An Experimental Investigation on Mechanical Properties of Waste Marble Powder Concrete

Prof. Roshan Lal[1], Er. Kuldeep Kumar[2], Er. Piyush Sharma[3]
[1](PEC,University of Engineering & Technology, Dept. of Civil Engg.Chandigarh)
[2](Chandigarh College of Engineering & Technology Sector-26, Chandigarh)
[3](Assistant Engineer Irrigation Department, Haryana)

ABSTRACT : This paper is the study related to significant developments regarding performance and applications of Marble dust based concrete. With the increase in population and advancement of construction technology the use of concrete has increased manifold in the recent years. This may lead to the depletion of natural resources, presently on an average about 45-50 metric tonnes of marble is cut in a day in medium scale unit, which leads to about huge quantity of marble dust. The disposal of marble dust is a serious threat to environment, so there is a strong need to utilize this solid waste as an alternative material to lessen the burden of this pollutant on environment. The present study was therefore planned to explore the possibility of usage of waste marble powder (WMP) as partial replacement of sand for production of concrete.

Keywords –Compressive Strength, Split-tensile Strength, Flexural Strength and Waste Marble Dust (WMD) .

I INTRODUCTION

Concrete plays an inevitable role in meeting the requirements of globalization, in construction of buildings and other structures and a large quantum of concrete is being utilized. River sand, which is one of the constituent used in productions of conventional concrete, has become highly expensive and also scarce. In a backdrop of such an atmosphere, there is a large demand for alternative materials from industrial waste to be used for concrete industry. As we know that it is the stone industry where the raw materials are continually transformed into industrial product results in waste generation. Consequently, recycling of industrial wastes and by products is becoming crucial demand by the environmental laws in agreement with the concept of sustainable development. The advancement of concrete technology can reduce the consumption of natural resources and energy sources and lessen the burden of pollutants on environment. Presently large amounts of marble dust are generated in marble processing plants which has an adverse impact on environment and humans. Hence the reuse of waste material has been emphasized. Waste can be used to produce new products or can be used as admixtures so that natural resources are used more efficiently and the environment is protected from waste deposits.

II. LITERATURE REVIEW

Bahar Demirel etal(2010) took total of four series of concrete specimens including the control specimen, prepared in order to examine the effect of substituting marble dust(0, 25, 50 and 100% by weight) for the fine material (passing through 0.25 mm sieve) on the mechanical properties of the series. Commercial grades ASTM Type I Portland cement, which is produced in Turkey was used in order to prepare all concrete specimens.The marble sludge was obtained in wet form as an industrial by-product directly from the deposits of marble factories, which forms during the sawing, shaping and polishing processes of marble in Elazigregion. The wet marble sludge was dried up prior to the preparation of the samples. The dried material was sieved through a 0.25mm sieve and finally the waste marble dust (WMD) was obtained to be used in the experiments as fine sand aggregate. The maximum size of aggregates used was 16mm. The density of coarse and fine aggregates from the 0–4mm(river sand)and 4- 16 mm river aggregates group were 2780 and 2730 kg/m^3,respectively. In concrete mix proportioning, aggregates were composed of 53% sand (0–4mm) and 47% gravel (4–16mm).Tap water was used as the mixing water during the preparation of the concrete specimens.

The test results of above study showed that compressive strength increases with the increase WMD content. The increase for MD100 (100% Replacement of fine aggregates by marble dust) was approximately 10% and 5% at 28 and 90 days respectively, compared to the MD0 (without WMD).It is explained that as the curing age increased, its contribution to the compressive strength of the WMD is reduced. As the curing time increases, the WMD's contribution to the compressive strength decreases. The highest compressive strength at curing ages of 3, 7, 28 and 90days has been exhibited by MD100. In cases where the marble dust has been used as a substitute for cement at equal weights, an increase in amount of added marble dust decreases the compressive strength (Val's et al.,2004). Türker et al. (2002)

have stated that this decrease arises from the dilution of C_2S and C_3S, which are the main constituent sand strength providers of cement, by the marble dust additive.

Akbulut and Gurer (2011) found in their studies that the concrete containing waste marble dust or waste marble aggregate, such as its addition into self-compacting concrete as an admixture or sand as well as its utilization in the mixture of asphaltic concrete and its utilization as an additive in cement production, the usage of marble as a coarse aggregate and as a fine aggregate passing through 1 mm sieve.

