An Experimental Study of Properties of Concrete Using Copper Slag as Replacement Material of Fine Aggregates

Nishchay R. More[1], Prof. Jayant S. Kanase[2]
[1, 2] Department of Civil Engineering
[1, 2] KJEI's Trinity College of Engineering and Research, Pune, Savitribai Phule Pune University, Pune, India

Abstract- *This paper presents the experimental study of properties of concrete using copper slag as replacement material of fine aggregates to increase the hardened concrete properties such as compressive strength, split tensile strength and flexural strength of concrete. The present study encouraged the use of industrial waste copper slag material as replacement of fine aggregates in concrete. Mix proportion has to be done for M25 grade of concrete. The fine aggregate is replaced with copper slag in proportions of 0%, 20%, 30%, 40%, 50%, 60%, 80%, and 100%. Tests were performed for properties of fresh concrete and hardened concrete. All concrete specimens were cured for 28 days before compression strength test, split tensile strength test and flexural strength test. The results indicate that workability and density of concrete increases significantly with the increase of copper slag content in concrete mixes. The results also demonstrated that the use of copper slag in concrete increases the compressive strength, split tensile strength and flexural strength of 45.92%, 30.50% and 14.71% as compared to control mixture.*

Keywords- Cement, Copper slag, Fine aggregate, compressive strength, split tensile strength, flexural strength, density, workability

I. INTRODUCTION

Large quantities of industrial waste or by-products accumulated every year by various industries in the developing countries. The main objective of environmental protection agencies and governments are to look for ways to minimize the dual problems of disposal and health hazards of these by-products. For many years, by-products such as silica fume, fly ash and copper slag were considered as waste materials. They have been successfully used in the construction industry as a fine aggregate substitute [1]. For every ton of copper production, about 2.2 tons of copper slag is generated. Therefore, in india 8 lakhs tons of copper slag is generated every year and in world-wide generation of annually about 24.6 million tonnes of slag. Copper slag is widely used in the sand blasting industry and it has been used in the manufacture of abrasive tools, cutting tools, roofing granules, glass, tiles, road based construction and rail road ballast [2]. Application of copper slag in concrete as a replacement material investigates the possibility of reducing the environmental impact. Copper slag is granular and has similar properties to that of sand [3]. It has been reported by researchers that copper slag does not cause leaching [4].

Caijun Shi et al (2008) investigated the effect of copper slag on the Engineering properties of cement mortars and concrete. They reported that the utilization of copper slag in cement mortar and concrete is very effective and beneficial for all related industries, particularly in areas where a considerable amount of copper slag is produced. It proved both environmental as well as technical benefits. They observed that there was more than 70% improvement in the compressive strength of mortars with 50% copper slag substitution [5]. Velumani and Maheswari studied on Mechanical and Durability Properties of RC Beams Using Copper Slag as Fine Aggregate in Concrete. Copper slag has physical properties similar to the fine aggregate, so it can be used as a replacement of fine aggregate in concrete. Copper slag has lower absorption and higher strength properties than fine aggregate. Replacement of copper slag increases the self-weight of concrete specimens to the maximum of 15% to 20% [6]. Patil et al observe the Performance of Copper Slag as Sand Replacement in Concrete. M30 concrete was used and various tests like compressive, flexural, split tensile strength were conducted for different percentages of copper slag and sand from 0 to 100%. The result showed that workability increases with increase in percentage of copper slag. Maximum Compressive strength of concrete increased by 34 % at 20% replacement of fine aggregate with copper slag, and up to 80% replacement of copper slag, concrete gain more strength than normal concrete strength. The flexural strength of concrete found to be increased by 14% with 30% replacement of copper slag [7]. Madhavi et al studied on Effect of Copper Slag on the Mechanical Strengths of Concrete. Experimental investigations are carried out by replacing the sand with copper slag in proportions of 10%, 20%, 30%, 40%, 50%, 60% and 100% keeping all other ingredients constant. It was seen that the optimum content of copper slag is 40% beyond which the strength starts decreasing [8].

II. OBJECTIVES

To study the properties of concrete like Density, workability, compressive strength, Split tensile strength and Flexural strength test with partial or full replacement of fine aggregate with copper slag in concrete.

