumes and Copper Slag on the mechanical properties of concrete which are being utilized as partial replacement additives for cement and fine aggregates respectively in a concrete grade of M-30.

b) Depending upon the behavior of the usage of these two materials in concrete, an attempt was also made to study that how the additive fibers will behave along with Silica fumes and Copper slag at a time in concrete.

For this, an optimum percentage replacement of both the materials were found out initially and later the same was used with a constant dosage of the additive fibers.

c) Comparison of the results were done for arriving at a conclusion.

III. MATERIALS & METHODOLOGY

The materials used in this work are Cement, Silica Fumes, Copper Slag, Coarse Aggregates (both 20 & 12.5 mm), Fine Aggregates (crushed stone sand), Superplasticizers, Water and Polypropylene fibers of 12 mm.

a) Cement

Ordinary Portland cement of grade 53 with a brand name as Penna Cement is used in this work confirming to IS 12269:2013 **[8]**, with a specific gravity of 3.122. It is procured from Boyareddypalli, Andhra Pradesh, which is a single source supplier of cement of this brand. Its physical requirements are obtained directly from the suppliers of Penna Cement Industries Ltd. which are tabulated as follows:

Table 1: Properties of Cement

Sl. No.	Test Particulars	Test Results	Requirements as per IS 12269:2013
1.	Fineness (m^2/kg)	327.5	225 minimum
2.	Normal Consistency (%)	28.5	-
3.	Setting Time (minutes) Initial Final	 190 285	 30 minimum 600 maximum

b) Silica Fume

Silica fume of brand 'CORNICHE SF' is used which is an ultra-fine powder and is light to dark grey in color bearing a specific gravity of 1.86 confirming to ASTM C 1240:2005 and IS 15388:2003 specifications

[9]. It is a co-product from the silicon or ferrosilicon industry and is rich in silicon-di-oxide (SiO_2) which is supplied by Corniche India Pvt. Ltd., Maharashtra as which is shown as follows. Its properties were obtained from the suppliers which are tabulated as follows:

Figure 1: Silica Fume Sample

Table 2: Properties of Silica Fume

Sl. No.	Particulars	Specified Range
1.	Moisture (%)	3.0 % Maximum
2.	Bulk Density (kg/m^3)	550 – 700
3.	Silicon Dioxide (%)	85 % minimum

c) Coarse Aggregates

The coarse aggregates are obtained from local crushers around Mangalore consisting of both 20 mm and 12.5 mm sized aggregates confirming to IS 383: 1970 specifications [10]. It is observed that they should be hard, strong, durable, and free from any unwanted coating, organic impurities and other foreign substances.

The physical properties were analyzed and detailed particle distribution of both 20 and 12.5 mm sized aggregates was done using IS sieve sizes which are placed in the descending order viz. 40 mm, 31.5 mm, 25 mm, 20 mm, 16 mm, 12.5 mm, 10 mm, 6.3 mm and 4.75 mm.

Table 3: Physical Properties of Coarse Aggregates

Sl. No.	Particulars	Results
1.	Shape of Coarse Aggregate	Angular
2.	Specific Gravity (Saturated Surface Dry Condition) I) 20 mm II) 12.5 mm	 2.66 2.68
3.	Water Absorption (%) I) 20 mm II) 12.5 mm	 0.28 0.25
4.	Fineness Modulus I) 20 mm II) 12.5 mm	 4.66 2.08

After obtaining the particle size distribution of both 20 and 12.5 mm sized coarse aggregates by physical tests and particle size distribution analysis, it is decided that these two-different sized coarse aggregates are used in a proportion which are adjusted according to the required water-cement ratio in mix designing of concrete as specified in Table No. 3 of IS 10262:2009 [11].

Here, the 20 and 12.5 mm sized coarse aggregates are used in a proportion viz. is (60%:40%) i.e. out of 100% of coarse aggregates, 60% will be 20 mm and 40% will be 12.5 mm sized coarse aggregates.

d) Fine Aggregates

Due to the unavailability of natural sand in Mangalore, manufactured sand or Crushed Stone Sand of Zone – II is used in this work. It is seen that the particles are free from any foreign or inorganic materials, hard and durable confirming to IS: 383 – 1970 specifications.

Its physical properties were found and particle size distribution was carried out by using the IS sieve sizes which are placed in the descending order viz. 10 mm, 4.75 mm, 2.36 mm, 1.18 mm, 600µ, 300µ, 150µ and 75µ. The results obtained from all these analyses are tabulated as follows.

