DURABILITY STUDIES ON DIFFERENTGRADES OF CONCRETE BY REPLACEMENT OF RIVER SAND WITH ROBO SAND

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Abstract - - *At present the construction industry in India is facing one of the major problem that is scarcity of River sand, which is used as a fine aggregate in concrete and plays major role in mix design. The rapid urbanization and infrastructure developmental activities requires billions of tons of sand every year, thus the demand for sand was surpassing its availability and on the other side the environmental pressures to reduce extraction of sand from Rivers led to non-availability or shortage of River sand. This will affect the construction industry, hence researchers found Robo sand or M-sand as an alternative to River sand. The experimental study has been carried out to investigate the strength and durability with 100% River sand and 100% replacement with Robo sand as a fine aggregate in M20, M30 & M40 grades of concrete. The compressive strength values at 28, 56, 90 & 120 days age of concrete cubes were determined. Then durability studies i.e., strength loss and weight loss values after acid attack on concrete cubes for certain durations were determined. The durability tests were conducted by immersing the concrete cubes with 5 % of H_2SO_4 by weight of water solution for a period of 28, 56& 90 days. These compressive strength and durability values for concrete cubes with 100% River sand and 100% Robo sand were compared.*

Key Words: River sand, Robo sand, Durability, Mix design, Compressive strength, Weight loss

1.INTRODUCTION

1.1General

Infrastructure development across the world created demand for construction materials. Concrete is the premier Civil Engineering construction material. Concrete manufacturing involves consumption of ingredients such as cement, fine aggregate, coarse aggregate, water, admixture (if necessary). Among all the ingredients aggregate form the major part. Fine aggregate is necessary for workability of concrete in plastic state and for strength, surface finish and low porosity in hardened state. Normally in conventional concrete, River sand is used as fine aggregate. But today with the rapid urbanization and growing infrastructure facilities the demand of sand is surpassing its availability. So as to meet the demand, alternative materials such as Robo sand or Manufactured sand, granular slag, fly ash were investigated to replace the natural sand as a fine aggregate in concrete. Few studies identified Robo sand has potential to replace natural sand, but limited research was conducted on the durability of concrete made with Robo sand as fine aggregate. There is a need to provide more data on strength and durability of concrete made with Robo sand as a replacement to River sand. Durability is an important engineering property of concrete, which determines the service life of concrete structures significantly. Due to the interactions of concrete with external influences, the mechanical and physical properties of concrete may be threatened and lost. Among the threatening factors like freezing and thawing, abrasion, corrosion of steel, chemical attack may also deteriorate concrete within time. ACI Committee Report 201 (2001) has classified chemical attacks into several types that include acidic attack, alkali attack, carbonation, chloride attack and leaching and sulfate attack. It can be accepted as a general rule that acids are deleterious to concrete.

1.2 Robo Sand as a Fine Aggregate

The denser particle packing and silt free nature of Robo sand as compared to that of River sand, as a fine aggregate increases the strength of concrete. International centre for aggregate research (ICAR) has conducted extensive research on the use of manufactured micro fines. Researchers concluded that, compared to concrete made from natural sand, high fines concrete generally had higher flexural strength, improved abrasion resistance, higher unit weight and lower permeability due to filling the pores with micro fines. There is no appreciable difference in dry shrinkage in concrete made with Robo sand as compared to River sand. Robo sand is more angular and has rougher surface texture than naturally weathered sand particles. Aggregate that is more angular will have more water demands compared to River sand. Increase in water demand has to be compensated by the increasing cement content to maintain the same water cement ratio. Their particle size distribution helps in higher packing density which enhances the durability of the concrete.

2. MATERIALS USED

2.1 Cement

Ordinary Portland Cement (OPC) is the cement best suited to general concreting purposes. OPC 53 grade confirming with

IS: 8112-2007 is used. The cement is kept in an airtight container and stored in the humidity controlled room to prevent cement from being exposed to moisture. The physical properties of cement used in the present study are shown in table 1.