III. MATERIALS AND PROPERTIES

A. Cement

Ordinary Portland Cement of 53 Grade from Birla Super Cement brand conforming to IS 12269-1987 is used in this experimental work [9]. This cement is most widely used in the construction industry in India. The different physical properties of Ordinary Portland Cement (OPC) are mentioned in Table 1 below.

Table 1. Physical properties of cement

Sr. No.	Cement	Initial Setting Time	Final Setting Time	Specific Gravity
1	OPC 53 Grade	30 min	620 min	3.15

B. Fine Aggregate

The aggregate size is lesser than 4.75 mm is considered as fine aggregate. The fine aggregate particles should be free from any clay or inorganic materials and found to be hard and durable. The fine aggregate used in this study is river sand conforming to grading zone II Table 1 of IS 383-1970 were procured from local river in Maharashtra. [10]. some physical properties of fine aggregate are mentioned in Table 2 below.

Table 2. Physical properties of fine aggregate.

Sr. No.	Test	Fine Aggregate
1	Specific gravity	2.50
2	Fineness modulus	2.91
3	Water absorption (%)	1.21

C. Coarse Aggregate

The aggregate size larger than 4.75 mm is considered as coarse aggregate. It can be found from original bed rocks. Coarse aggregate are available in different shape like rounded, Irregular or partly rounded, Angular, Flaky etc. It should be free from any organic impurities and the dirt content was negligible. The coarse aggregate used in this project is of angular in shape and the maximum nominal size of coarse aggregate is 20 mm and it is Conforming to Table 2 of IS 383 and which is taken from pune area [10]. Some physical properties of coarse aggregate are mentioned in Table 3 below.

Table 3. Physical properties of coarse aggregate.

Sr. No.	Test	Coarse Aggregate
1	Specific gravity	2.68
2	Fineness modulus	4.95
3	Water absorption (%)	1.29

D. Copper Slag

Copper slag is a by-product material produced from the process of manufacturing copper. As the copper settles down in the smelter, it has a higher density, impurities stay in the top layer and then are transported to a water basin with a low temperature for solidification. The final product is a solid, hard material that goes to the crusher for next processing. Copper slag is an irregular, black, glassy and granular in nature and its properties are similar to the river sand. Copper slag used for this work is taken from Sundara Enterprises (zone-II), a dealer in Bhosari MIDC area, Pune. Which is used for sand blasting and the supplier brought the copper slag from Baruch, Gujarat. The nature of copper slag used in experimental work shown in fig. 1. The physical and chemical properties of Copper slag are shown in table 4 and table 5.

Figure 1. Copper slag

Table 4. Physical properties of copper slag.

Sr. No.	Physical Properties	Copper Slag
1	Particle shape	Irregular
2	Appearance	Black and glassy
3	Type	Air cooled
4	Specific gravity	3.74
5	Fineness modulus	2.89
6	Water absorption	0.40

Table 5. Chemical properties of copper slag

Sr. No.	Component	Copper Slag (%)
1	Sio_2	97.02
2	Al_2O_3	0.095
3	Fe_2O_3	1.07
4	CaO	1.064
5	MgO	0.118
6	SO_3	0.008
7	K_2O	0.029
8	Na_2O	0.118
9	TiO_2	0.120
10	Mn_2O_3	0.002
11	CI	0.01
12	CuO	0.183
13	Sulphide sulphur	0.082
14	Water Insoluble Residue	98.48
15	Chloride	0.350
16	Loss on Ignition	0.190

Here the parts are arrived and then passed to the machining station 1 by the conveyor and then passed through the next station consequently by the help of mean conveyor belt system and the after the third station they are made into batches and then palletized and then sent into the warehouse for the storing and transportation.

E. Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. This bonds the other components together, creating a robust stone like material. It gives strength to cement and workability to the concrete. The tap water is used for casting and curing of the concrete specimens.

IV. METHODOLOGY

The study aims to investigate the properties of concrete using copper slag as replacement material of fine aggregates of M25 grade concrete. The proportions of ingredients of the control concrete of grade M25 had to be determined by mix design as per IS 10262: 2009 code [11]. The specimens were casted by replacements of fine aggregate with copper slag by 0% (for the control mix), 20%, 30%, 40%, 50%, 60%, 80% and 100%. For each concrete mixture, three cubes, three beams and three cylinders were casted. Then the specimens were cured for 28 days. In fresh state; the workability parameters such as slump value was studied. In hardened state; the strength tests such as compressive strength, split tensile strength, flexural strength and density were studied. The obtained results are tabulated. The conclusions were made from the results and discussions.