Ali Ergun (2011) carried out laboratory investigation of mechanical properties of the concrete specimens containing diatomite and waste marble powder (WMP) by partially replacing 5% cement content by weight with WMP in one case and by replacing 5% cement by weight as well as 10% diatomite by weight with WMP in the other and found better compressive and flexural strength and came to the conclusion that the mechanical properties of concrete could be improved by reducing cement and diatomite content and by adding equal amount of WMP as a super plasticizing admixture.

Baboo Rai, Khan Naushad (2011) conducted the study on cubes of mortar (1:3) with varying partial replacement of cement with the same amount of WMP and tested at three different intervals of curing. Also cubes of (1:3) mortar with partial replacement of sand with the same amount of WMP Granuals were casted and their strength was evaluated after 7, 14, and 28 days in different lots. Their results were compared with those of standard (1:3) mortar and concrete cubes.

It is observed here that with increase of WMP (replacing cement) the strength falls remarkably upto10N when the WMP is 15% or 20%, the rate of fall being uniform upto 15% replacement.

This trend can be attributed to decrease in adhesive strength between the surface of marble powder and cement. When marble waste granules are partially replaced in fine aggregate by weight then there is increase in compressive strength at each curing age. This trend is shown only up to 15% replacement of fine aggregate with marble granules. This trend can be attributed to the marble granules to have cementing properties. On increasing the percentage replacement beyond 10%, there is a slight reduction in the compressive strength value. By increasing the waste marble granules thecompressive strength values of concrete tends to increase at each curing age. This trend can be attributed to the fact that marble granules possess cementing properties. It is also as much effective in enhancing cohesiveness due to lower fineness modulus of the marble powder or granules both. Furthermore, the mean strength of concrete mixes with marble granules was 5-10% higher than the reference concretes. However, there is a slight decrease in compressive strength value concrete mix when 20% marble granule is used as compared with that of 15% marble granule mix.

The results of the flexural strength tests for the waste plastic mix concrete shows that the flexural strength of waste marble mix concrete increases with the increase of the waste marble ratio in these mixtures. This trend can again be attributed to the fact that marble granules possess cementing properties.

When marble powder is partially replaced in cement by weight, there is a marked reduction in compressive strength values of mortar mix with increasing marble powder content when compared with control sample at each curing age. No mortar cube with partial replacement of marble granules conform to the standard of IS:8112– 1989.

Surprisingly when sand is partial replaced by marble powder, all mortar cubes except that replacement of 20% does not conform to IS:8112–1989.On increasing marble waste fine aggregate ratio i.e. when marble waste/granules are partially replaced in fine aggregate by weight then there is increase in compressive strength values of marble waste mortar at each curing age.

III EXPERIMENTAL PROGRAMME

The objective of this programme is to obtain the properties of the different constituent materials to be used for making the specimens for the experimental studies. The data is useful to classify the cement, sand, coarse aggregate and marble dust.

The cement use for the experimental studies was Ultratech 43 grade OPC .The various test performed on the cement and their values are shown in the Table 1.

Table 1: Characteristics Properties of Cement

Sr.No	Characteristics	Results
1	%Consistency of cement	32.5
2	Specific gravity	3.101
3	Initial setting time (minutes)	41
4	Final setting time (minutes)	347
5	Compressive strength (N/mm^2) (i) 3 days (ii) 7 days (iii)28days	 24.10 34.56 47.92
6	Soundness (mm)	1.00
7	Fineness of Cement (gm)	0.50

The results of the tests performed on the fine aggregate such as fineness modulus and its physical properties are shown in Table 2 and 3 respectively.

Total Weight of Sand taken= 1000gm

Table 2: Sieve Analysis of Fine Aggregate

IS Sieve	Wt. Retained on sieve (gm)	Cumulative %age retained	%age passing
4.75mm	15	1.5	98.5
2.36mm	120	13.5	86.5
1.18mm	107	24.2	75.8
600µ	354	59.6	40.4
300µ	297	89.3	10.7
150µ	90	98.3	1.7
Pan	17	∑F = 2.86	

Fineness Modulus of fine sand = 2.86

Table 3: Physical Properties of Fine Aggregate

Property	Result
Specific Gravity of Fine	2.60
Free Moisture Content	2%
Water Absorption	1.82%

Coarse Aggregate used was a mixture of two available crushed stones of 10mm and 20mm size in 40:60 proportions. The sieve analysis and physical properties of coarse aggregate satisfied the requirement of IS: 383-1970 and the results are given in table 4 and table 5 respectively.