Table 1: Physical Properties of Cement

Physical property	Obtained value
Fineness (retained on IS sieve 90-µm sieve)	3 %
Normal Consistency	30.5 %
Initial setting time	95 min
Final setting time	145 min
Specific gravity	3.15

Table 2: Chemical composition of Cement

Cement constituents	Percentage by mass
Loss on Ignition	2.65
Silica as SiO_2	21.5
Iron as Fe_2O_3	0.55
Aluminium as Al_2O_3	5.50
Titanium as TiO_2	Nil
Calcium as CaO	63.5
Magnesium as MgO	2.15
Sodium as Na_2O	0.85
Potassium as K_2O	0.85

2.2 Fine Aggregate

The material which passes through 4.75 mm sieve is termed as fine aggregate. In this research two materials were used as fine aggregate, they are (1) River sand, (2) Robo sand. These fine aggregate are clean and free from organic matter, silt, clay.

2.2.1 River Sand

The sand used in this research for preparation of normal concrete is natural River sand conforming to grading zone-II as per IS: 383-1970 with specific gravity 2.57 and having fineness modulus as 2.87. This material is dried at room temperature for 24 hours to control the water content in the concrete. The maximum size of FA is taken to be 4.75 mm. The testing of sand is done as per IS: 2386 – 1963. The physical properties of River sand as shown in table 3.

Table 3: Physical Properties of River sand

Property	River Sand
Specific gravity	2.57
Bulk relative density (kg/m^3)	1780
Bulking of River sand (%)	25.5
Moisture content (%)	Nil
Fineness modulus	2.87
Sieve analysis	Zone-2

2.2.2 Robo Sand (RS)

Robo Sand (RS) is obtained in wet form directly taken from deposits of Crushed stone factories. Wet Robo Sand was dried before the sample preparation. Robo Sand contains several crushed stones. Hence, Robo Sand is sieved through 4.75 mm sieve. The artificial sand is also tested to identify the absence of organic matter, thus confirming that it could be used in concrete mix. The specific gravity of the RS is 2.49 and bulk density is 1822 kg/m^3 and its fineness modulus is 2.91 and the physical characteristics of the RS are furnished In Table 4. The chemical composition analysis of Robo sand was found by X-Ray Fluorescence (XRF) shown in Table 5.

Fig.1 Manufacture Unit of Robo Sand

Fig. 2 Robo Sand

Table 4: Physical Properties of Robo Sand

Property	Robo Sand
Specific gravity	2.49
Bulk relative density (kg/m^3)	1822
Bulking of Robo sand (%)	22.50
Moisture content (%)	Nil
Fineness modulus	2.91

Table 5: Chemical Composition of Robo sand (XRF)

S.No	Robo sand Constituents	Percentage by mass
1	SiO_2	39.99
2	CaO	41.13
3	Al_2O_3	9.73
4	Fe_2O_3	3.56
5	MgO	3.38
6	SO_3	0.67
7	K_2O	0.58
8	Na_2O	0.01

2.3 Coarse Aggregate

Locally available coarse aggregate having the maximum size of 20 mm was used in this work. The aggregate were washed to remove dust and dirt and were dried to surface dry condition. The aggregate were tested as per IS: 383-1970. Specific gravity and other properties of coarse aggregate are given in table 6.

Table 6: Properties of Coarse Aggregate

Characteristics	Value
Colour	Grey
Shape	Angular
Maximum Size	20 mm
Specific Gravity	2.69

2.4 Water

The potable water available in the laboratory was used for mixing and curing of concrete.

3. MIX PROPORTIONS OF CONCRETE

3.1 General

Mix design can be defined as the process of selecting suitable ingredients of concrete such as cement, aggregate, water and determining their relative proportions with the object of producing concrete of required minimum strength, workability and durability as economically as possible, is termed the **concrete mix design**. The purpose of designing can be seen from the above definitions, as two-fold. The first objective is to achieve the stipulated minimum strength and durability. The second objective is to make the concrete in the most economical manner. The grades of concrete used in the present investigation are ordinary grade concrete and standard grade concrete**.** The mix design of concrete with Robo sand is not different from that of conventional concrete with River sand. The mix design procedure as per Indian Standard recommended guidelines given in **IS:10262-2009** and **IS: 456-2000** were adopted.