Table 4: Physical Properties of Fine Aggregates

Sl. No.	Particulars	Results
1.	Specific Gravity (Saturated Surface Dry Condition)	2.544
2.	Water Absorption (%)	3.212
3.	Silt Content (%)	8
4.	Fineness Modulus	2.58

e) Superplasticizer

'FLOWCON PCE G 166 KI' (High range of water reducing and retarding hyper plasticizer) was used as a super-plasticizer in this work confirming to IS 9103-1999 (reaffirmed 2004) [12]. The properties of this admixture are directly procured from its manufacturers and suppliers i.e. H & R Jhonson India.

f) Copper Slag

Copper slag is a by-product created during the copper smelting and refining process. As refineries draw metal out of copper ore, they produce a large volume of non-metallic dust, soot, and rock. Collectively, these materials make up slag, which can be used for a surprising number of applications in the building and industrial fields.

The Copper Slag used in this work is brought from Sterlite Industries Ltd. Tuticorin, Tamilnadu. Its physical properties were found and particle size distribution was carried out by using the IS sieve sizes which are placed in the descending order viz. 10 mm, 4.75 mm, 2.36 mm, 1.18 mm, 600µ, 300µ, 150µ and 75µ.

Figure 2: Copper Slag Sample

Table 5: Physical Properties of Copper Slag

Sl. No.	Particulars	Results
1.	Specific Gravity (Saturated Surface Dry Condition)	3.13
2.	Water Absorption (%)	3.21
3.	Silt Content (%)	2

g) Recron 3S Polypropylene Fibers

Recron 3S fibers are Engineered Micro Fibers which are supplied by Reliance Industries Ltd., Mumbai. These fibers have a unique "Triangular" cross-section, used in secondary reinforcement of concrete.

It complements structural steel in enhancing concrete's resistance to shrinkage cracking and improves mechanical properties such as flexural / split tensile and transverse strengths of concrete along with the desired improvement in abrasion and impact strengths. These fibers comply with ASTM C 1116, Type 111 fiber reinforced concrete.

Figure 3: Recron 3S Polypropylene fibers Sample

IV. MIX DESIGN PROPORTIONING

Concrete mix is designed according to IS: 10262-2009. Based on the results obtained from the tests conducted on the individual materials, proper selection, mix proportioning, and dosage of these is designed thoroughly in this mix design.

The mix proportions for M-30 grade control concrete are as follows:

Table 6: Mix proportions

Materials	Quantity (kg/m^3)
Cement	395
20 mm Coarse Aggregates	656.73
12.5 mm Coarse Aggregates	441.11
Crushed Stone Sand (Fine Aggregates)	770.578
Water	1.58
Chemical Admixture	158 liters

The other mix design proportions with the varying proportions of these two extra additives i.e. Silica Fumes and Copper Slag is designed based on this main mix design proportioning done for M-30 grade concrete which is tabulated as follows.

Table 7: Type of Concrete Mixes

Mix Designations	Description of Mixes with Varying Percentages of the Additives
Trail Mix-1	Normal Concrete of grade M 30
Trail Mix-2	5 % Silica Fumes + 15 % Copper Slag
Trail Mix-3	5 % Silica Fumes + 20 % Copper Slag
Trail Mix-4	5 % Silica Fumes + 25 % Copper Slag
Trail Mix-5	5 % Silica Fumes + 30 % Copper Slag
Trail Mix-6	5 % Silica Fumes + 35 % Copper Slag
Trail Mix-7	5 % Silica Fumes + 40 % Copper Slag

As shown in the above table, Silica fume which is used as the partial replacement for Cement, its percentage of variation is kept constant as 5 % in Trail Mixes (from TM-2 to TM-7), and Copper Slag which is used as the partial replacement for Fine Aggregates, whose percentage of variation ranges from 15-40 % in Trail mixes (from TM-2 to TM-9).

Since this whole work is about the study of the behavior of the two extra partial replacement additives for cement and fine aggregates, i.e. Silica Fumes and Copper Slag, an attempt was also made to study the same with the addition of engineered Polypropylene fibers. After the completion of the whole procedure of casting, curing and testing of specimens, a decision is made in order to select a specific mix proportion wherein all the mechanical properties of concrete i.e.

compressive, split tensile and flexural strength have reached the peak point and got declined thereafter. This kind of mix proportion can be mentioned as an optimum mix proportion which fits for the addition of these engineered fibers along with the two partial replacement additives and helps to study its behavior in concrete.