Total weight of 10mm aggregate = 5000gm

Table 4 :Proportioning of Coarse Aggregate

IS Sieve	Cum.% passing of 10mm aggregates (gm)	Cum.% passing of 20mm aggregates (gm)	Proportion 40 : 60 (10mm : 20mm)
80mm	100	100	100
40mm	100	100	100
20mm	100	100	100
10mm	61.0	34.5	45.1
4.75mm	8.0	1.0	3.8

Table 5: Physical Properties of Coarse Aggregate

Property	Result
Specific Gravity of coarse	2.70
Free Moisture Content	Nil
Water Absorption	0.15%

Water

The water used in the concreting work was the potable water as supplied in the PG Structures lab of our college. Water used for mixing and curing was clean and free from injurious amounts of oils, acids, alkalis, salts and sugar, organic substances that may be deleterious to concrete. As per IS 456- 2000 Potable water is generally considered satisfactory for mixing and curing of concrete. Accordingly potable tap water was used for the preparation of all concrete specimens.

Waste Marble Powder (WMP)

The waste marble powder (WMP) was procured from a marble dealer at Dhanas, Chandigarh and sieve analysis was carried out as shown in table 6.The typical properties of marble powder are shown in table 7 and table 8. The waste marble powder used in investigation is shown in plate 1.

Table 6: Sieve Analysis of Waste Marble Powder

IS Sieve	Wt. Retained on sieve (gm)	Cumulative %age retained	%age passing
4.75mm	0	0	100
2.36mm	110	11	89
1.18mm	530	64	36
600µ	275	91.5	8.5
300µ	40	95.5	4.5
150µ	17.5	97.25	2.75
Pan	27.5	∑F = 3.59	

Table 7: Chemical Properties of Waste Marble Powder

Constituents of Marble dust	Constituents present in marble dust in %
Fe_2O_3	11.89
Silica (SiO_2)	64.86
Alumina (Al_2O_3)	4.45
MnO	0.08
Magnesium Oxide	8.74
Calcium Oxide (CaO)	1.58

Table 8 : Physical Properties of Waste Marble Powder

Characteristics	Values
Color	Light green, white
Moisture content (wet/dry) %	23.35/ 1.59
Specific Gravity	2.21
Surface Area (cm^2/gm)	4680
Coefficient of uniformity	1.58
Bulk Density (kg/m^3)	1118
Loss on ignition	46.46

Plate 1:Waste Marble Powders Used in Study

The details of the mix used in the present study are shown in table 8.

Table 8: Mix Design Proportion of Standard (M 25) Grade Concrete

Mix	Water	Cement	Fine aggregate	Coarse aggregat e
MX0	186 lt/m^3	432 kg/m^3	659 kg/m^3	1122.16 kg/m^3
Prop.	.430	1	1.52	2.63

For the marble based concrete mixes taking, Water=186 litre/m^3, Cement=432kg/m^3 and Coarse Aggregates=1122.16kg/m^3, the proportioning of various other constituents in shown in Table 9.

Table 9: Marble Dust Based Concrete Mix

IV DISCUSSION OF RESULTS

Compressive Strength

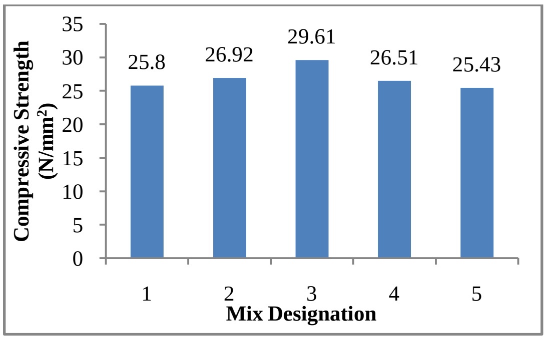
The compressive strength was conducted on various specimens as per the guidelines given in IS 516-1959. The specimens were surface dried before testing the same on Universal Testing Machine of 200 tonnes capacity. The result of compression test using waste marble powder (WMP) in varying percentages i.e. (0%, 10%, 20%, 30%, and 40%) as partial replacement of sand at the moist curing age of 7 days and 28 days are presented in Table 10 .