V. EXPERIMENTAL WORK

In this research work, the concrete strength and replaced concrete strength for M25 grade of concrete was found out. The properties of concrete materials and concrete strength were determined. Mix design carried for M25 grade of concrete by IS 10262-2009 yielded mix proportions of 1:1.68:2.94 with water cement ratio of 0.55. Keeping w/c ratio as constant for control mix and by 0, 20, 30, 40, 50, 60, 80 and 100 % replacements. Specimens were prepared according to the mix proportion and by replacing sand with copper slag in different proportions.

A. Mix Proportion of Concrete Grade

As per IS 10262: 2009, mix design for M25 grade concrete is given in table 6.

Table 6. Mix proportion by weight

Water L/m^3	Cement Kg/m^3	Sand Kg/m^3	Coarse Aggregate Kg/m^3
214.20	383.16	644.48	1126.31
0.55	1	1.68	2.94

B. Various Replacements of Copper Slag In Concrete

The concrete mixtures with various proportion of copper slag with fine aggregate are given in Table 7:

Table 7. Concrete mixtures with various proportion of copper slag with fine aggregate

Mix Identity	Cement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Copper Slag (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Water (Kg/m^3)
CC	383.16	644.48	0	1126.31	214.20
CS20	383.16	515.58	128.90	1126.31	214.20
CS30	383.16	451.14	193.34	1126.31	214.20

CS40	383.16	386.70	257.80	1126.31	214.20
CS50	383.16	322.24	322.24	1126.31	214.20
CS60	383.16	257.78	386.70	1126.31	214.20
CS80	383.16	128.9	515.58	1126.31	214.20
CS100	383.16	0	644.48	1126.31	214.20

C. Description of specimen

The number of specimen casted was as per the below mentioned details. The size of the cube is 150×150×150 mm, size of cylinder is 150 mm in diameter and 300 mm in height and size of beam is 700 × 150 × 150 mm.

Table 8. Description of specimen

Sr. No.	% Addition of Copper Slag	Mix Identity	Specimen		
			Cube	Cylinder	Beam
1	0	CC	3	3	3
2	20	CS20	3	3	3
3	30	CS30	3	3	3
4	40	CS40	3	3	3
5	50	CS50	3	3	3
6	60	CS60	3	3	3
7	80	CS80	3	3	3
8	100	CS100	3	3	3
Total Specimen			**24**	**24**	**24**

VI. RESULT AND DISCUSSIONS

A. Fresh Concrete

a. Workability

Workability of fresh concrete is immediately checked after mixing of water in dry concrete with the help of slump cone instrument. Slump test as per IS: 1199-1959 is followed [12]. Table 9 shows results of workability of various sets of concrete. The variation in average value of slump for each set is presented in graph 1.

Table 9. Workability of Concrete Mixture

Sr. No.	Mix Identity	Slump (mm)
1	CC	92
2	CS20	109
3	CS30	118
4	CS40	130
5	CS50	146
6	CS60	157
7	CS80	171
8	CS100	180

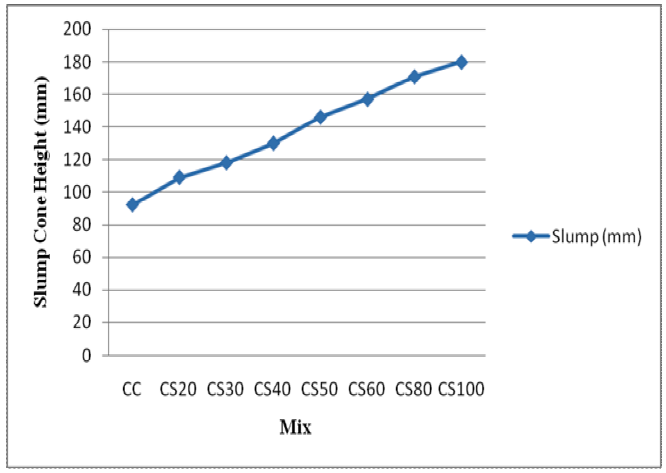

Figure 2. Workability Results

From Graph 1 it was observed that there is a substantial increase in the workability of concrete mixture as copper slag content increases. This significant increase in the workability was due to the small amount of water absorption and glassy surface of copper slag compared with sand in concrete.