Figure 5: Casted Test Specimens

V. RESULTS AND DISCUSSION

1. Compressive Strength Test Results:

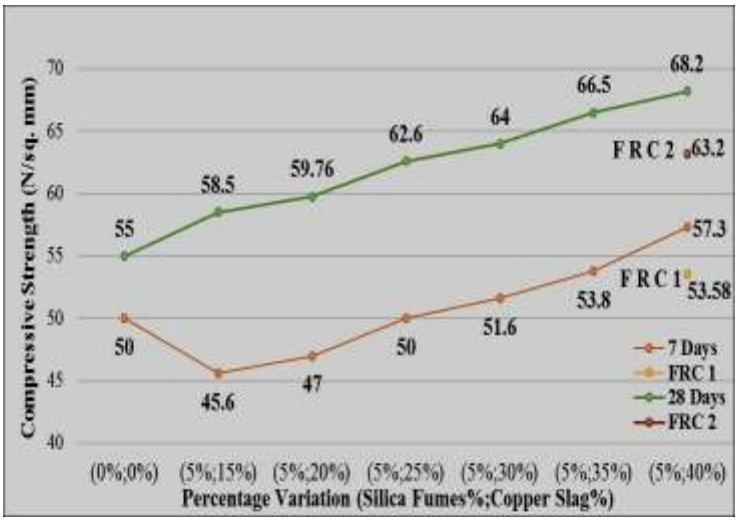
For each trail mix, 6 Cubes of size 150 x 150 x 150 mm were casted and tested for their compressive strength for both 7 and 28 days ages. The calculation of compressive strength values for the concrete was done confirming to IS:516 (1959) **[13]**.

Figure 6: Testing of cubes

The table below gives the overall result of compressive strength of silica fume concrete produced with different percentages of silica fume. The variation of compressive strength in the form of graph given below.

Table 8: Overall results of Compressive strength

Mix ID	Compressive Strength (N/mm²)	
	7 Days	28 Days
TM-1	50.0	55.00
TM-2	45.6	58.50
TM-3	47.0	59.76
TM-4	50.0	62.60
TM-5	51.6	64.00
TM-6	53.8	66.50
TM-7	57.3	68.20
Trail mix with Optimum % Replacement	53.58	63.2



Graph 1: Comparison of 7 & 28 Days Compressive Strength

From the graphs shown, the 7 & 28 days' compressive strength for normal concrete was found to be 50 N/mm^2 and 55 N/mm^2 for TM-1 respectively. Initially, in the case of 7-days' strength, there was a drop in it, but gradually it increased from TM-3 to TM-7. It was recorded maximum for TM-7 which is 57.3 N/mm^2, which represents there was an about 15% increase in the strength when compared to normal concrete.

In the case of 28-days strength, it started to increase from beginning itself i.e. from TM-2 to TM-7, and it was found to be maximum for TM-7 which is 68.2 N/mm^2, which represents there was an about 24% increase in the strength when compared to normal concrete.

Therefore, the mix proportion with 5% replacement of cement with Silica fumes and 40% replacement of fine aggregates with Copper slag which has represented that highest strength was selected for the addition of fibers in concrete. From the graphs, it can be seen that there was a drop in the strength at both the ages with the addition of fibers in concrete.

2. Split Tensile Strength Test Results

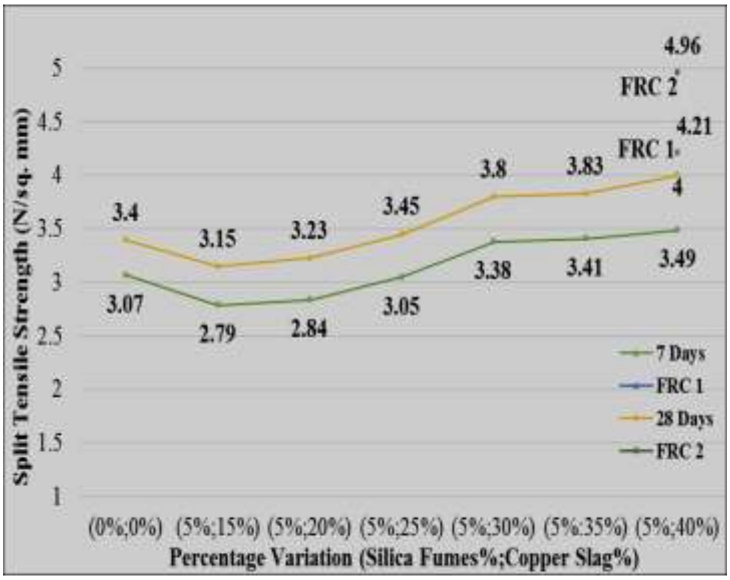
For each trail mix, 6 Cylinders of size 100 x 200 mm were casted for determining the split tensile strength at 7 and 28 days age. The calculation of split tensile strength values for the concrete was done confirming to IS 5816: 1999 (reaffirmed 2004) **[14]**.