Table 7: Mix proportions of M20, M30& M40 grades of concrete

Grade of concrete	Cement	Fine Aggregate	Coarse Aggregat	Water
M20	1	1.90	3.24	0.50
M30	1	1.50	2.73	0.42
M40	1	1.35	2.52	0.40

4. EXPERIMENTAL WORK

4.1 General

In this research work M20, M30& M40 grades of concrete cubes of each 42 in number were cast. Therefore total number of cubes is 126. Further in detail among 42 concrete cubes of each grade, 21 were made with 100% Robo sand and other 21 cubes with 100% River sand as Fine aggregate. These 126 cubes were been cured in water for 28 days. After completion of 28 days curing, 54 cubes among them will be immersed in 5% H_2SO_4 by weight of water solution and the remaining 72 cubes which are not immersed in acid solution are used to determine the compressive strength of concrete at ages of 28, 56, 84& 118 days.

(a)Compressive strength test of concrete cubes at their respective ages

After completion of 28 days of curing, 18 cubes from the 72 cubes of concrete of three grades M20, M30& M40 which are not immersed in 5% H_2SO_4 solution were weighed and then tested for compressive strength. These values represent compressive strengths of concrete cubes at 28 days of age. These 18 cubes are some of 6 cubes from each grade of concrete of three different grades and in further 6 cubes of each grade are some of 3 cubes with 100% River sand and the other 3 cubes with 100% Robo sand as fine aggregates. Likewise the compressive strengths of three grades of concrete cubes at their respective ages of 84& 118 days were determined by conducting compressive strength test and prior to test their weights were measured and recorded.

(b)Weight Loss And Strength Loss Test Of Concrete Cubes

The 54 concrete cubes of three grades which are immersed in acid solution are taken out from the solution after an immersion periods of 28, 56& 90 days. At each time 18 cubes in number were taken out and then these cubes are weighed and tested for compressive strength.

Generally after the acid attack test the concrete cubes strength and weight will be reduced in such way that concrete cubes which are immersed in acid solution for more no of days will exhibit extra loss than the strength loss and weight loss values of cubes which are in acid solution for less time, whereas the strength and weight values are gained for concrete cubes with the increase of age when they are not immersed in 5% H_2SO_4 solution. So therefore these weights and compressive strengths values after the acid attack test for 28, 56& 90 days were compared with the weights and compressive strengths of concrete cubes which are not immersed in acid solution, at their corresponding ages of 56, 84& 118 days. So from the difference in weight loss and strength loss values among concrete cubes made with 100% River sand and with 100% Robo sand to determine which concrete of three different grades has better durability.

5. TEST RESULTS& DISCUSSION

The results of the experimental investigation are presented in this chapter. The following test were conducted on M20, M30& M40 grades of concrete made with River sand and with Robo sand and then the results were compared.

(1)Compressive strength test results

(2) Durability test results

(a) Strength loss test results

(b) Weight loss test results

5.1 Compressive Strength Test Results

Table 8: Compressive strength of concrete made with 100% River sand

Mix. No	W/C	Average compressive strength at 28 days (MPa) (Robo sand)
M20R	0.50	33.26
M30R	0.42	49.68
M40R	0.40	60.03

Table 9: Compressive strength of concrete made with 100% Robo sand

Mix. No	W/C	Average compressive strength at 28 days (MPa) (River sand)
M20S	0.50	28.0
M30S	0.42	40.25
M40S	0.40	51.00

By comparing the table 8 and 9 values of compressive strength at age of 28 days of concrete it was observed that the compressive strength of concrete made with 100 % Robo sand has an increase in the strengths as 18.78 % more for M20, 23.42% more for M30 and 17.70% more for M40 grades of concrete when compared to the strengths of concrete made with 100% River sand.