Table 10: Compressive Strength Test Results

Mix	% marble	Average Compressive Strength (N/mm^2) (7days)	Average Compressive Strength (N/mm^2) (28days)
MX0	0	25.80	36.35
MX1	10	26.92	38.29
MX2	20	29.61	40.43
MX3	30	26.51	37.61
MX4	40	25.43	36.34

The comparison of compressive strength of various mixes containing WMP in different percentages is shown in Figure 1 and 2.

It can be seen from the table 10 and figure 1 and 2 that the replacement of sand by WMP resulted in increase in compressive strength of concrete up to replacement of 20%, both at the curing age of 7 days and 28 days respectively. The compressive strength of mixes containing 30% and 40% WMP decreased as compared to mix containing 10% and 20% WMP. However the compressive strength of the mixes was found to be comparable to the control mix containing no WMP. The increase in compressive strength of mixes with replacement of sand by WMP may be attributed to the fact that WMP possesses cementing properties. The increase in compressive strength may also be due to the better cohesiveness provided by the WMP. The decrease in compressive strength of the mixes containing 30% and 40% WMP may be due to the effect of the WMP on the overall grading of sand with addition of higher contents of WMP and thus affecting the compressive strength of concrete.



Mix	% WMP	Fine aggregate (kg/m^3)	Marble Powder (kg/m^3)
MX1	10	593.10	65.90
MX2	20	527.20	131.80
MX3	30	461.30	197.70
MX4	40	395.40	263.60

Figure 1: Variation of Compressive Strength of Mixes after 7 Days

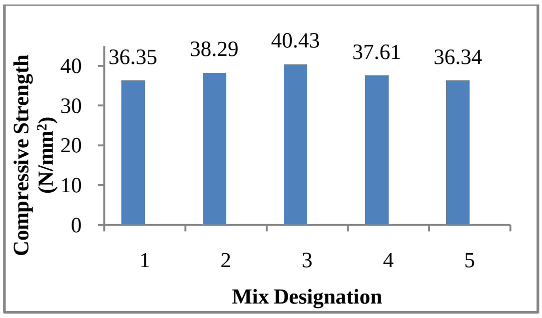


Figure 2: Variation of Compressive Strength of Mixes after 28 Days

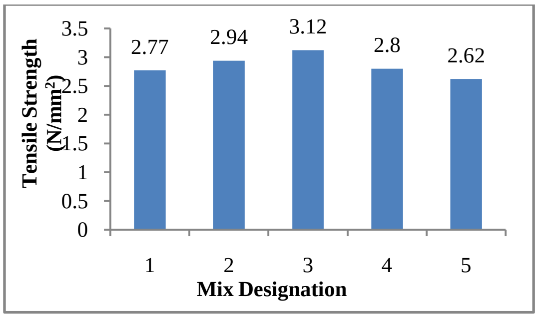


Figure 3: Variation of Split Tensile Strength of Mixes after 7 Days

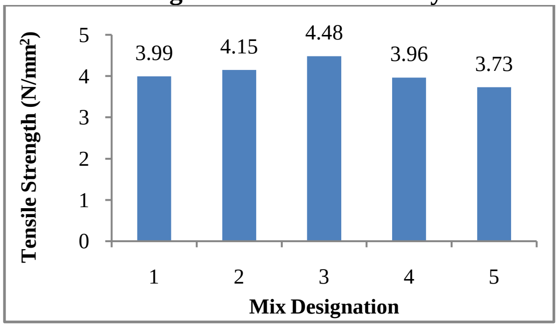


Figure 4: Variation of Split Tensile Strength of Mixes after 28 Days

Split Tensile Strength Test

The split tensile strength of concrete was conducted on various mixes as per guidelines of IS 516-1970. The cylindrical specimens were tested at the age of 7 days and 28 days after surface drying the same. The test was conducted on universal testing machine. The result obtained for various mixes at the curing age of 7 days and 28 days are presented in Table 11. The comparison of the split tensile strength of various mixes at the age of 7 days and 28 days of curing is shown in figure 3 and 4 respectively.