The table below gives the overall result of split tensile strength of silica fume concrete produced with different percentages of silica fume. The variation of split tensile strength in the form of graph given below.

Figure 7: Testing of Cylinder

Table 9: Overall results of Split tensile strength

Mix ID	Split Tensile Strength (N/mm^2)	
	7 Days	28 Days
TM-1	3.07	3.4
TM-2	2.79	3.15
TM-3	2.84	3.23
TM-4	3.05	3.45
TM-5	3.38	3.8
TM-6	3.41	3.83
TM-7	3.49	4.0
Trail mix with Optimum % Replacement	4.21	4.96



Graph 2: Comparison of 7 & 28 Days Split Tensile Strength

According to the above graphs, the 7 & 28 days split tensile strength for normal concrete was found to be 3.49 N/mm^2 and 4.0 N/mm^2 for TM-1 respectively.

Initially, in the case of 7-days strength, there was a drop in it, but gradually it increased from TM-3 to TM-7. It was recorded maximum for TM-7 which is 3.49 N/mm^2, which represents there was an about 14% increase in the strength when compared to normal concrete.

In the case of 28-days strength, it was found that for normal concrete it was 3.4 N/mm^2 which started declining initially from TM-2 to TM-3, which later on increased and was found to be maximum for TM-7 which is 4 N/mm^2, which means there was an about 18% increase in the Split tensile strength compared to normal concrete.

With the addition of fibers for Trail Mix-7, an appreciable increase of about 37% and 46% was observed in case of both 7 & 28 days split tensile strength.

3. Flexural Strength Test Results

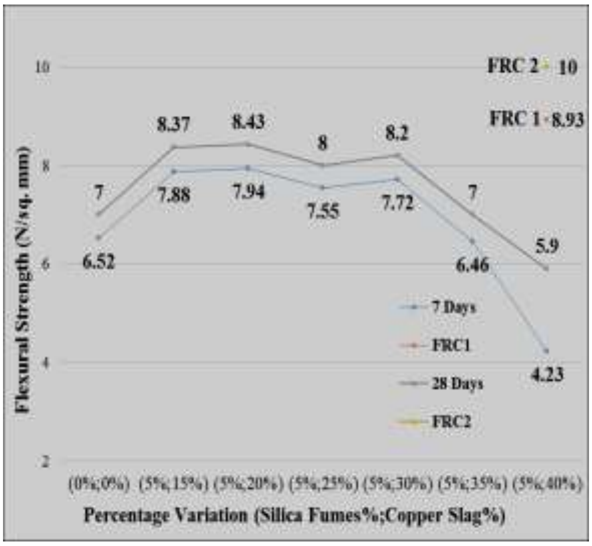
For each trail mix, 6 beams of size 100 x 100 x 500 mm were casted for determining the flexural strength at 7 and 28 days age. The calculation of flexural strength values for the concrete was done confirming to IS:516 (1959).

Figure 8: Testing of Beams

The table below gives the overall result of flexural strength of silica fume concrete produced with different percentages of silica fume.

Table 10: Overall results of Flexural strength

Mix ID	Flexural Strength (N/mm^2)	
	7 Days	28 Days
TM-1	6.520	7.0
TM-2	7.88	8.37
TM-3	7.937	8.43
TM-4	7.55	8.0
TM-5	7.72	8.2
TM-6	6.46	7.0
TM-7	4.23	5.9
Trail mix with Optimum % Replacement	8.93	10.0



Graph 3: Comparison of 7 & 28 Days Flexure Strength

According to the above graphs, the 7 & 28 days flexure strength for normal concrete was found to be 6.52 N/mm^2 and 7 N/mm^2 for TM-1 respectively. Since after that it, it went on increasing from TM-2 to TM-3, and gradually decreased from TM-4 to TM-7. Here, in this case, the maximum flexural strength was recorded for TM-2 in both the cases as 7.94 N/mm^2 and 8.43 N/mm^2 respectively relatively less for TM-7
Since in the previous strength test results, the addition of fibers were carried out by taking TM-7 into consideration. With the addition of fibers for TM-7, an appreciable increase of about 37% and 43% was observed in case of both 7 & 28 days flexural strength respectively.