Table 10: Compressive strength of concrete made with 100% River sand at age of 56, 84& 118 days

Table 11: Compressive strength of concrete made with 100% Robo sand at age of 56, 84& 118 days

Mix.No	W/C	Average compressive strength (in Mpa) for concrete with 100% River Sand		
		At age of 56 days	At age of 84 days	At age of 118 days
M20S	0.50	29.40	30.52	31.36
M30S	0.42	42.00	43.00	44.20
M40S	0.40	53.10	54.00	55.30

Mix.No	W/C	Average compressive strength (in Mpa) for concrete with 100% Robo Sand		
		At age of 56 days	At age of 84 days	At age of 118 days
M20R	0.50	34.92	36.25	37.25
M30R	0.42	52.16	54.15	55.64
M40R	0.40	63.03	65.43	67.23

By comparing the table 10 and 11 values of compressive strength at age of 28 days of concrete it was observed that the compressive strength of concrete made with 100 % Robo sand has an increase in the strengths as 18.77% more for M20, 25.33% more for M30 and 20.47% more for M40 grades of concrete when compared to the strengths of concrete made with 100% River sand.

5.2 Durability Test Results

5.2.1 Strength Loss Test Results for 28, 56 & 90 days of Immersion in 5% H_2S0_4 by Weight of Water Solution

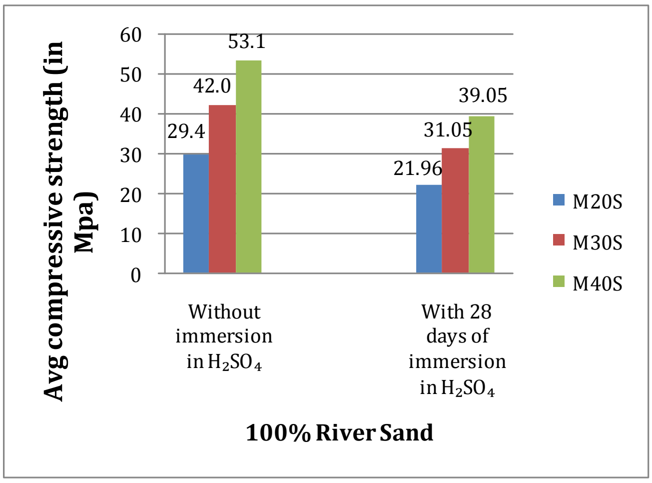

Fig 3 Compares the Average compressive strengths of concrete cubes made of 100% River sand as FA without and with 28 days of immersion in 5%H_2S0_4

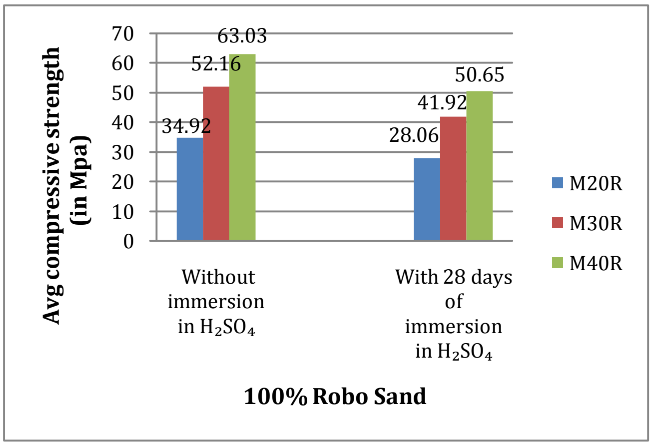

Fig 4 Compares the Average compressive strengths of concrete of 100% Robo sand as FA without and with 28 days of immersion in 5%H_2SO_4

By comparing figs 3& 4 the strength loss after 28 days of immersion in H_2SO_4 solution was observed more in concrete cube specimens with 100% River sand as a fine aggregate than the concrete cube specimens with 100% Robo sand as fine aggregate. The percentage strength loss of Robo sand concrete was 19.64% for M20, 19.63% for M30 and 19.64% for M40 grade concretes respectively, whereas the same for River sand concrete is 25.30% for M20, 26.07% for M30 and 26.45% for M40 grade concretes respectively.