B. Hardened Concrete

a. Density of Concrete

The density of hardened concrete at saturated surface dried condition was measured at the age of 28 days of curing. The variation in average value of density for each mix is presented in graph 2.

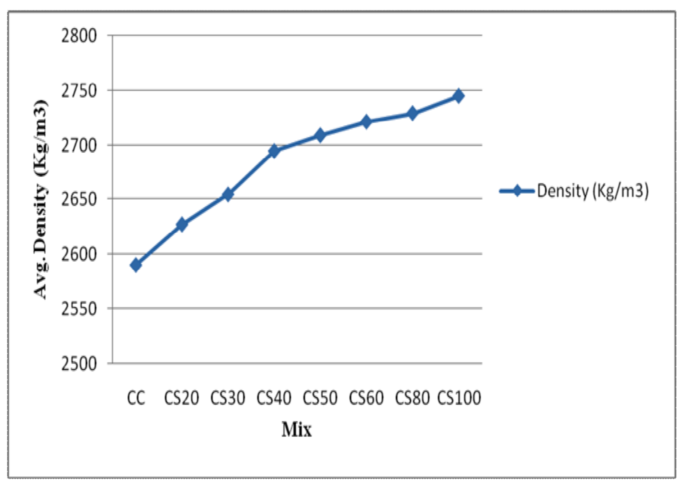

Figure 3. Density Results

From graph 2 it can be seen that there is a substantial increase in the density of concrete as copper slag content increases. Density of concrete was increased by 5.97% (for 100 % replacement). This is because of the higher specific gravity of the copper slag, i. e. 3.74 which is comparatively more than fine aggregate which is 2.50. However compared with the large difference in the specific gravity of the copper slag and the fine aggregate, it increased density of concrete.

Compressive Strength

In order to determine the compressive strength cube mould of size 150×150×150 mm were casted. The cubes were casted for different percentage of copper slag ranging from 0% to 100%. For each proportion three cubes were casted and the surface of the cubes is allowed to dry for 24 hours in saturated condition. Curing of the cubes was done for 28 days. A gradual load is applied on the surface on the cube to obtain maximum compressive load. The cubes are tested under compression testing machine (CTM). Readings are noted and graphs are drawn. The Fig.2 shows the compression testing machine. The compression test is done according to the specification IS 516:1959 [13]. The compressive strength is calculated using the formula,

Compressive strength (N/mm2) = P/A (1)

Where,

P – Ultimate Load (N)

A – Loaded area of the cube (mm2)

Figure 4. Experimental setup of compression testing machine.

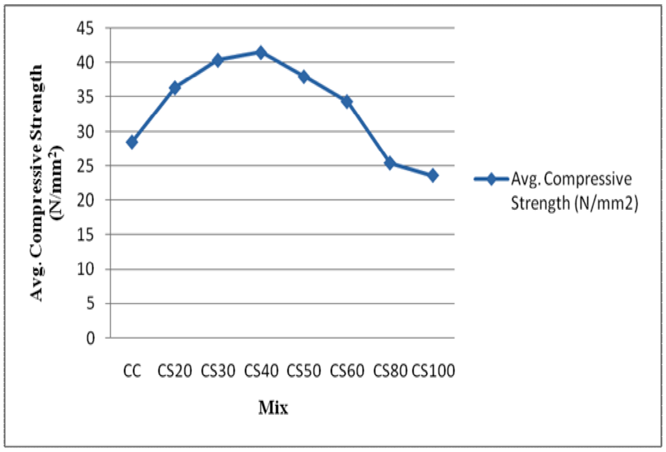

Figure 5. Graph 3: Average compressive strength results

From graph 3, it can be seen that the optimum percentage of replacement was obtained at 40 % replacement of copper slag with fine aggregate. The maximum percentage of increase in strength is found to be 45.92 % at 40 % replacement of sand by copper slag (CS40), which was about 41.53 N/mm2 compared with 28.46 N/mm2 for the control mixture (CC). Afterwards there was gradually a decrease up to 17.15 % for 100 % replacement (CS100) of sand in concrete as shown in graph 3. This is due to the excessive free water content in the mixes with high copper slag content causes the particles of the constituents to separate leaving pores in the hardened concrete which consequently causes reduction in the concrete strength.