VI. CONCLUSION

The conclusions which can be drawn from this work as listed as follows:

1. The usage of Silica fumes and Copper Slag in concrete has given dual benefits which are nothing but the attempts to protect the environment and bringing up the new ideas of reusing them in concrete for obtaining qualitative results.

2. In cases of Compression and Split tensile strength test results conducted, for both 7 & 28 days ages, the strengths were seen to be maximum for the mix proportion with 5% Silica fumes and 40% Copper Slag as partial replacements for cement and fine aggregates respectively but it was relatively less in the case of its Flexural Strength

3. There was an about 15% and 24% increment in 7th and 28th day Compressive strength in comparison with normal concrete's strength in these respective ages.

Addition of Recron 3S fibers in concrete has decreased the strength in both the ages, which proves that there is no much effect on strength with their utilization in concrete.

4. In the case of Splitting tensile strength of concrete, the increment was seen as 14% and 18%. In addition to this, an appreciable increase of about 37% and 46% was obtained at both 7 & 28 days ages in comparison with the respective strengths of normal concrete which concludes that addition of these fibers can have a very good influence on split tensile strength.

5. The Flexural strength of concrete increased initially which later on decreased gradually with more and more addition of copper slag. Utilization of fibers has given a boost of about 37% and 43% in the strength at both the ages which states that it is very much beneficial of using fibers in order to acquire a good flexural strength.

6. The effect of using Recron 3S fibers can be witnessed in the cases of Split tensile and Flexural strengths only, whereas it didn't influence much of compression strength of concrete.

7.Keeping in view of the mix proportioning procedure with the usage of these two admixing materials, it can be concluded that for with the presence of minimum cement content and 40% of copper slag replaced partly for fines content in concrete, a high performance and high strength concrete can be acquired.

REFERENCES

[1] Venkatesh Babu D L, Nateshan S C, "Investigations on Silica Fume Concrete", The Indian concrete Journal, September 2004.

[2] Khedr, S. A., Abou - Zeid, M. N., (1994) "Characteristics of Silica-Fume Concrete", Journal of Materials in Civil Engineering and Bhanja Santanu, and Sengupta, Bratish, (2003) "Optimum Silica Fume Content and its Mode of Action on Concrete," ACI Materials Journal.

[3] Sensualle G R, "Strength development of concrete with Silica Fumes", Cement and Concrete Composites 2006.

[4] Brindha D, Baskaran T, Nagan S, "Assessment of Corrosion and Durability Characteristics of Copper Slag Admixed Concrete", International Journal of Civil and Structural Engineering, Vol. 1, No. 2, 2010.

[5] Bipra Gorai, R.K. Jana and Premchand, "Characteristics and utilization of copper slag-a review", Resources, Conservation and Recycling, Vol. 39, No. 4, pages 299-313, 2002.

[6] Muhsin Mohyiddeen and Maya T.M, "Effect of Silica Fume on Concrete Containing Copper Slag as Fine Aggregate", International Journal of Research in Advent Technology", 10-11 June 2015.

[7] Nija Benny, "Performance Evaluation of Pozzolanos on A Fiber Reinforced Concrete", International Journal of Civil Engineering, Volume 1 Issue 4 September 2014.

[8] IS: 12269: 2013, "Ordinary Portland Cement, 53 Grade — Specification", Bureau of Indian standards (BIS), New Delhi, India.

[9] IS 15388:2003, "Silica Fume – Specification", Bureau of Indian standards (BIS), New Delhi, India and ASTM C 1240:2005, "Standard Specification for Silica Fume Used in Cementitious Mixtures", ASTM International.

[10] IS 383: 1970, "Specification for Coarse and fine Aggregates from Natural Sources for Concrete", Bureau of Indian standards (BIS), New Delhi, India.

[11] IS: 10262-2009, "Concrete mix proportioning – guidelines", Bureau of Indian standards (BIS), New Delhi, India.

[12] IS 9103-1999, "Concrete Admixtures — Specification", Bureau of Indian standards (BIS), New Delhi, India.

[13] IS 516-1959, "Methods of test for strength of concrete", Bureau of Indian standards (BIS), New Delhi, India.

[14] IS 5819-1999, "Splitting Tensile Strength of Concrete - Method of Test", Bureau of Indian standards (BIS), New Delhi, India