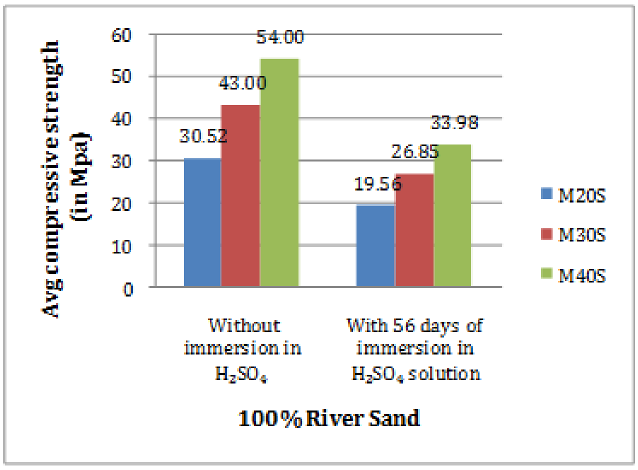

Fig 5 Compares the Average compressive strengths of concrete of 100% River sand as FA without and with 56 days of immersion in 5%H_2SO_4

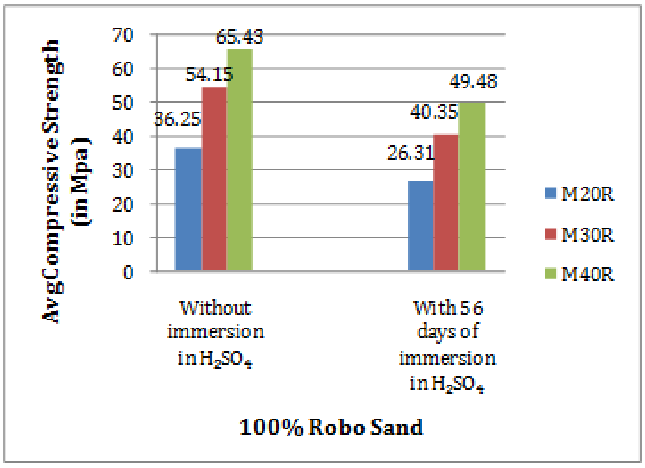

Fig 6 compares the Average compressive strength of concrete of 100% Robo sand as FA without and with 56 days of immersion in 5% H_2SO_4

By comparing figs 5& 6 the strength loss after 56 days of immersion in H_2SO_4 solution was observed more in concrete cube specimens with 100% River sand as a fine aggregate than the concrete cube specimens with 100% Robo sand as fine aggregate. The percentage strength loss of Robo sand concrete was 27.42% for M20, 25.48% for M30 and 24.37% for M40 grade concretes respectively, whereas for the River sand concrete 35.91% for M20, 37.55% for M30 and 37.07% for M40 grade concretes respectively.

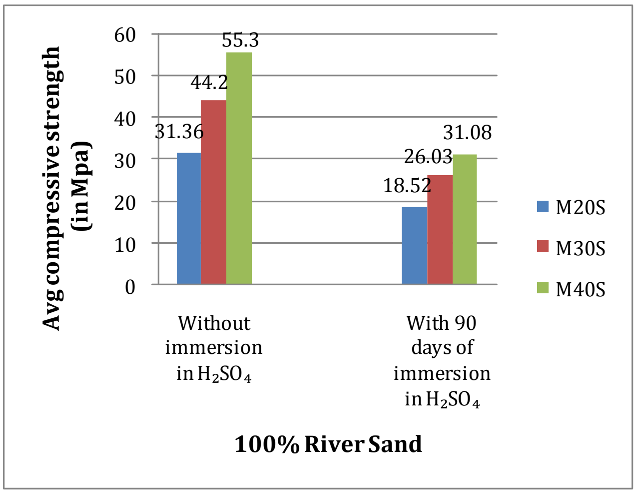

Fig 7 compares the Average compressive strength of concrete of 100% River Sand as FA without and with 90 days of immersion in 5% H_2SO_4

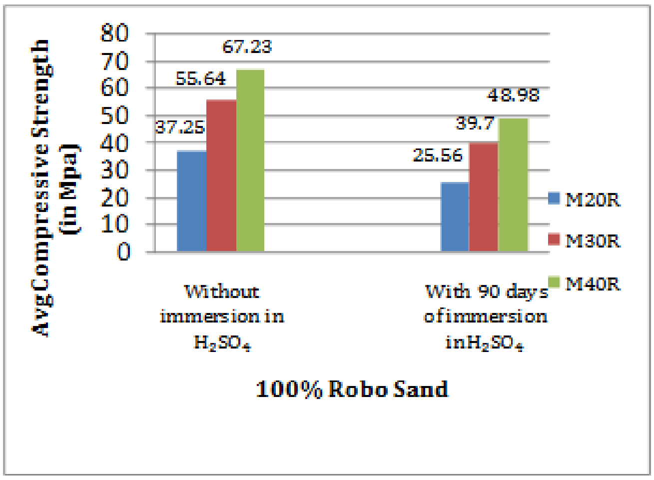

Fig 8 Compares the Average compressive strength of concrete of 100% Robo Sand as FA without and with 90 days of immersion in 5% H_2SO_4