Split Tensile Strength

testing split tensile strength, concrete cylinder of size 150 mm diameter and 300 mm height were casted with different percentage of copper slag ranging from 0% to 100%. For each proportion three cylinders were casted and allowed to dry for 24 hours in saturated condition. Curing of the cylinders was done for 28 days. After curing was done samples are allowed to dry to remove the moisture content. Testing of samples was done and readings are noted. The Fig.3 shows the split tensile strength test setup. Graphs are drawn for strength verses replacement. The split tensile strength test for cylinders was carried out as per IS 516: 1959 [13]. The split tensile strength is calculated using the formula,

Split tensile strength (N/mm2) = 2P/πLD (2)

Where,

P – Ultimate Load (N)

L - Length of cylinder (mm)

D = Diameter of cylinder (mm)

Figure 6. Split tensile strength test setup

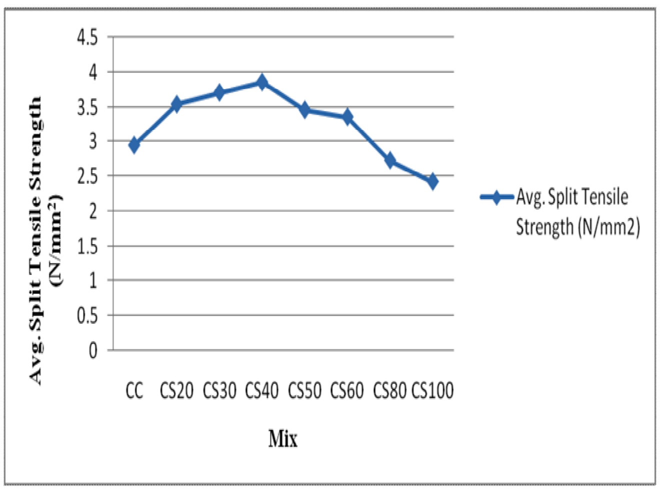

Figure 7. Graph 4: Average split tensile strength results

From the test results, it was observed that the split tensile strength of cylinder showed a similar behaviour to the compressive strength of the cube for all mixtures. Graph 4 showed that the split tensile strength of cylinder was found to be 2.95 N/mm2 at 0% fine aggregate replacement (CC) and of 2.42 N/mm2 at 100% fine aggregate replacement (CS100). The maximum split tensile strength was found to be at 40% fine aggregate replacement (CS40) of about 3.86 N/mm2. This means that there is an increase in the strength of almost 30.50% compared to the control mix (CC). The split tensile strength of copper slag added concrete was gradually increased up to 40% replacement (CS40) and then decreased with further fine aggregate replacement.

Flexural Strength

For flexural strength, concrete beam of size 700 × 150 × 150 mm, were casted with different percentage of copper slag ranging from 0% to 100%. For each proportion Three samples were casted and allowed to dry for 24 hours in saturated condition. Curing of the beams was done for 28 days. After curing was done samples were allowed to dry to remove the moisture content. Testing of samples was done and readings are noted. Graphs are drawn for strength verses replacement. The Fig. 4 shows the flexural strength test setup. The flexural strength test for beams was carried out as per IS 516: 1959 [13]. The flexural strength is calculated using the formula,

$$F = PL/bd^2 \quad (3)$$

Where,

F = Flexural Strength (N/mm2)

P = Ultimate load (N)

L = span length (mm)

b = average width (mm)

d = average depth (mm)