Table 11: Split Tensile Strength Test Results

Mix	% Marble	Split Strength (7 Days) (N/mm²)	Split Strength (28Days) (N/mm²)
MX0	0	2.77	3.97
MX1	10	2.94	4.15
MX2	20	3.12	4.48
MX3	30	2.8	3.96
MX4	40	2.62	3.73

It can be seen from the above table 11 and figure 3 and 4 that the split tensile strength of the mixes containing 10% and 20% WMP are higher as compared to the control mix. However the split tensile strength of the mix containing 30% and 40% WMP are lower as compared to the mix containing 10% and 20% WMP,but comparable to the split tensile strength of the control mix. This trend is similar to the trend obtained for the compressive strength test. The reason for the increase in compressive strength up to 20% replacement of fine sand by WMP and a slight decrease beyond 20% replacement of sand by WMP being the same as already explained in the case of compressive strength.

Flexure Strength Test

Although the concrete is not designed to resist tension, the knowledge of tensile strength of concrete is of value in assessing the load at which crack will start appearing in concrete. The flexure test was conducted on various mixes. The result obtained for various mixes at the age of 7 days and 28 days are shown in table 12. The comparison of flexural strength of the various mixes containing varying percentages of WMP is shown in figure 5 and 6 respectively.

Table 12: Flexure Strength Test Results

Mix	% marble	Flexural Strength (N/mm²) (7 Days)	Flexural Strength (N/mm²) (28 Days)
MX0	0	3.52	4.19
MX1	10	3.6	4.25
MX2	20	3.75	4.38
MX3	30	3.58	4.22
MX4	40	3.57	4.17

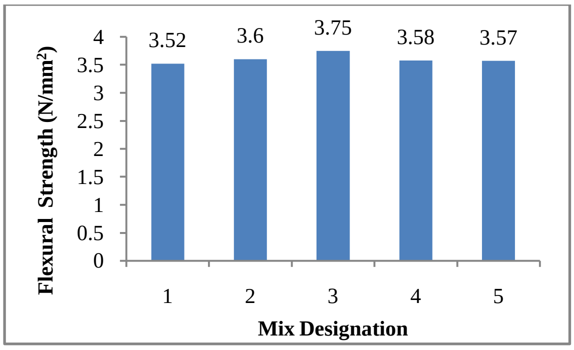


Figure 5: Variation of Flexural Strength of Mixes after 7 Days

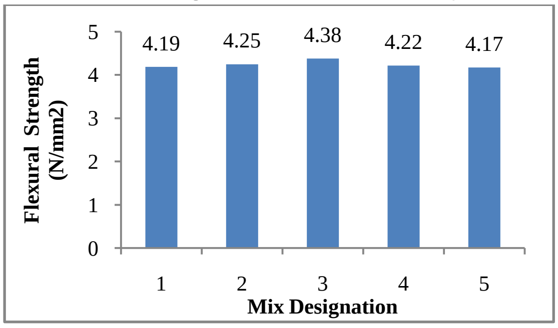


Figure 6: Variation of Flexural Strength of Mixes after 28 Days

It can be seen from tables 12 and figures 5 and 6 that the flexural strength of concrete mixes containing 10% and 20% WMP are about 5% to 10% higher than the flexural strength of the control mix, however the flexural strength of the mix containing 30% and 40% WMP are comparable to the flexural strength obtained for the control mix. This trend is similar to the trends obtained for compressive strength and split tensile strength and the reason for the same is as already explained.

Correlation Between Compressive Strength And Split Tensile Strength

Regression analysis was carried out to develop the relationship between two variables. Compressive strength is plotted on X-axis (as independent variable) and split tensile strength to be predicted from compressive strength is plotted on Y-axis as dependent variable. The relationship between compressive strength and split tensile strength obtained from regression analysis is shown in figure 7.

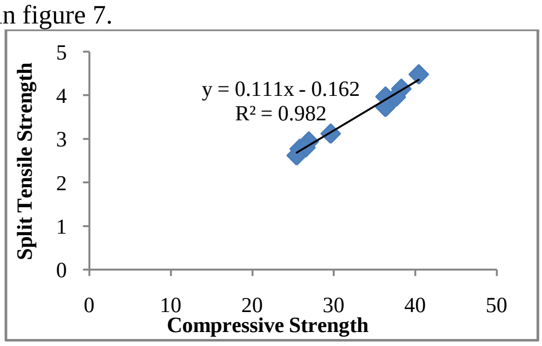


Figure 7: Regression Analysis Between Compressive Strength and Split Tensile Strength

It can be seen from figure 7 that there is good correlation between observed and predicted values of split tensile strength of concrete containing WMP.