By comparing figs 7& 8 the strength loss after 90 days of immersion in H_2SO_4 solution was observed more in concrete cube specimens with 100% River sand as a fine aggregate than the concrete cube specimens with 100% Robo sand as fine aggregate. The percentage strength loss of Robo sand concrete was 31.38% for M20, 28.64% for M30 and 27.14% for M40 grade concretes respectively, whereas for the River sand concrete 40.94% for M20, 41.10% for M30 and 43.79% for M40 grade concretes respectively.

Table 12: Comparison of % Average compressive strength loss between concrete made with 100% River sand and replacement with 100% Robo sand for three grades of concrete

Grade of concrete	Number of days immersed in 5% H_2SO_4 solution	(%) Avg compressive strength loss due to immersion in 5% H_2SO_4 solution		% Decrease in compressive strength loss for concrete with 100% Robo Sand
		River Sand	Robo Sand	
M20	28 days	25.30	19.64	5.66
M30		26.07	19.63	6.44
M40		26.45	19.64	6.81
M20	56 days	35.91	27.42	8.49
M30		37.55	25.48	12.07
M40		37.07	24.37	12.70
M20	90 days	40.94	31.38	9.56
M30		41.10	28.64	12.46
M40		43.79	27.14	16.65

Table 12 shows the difference in compressive strength loss (in %) between the concrete cubes with 100% River sand and with 100%Robo sand as a fine aggregate. The concrete made with 100 % River sand prone to more strength loss than that of concrete made with 100% Robo sand in all the three grades i.e., M20, M30& M40 , the same result were repeated in tests which are conducted after immersion periods of 28, 56& 90 days.

5.2.2 Weight Loss Test Results For 28, 56 & 90 days of Immersion in 5% H_2SO_4 by Weight of Water Solution

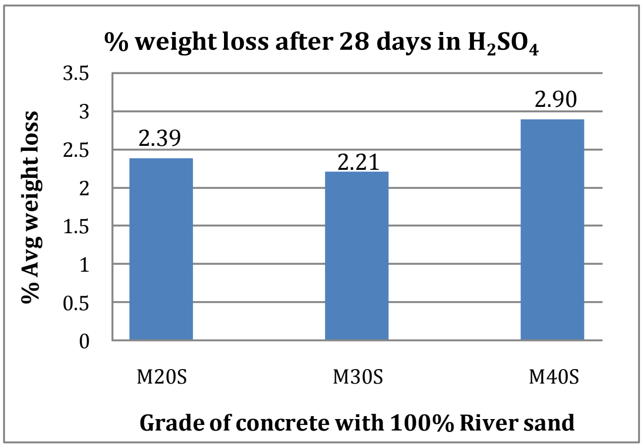

Fig 9 Average % weight loss for three grades of concrete with 100% River sand after 28 days of immersion in 5% H_2SO_4 solution

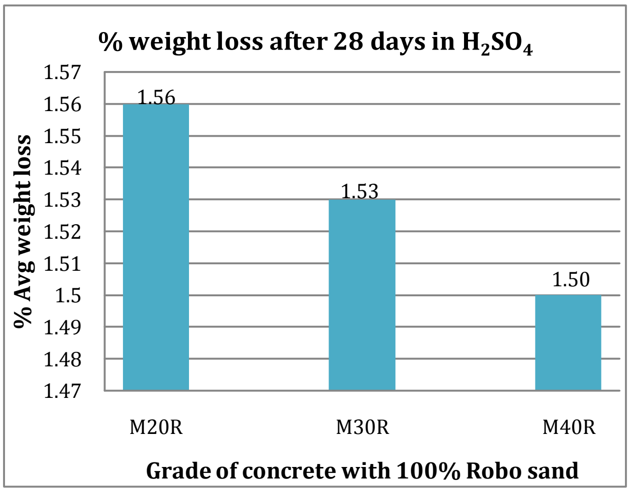

Fig 10 Average % loss for three grades of concrete with 100% Robo sand after 28 days of immersion in 5% H_2SO_4 solution