Figure 8. Flexural strength test setup

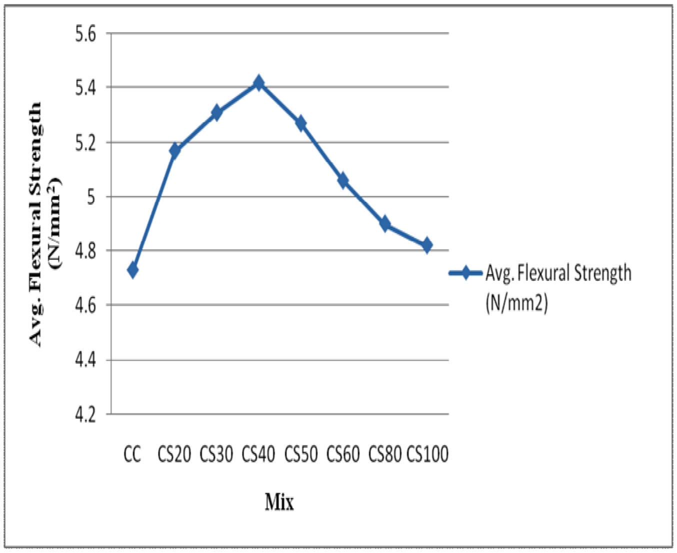

Figure 9. Average flexural strength results

VII. CONCLUSION

Based on this experimental study, the following conclusions are drawn

1. As the percentage of copper slag in design mix as replacement increases, the density of harden concrete observed to be increased. The density was increased by 5.97% when replacement of fine aggregate by 100% copper slag.
2. The workability of concrete increases significantly with the increase of copper slag content in concrete mixes.
3. Maximum Compressive strength of concrete increased by 46% at 40% replacement of fine aggregate by copper slag, and up to 60% replacement, concrete gain more strength than normal concrete strength.
4. Maximum Split Tensile strength of concrete increased by 30.5% at 40% replacement of fine aggregate by copper slag, and up to 60% replacement, concrete gain more strength than normal concrete strength.
5. It is observed that, the flexural strength of concrete at 28 days is higher than control mix concrete (Without replacement) for 40% replacement of fine aggregate by Copper slag, the flexural strength of concrete is increased by 14.71%. This also indicates for all other mixes the flexure strength is more than the control concrete.
6. Based upon the results obtained it was concluded that 40% of copper slag can be used as replacement of fine aggregates.
7. Replacement of copper slag in fine aggregate reduces the cost of making concrete.

ACKNOWLEDGMENT

The authors would like to express their thanks to the Principal and Department of Civil Engineering, Trinity College of Engineering and Research, Pune, Maharashtra for supporting this research study.

REFERENCES

[1] Al-Jabri K.S., Taha R.A., Al-Hashmi A. and Al-Harthy A.S. "Effect of copper slag and cement by-pass dust addition on mechanical properties of concrete", Construction and building materials, Vol. 20, pp. 322-331, 2006.

[2] BipraGorai, Jana R. K. and Premchand, "Characteristics and utilisation of copper slag-a review", Resources, Conservation and Recycling, Vol. 39, No. 4, pp. 299-313, 2002.

[3] ThongamPrantic Singh, Dr.Rajashekhara.M.R. andSuhas R., "Utilization of Copper Slag as Fine Aggregates in Cement Concrete Pavements", International Journal for Research in Applied Science and Engineering Technology, Vol. 2 Issue VII, pp. 358-365, 2014.

[4] Chavan R.R. and Kulkarni, D.B. "Performance of copper slag on strength properties as partial replacement of fine aggregate in concrete mix design", International Journal of Advanced Research and Studies, Vol.2, No.4, pp.95-98, 2013.

[5] Caijun Shi, Christian Meyer, and Ali Behnood, "Utilization of copper slag in cement and concrete", Resources Conservation and Recycling, Vol. 52, pp. 1115-1120, 2008.

[6] Maheswari, M. Mechanical and Durability Properties of RC Beams Using Copper Slag as Fine Aggregate in Concrete. International Research Journal of Engineering and Technology, 3(3), 2016.

[7] Patil, M. V. Performance of Copper Slag as Sand Replacement in Concrete. International Journal of Applied Engineering Research, 11(6), 4349-4353, 2016

[8] Madhavi,T.C. Effect of Copper Slag on the Mechanical Strengths of Concrete. International Journal of ChemTech Research, 8(12), 442 449, 2015.

[9] IS 12269 (1987) Indian Standard Ordinary Portland cement, 53 gradespecification. CED 2: Cement and

Concrete.

[10] IS 383 (1970) Indian Standard Specifications for Coarse and Fine aggregates from Natural Sources for Concrete. CED 2: Cement and Concrete.

[11] IS 10262 (2009) Guidelines for Indian Standard Concrete Mix Design Proportioning. CED 2: Cement and Concrete.

[12] IS 1199 (1959) Indian Standard Methods of sampling and analysis of concrete. CED 2: Cement and Concrete.

[13] IS 516 (1959) Indian Standard Methods of tests for strength of concrete. CED 2: Cement and Concrete.