Correlation Between Compressive Strength And Flexural Strength

Regression analysis was carried out to develop the relationship between two variables. Compressive strength is plotted on X-axis (as independent variable) and flexural strength to be predicted from compressive strength is plotted on Y-axis as dependent variable. The relationship between compressive strength and flexural strength obtained from regression analysis is shown in figure 8.

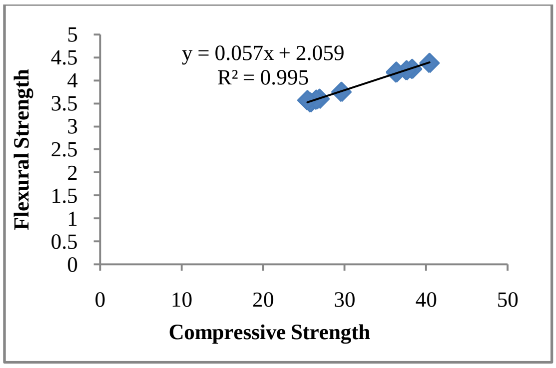


Figure 8 : Regression Analysis Between Compressive Strength and Flexure Strength

It can be seen from figure 8 that there is good correlation between observed and predicted values of split tensile strength of concrete containing WMP.

V CONCLUSIONS

Based on the results obtained in the present investigation, the following conclusion can be drawn

i) The results obtained in the present study indicates that it is feasible to replace the fine aggregates by waste marble powder for improving the strength characteristics of concrete, thus the WMP can be used as an alternative material for the production of concrete to address the waste disposal problems and to minimize the cost of construction with usages of WMP which is almost freely available.

ii) With the partial replacement of sand by WMP the compressive strength of concrete increased up to 20% replacement both at the curing age of 7 days and 28 days. The compressive strength of concrete containing 10% and 20% WMP increased in the range of 5% to 10% compared to the compressive strength of reference mix. However for the mixes containing 30% and 40% WMP the compressive strength were comparable to the compressive strength of control mix. The increase in compressive strength due to replacement of sand by WMP at the constant cement content is attributed to the contribution of marble dust to the hydration process and thus enhancing the compressive strength of concrete.

iii) The split tensile strength of concrete increased with addition of WMP up to 20% replacement of sand. Further addition of WMP resulted in decrease in split tensile strength. However the split tensile strength for the mixes containing 30% and 40% WMP were found to be comparable to the split tensile strength of reference mix. This trend was found similar to the trend obtained for compressive strength.

iv) The flexural strength of concrete mixes containing WMP followed similar trend obtained for compressive strength and split tensile strength. The flexural strength increased in the range of 4% to 8% when the fine aggregates were replaced with WMP by 10% to 20%, with further increase in WMP there is slight drop in flexural strength noticed, however the flexural strength was found comparable to the flexural strength of the control mix.

v) The split tensile strength and flexural strength were found to depend on compressive strength of concrete irrespective of WMP content. Further, a good co-relation was obtained between the predicted and observed values of split tensile strength and flexural strength using this relationship.

REFRENCES

1. Akbulut and Gurer (2007),“ Use of aggregates produced from marble quarry waste in asphalt pavements”. Build Environment, 42(5): 1921-1930.
2. Ali Ergun (2011),“Effects of the usage of diatomite and waste marble powder as partial replacement of cement on the mechanical properties of concrete”, Construction and Building material 25(2), pp 806812.
3. Bahar Demirel etal (2010),“The effect of the using waste marble dust as fines and on the mechanical properties of the concrete”, International Journal of the Physical Science 5(9), pp1372-138
4. IS: 10262-2009: Recommended guide lines for concrete mix design. Bureau of Indian Standards, New Delhi. 1982.
5. IS: 456-2000: Code of practice for plain and reinforced concrete. Bureau of Indian Standards, New Delhi. 2000
6. IS: 516-1959 (reaffirmed 1999): Methods of tests for strength of concrete. Bureau of Indian Standards, New Delhi. 1999.
7. IS:8112-1989: Specifications for ordinary Portland cement 43grade. Bureau of Indian Standards, New Delhi. 1989.
8. IS:383-1970(reaffirmed1997): Specifications for coarse and fine aggregates from natural sources for concrete. Bureau of Indian Standards, New Delhi. 1997.