From fig 9& 10 after 28 days of immersion in 5% H_2SO_4 the percentage weight loss of Robo sand concrete when immersed in H_2SO_4 solution was 1.56 % for M20, 1.53 % for M30 and 1.50% for M40 grade of concretes respectively, whereas for the River sand concrete 2.39% for M20, 2.21% for M30 and 2.90% for M40 grade concretes respectively.

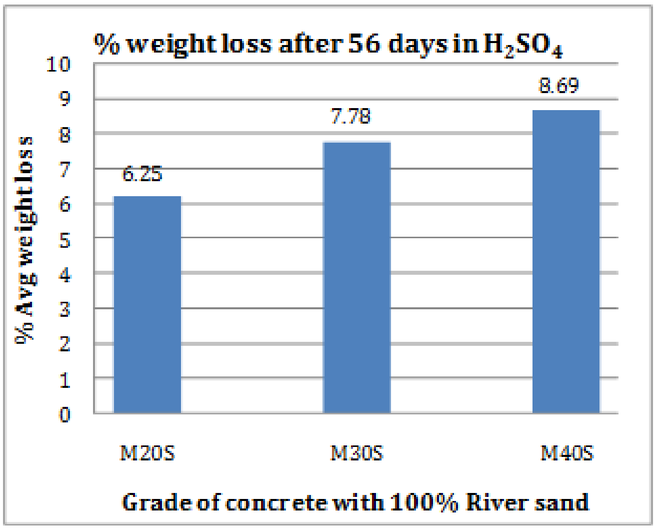

Fig 11 % weight loss for three grades of concrete with 100% River sand after 56 days of immersion in 5% H_2SO_4 solution

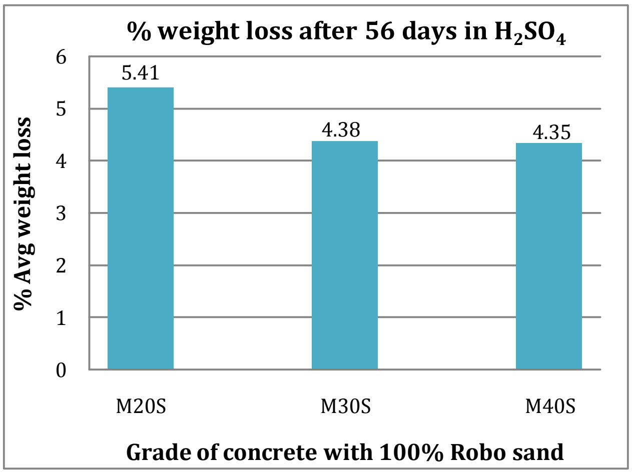

Fig 12 % weight loss for three grades of concrete with 100% Robo sand after 56 days of immersion in 5% H_2SO_4 solution

From fig 11& 12 after 56 days of immersion in 5% H_2SO_4 the percentage weight loss of Robo sand concrete when immersed in H_2SO_4 solution was 5.41 % for M20, 4.38 % for M30 and 4.35% for M40 grade concretes respectively, whereas for the River sand concrete 6.25 % for M20, 7.78% for M30 and 8.69% for M40 grade concretes respectively.

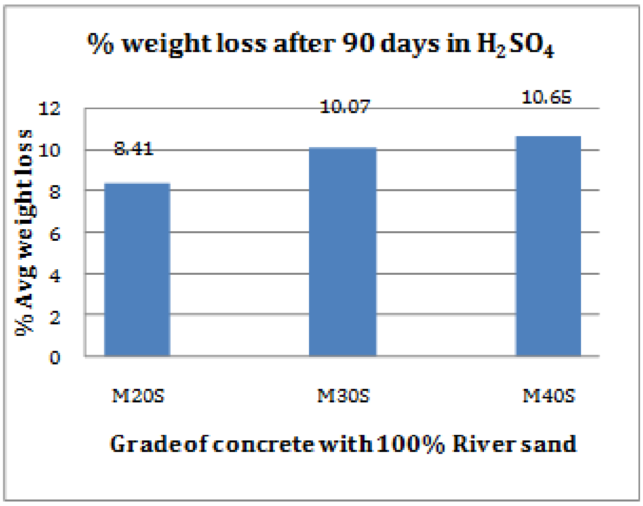

Fig 13 % weight loss for three grades of concrete with 100% River sand after 90 days of immersion in 5% H_2SO_4 solution

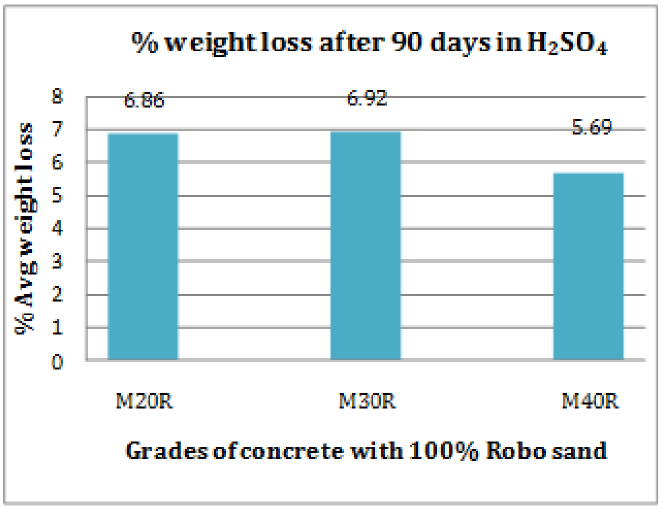

Fig 14 % weight loss for three grades of concrete with 100% Robo sand after 90 days of immersion in 5% H_2SO_4 solution

From fig 13& 14 after 90 days of immersion in 5% H_2SO_4 solution the percentage weight loss of Robo sand concrete was 6.86 % for M20, 6.92 % for M30 and 5.69 % for M40 grade concretes respectively, whereas for the River sand concrete 8.41 % for M20, 10.07% for M30 and 10.65% for M40 grade concretes respectively.

Table 13 : Comparison of % Average weight loss between concrete made with 100% River sand and replacement with 100% Robo sand for three grades of concrete

Grade of concrete	Number of days immersed in 5% H_2SO_4 solution	(%) Average weight loss due to immersion in 5% H_2SO_4 solution		% Decrease weight loss for concrete with 100% Robo Sand
		River Sand	Robo Sand	
M20	28 days	2.39	1.56	0.83
M30		2.21	1.53	0.68
M40		2.90	1.50	1.40
M20	56 days	6.25	5.41	0.84
M30		7.78	4.38	3.40
M40		8.69	4.35	4.34
M20	90 days	8.41	6.86	1.55
M30		10.07	6.92	3.15
M40		10.65	5.69	4.96

The Table 13 shows the difference in Average weight loss (in %) between the concrete cubes with 100% River sand and with 100%Robo sand as a fine aggregate. The concrete made with 100% River sand prone to more weight loss than that of concrete made with 100% Robo sand in all the three grades i.e., M20, M30& M40 , the same result was repeated in test after immersion periods of 28, 56& 90 days

7. CONCLUSIONS

1. The compressive strength of concrete cubes with 100% Robo sand as a fine aggregate has increased strength values than that of the concrete cubes made with 100% River sand, this strength difference was clearly observed in three grades of concrete.

2. It was found that the mixes with the Robo sand gives consistently higher strength than the mixes with the natural sand.

3. The results show that the concrete cubes of three grades M20, M30& M40 made with 100% Robo sand as a fine aggregate were less prone to compressive strength loss than that of the concrete cubes made with 100% River sand when immersed in 5% H_2SO_4 by weight of water solution for a period of 28, 56& 90 days. Prior to immersion in acid attack solution concrete cubes are cured for 28 days.

4. The average percentage weight loss for concrete cubes of grades M20, M30& M40 made with 100% Robo sand as fine aggregate is less to that of the respective grades of concrete cubes made with 100% River sand when immersed for 28, 56& 90 days in 5% H_2SO_4 by weight of water solution.

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