Durability of Concrete Using Manufactured Sand as a Complete Replacement of Natural Sand with Basalt Fibers

Suman Luitel[1`], Seema Thapa .K[2]

[1, 2]BE Student, Department of Civil Engineering, Brindavan College of Engineering, Yelahanka, 560063, Bangalore India

Abstract: ***The present investigation is an attempt to study durability properties of concrete with manufactured sand as complete replacement to natural sand and varying percentage of basalt fibers ranging from 0 to 4 kg/m^3 in interval of 1 kg/m^3 and aspect ratio of 20 is to be used to study the strength and durability of concrete. For present study M_{30} grade concrete is designed and its durability as well as workability properties are studied. Main focus of present work is to study durability properties such as Acid resistance test, sulphate resistance test, chloride resistance test, saturated water absorption test, elevated temperature test, residual compressive strength test, and to substantiate the better uses of manufactured sand and basalt fiber to enhance concrete strength and durability properties.***

Keywords: Basalt fibers, Fibro-Reinforced Concrete, Durability test, manufactured sand, Natural Sand, Residual Compressive Strength

1. Introduction

Concrete is a building material made from a mixture of coarse aggregate, fine aggregate, cement, and water, which can be spread or poured into moulds and forms a stone-like mass on hardening. It is the most widely used construction material today.

Rapid increase in construction activity has led to acute shortage of conventional construction material. Commonly river sand is used as a the fine aggregate but the administrative restrictions in developing countries like India has escalated the cost of sand even at the places where river sand is available in abundance.

Nowadays, Manufactured Sand has been incorporated in concrete mix design by replacing sand in fixed proportions or completely for economic considerations. Latest studies have been conducted considering the possibility of using Manufactured Sand as a complete replacement of sand without impairing the strength and its durability.

The introduction of basalt fibers provides fire resistance, low flammability, 15-20% tensile strength and modulus, and enhances the durability of the concrete in a long run. Unlike other fibers it can be reused and recycled and the fibers content with appropriate proportion makes the concrete last long.

2. Literature Review

Several reports on the design and construction of reinforced concrete have been published which gives information on the use of basalt fiber as well as use of manufactured sand as a replacement of natural sand. **Devi and Kannan (2011)** [1] have conducted experiments to investigate the use of m sand as fine aggregate in concrete. They studied the strength and corrosion resisting properties of concrete containing m sand as fine aggregate along with an organic inhibitor, Triethanolamine. It was concluded that 100% sand replacement with 2% Triethanolamine can be effectively used in reinforced concrete structures for delaying corrosion and to increase other strength and durability characteristics. **Ilangovan et al (2008)**[2] have conducted tests to study the feasibility of the usage of m sand as hundred percent substitute for natural sand in concrete. From the test results they reported that permeability of m sand concrete was less compared to controlled concrete. The m sand concrete have comparatively 10-15% more strength than the ordinary concrete. The durability of m sand replaced concrete under sulphate and acid action was found higher than the conventional concrete. **Lohani et al (2012)**[3] have studied the property of the m sand and the suitability to use it as partial replacement material for sand in concrete. Design mix of M20 grade concrete was used. The durability of concrete was studied by immersing the concrete cubes in 5% solution of $MgSO_4$, 5% solution of NaCl, and 2N solution of HCl for 28 and 91 days. From the test results it was observed that compressive strength of concrete was maximum at 30% replacement. Flexural and tensile strength were maximum at 20% sand replacement. **Prof M. R. Chitlange, Dr. P. S. Pajgade, Dr. P. B. Nagarnaik** [4] focused on Experimental Study of Artificial Sand Concrete. For the purpose of experimentation concrete mixes are designed for M20, M30 and M40 grades by 100% replacement of natural sand to artificial sand. Compressive and flexural tests are conducted to study the strength of concrete using artificial sand and the results are compared with that of natural sand concrete. **Rathod et al**, (2015) [5] has done an experimental research on normal strength concrete of grade M25 using basalt fiber. The fibers were replaced at a percentage of 0 to 2% at an interval of 1%. The Test conducted on this research is compressive strength and flexural strength at 14 days and 28 days. In the 14 days average strength was maximum when 2% fiber is used. About 40% to 50% increase in strength is observed. In the 28 days average compressive strength is maximum when 2% fibers are used. About 83% & 92% increase in compressive strength than the design strength, when the basalt fibers are introduce in concrete.

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3. Materials Used

3.1 Material Properties

3.1.1 Cement

Ordinary Portland cement of Birla super of grade 53 conforming to IS 12269:1987 was used. The properties of cement are given in the table 1.

Table 1: Properties of Cement

Sl.No	*Properties*	*Results*
1	Specific gravity	3.15
2	Standard consistency	33%
3	Initial setting time	90 minutes
4	Final setting time	300 minutes
5	Fineness of cement	4%

3.1.2 Fine Aggregate and Coarse Aggregate

M-sand, clear from organic impurities conform to IS 4031: 1988 and crushed stones of 20mm, 12.5mm and 6mm sizes conform to IS 2386: 1963 part 3 were used Properties of fine (M Sand & Natural Sand) and coarse aggregate are shown in Table 2, Table 3 & Table 4 respectively.

Table 2: Properties of Fine Aggregate (Manufactured Sand)

SL NO.	Properties	Results
1	Specific gravity	2.64
2	Sieve analysis	Zone II Table 4 of IS 383 (1970)
3	Water absorption	0.52%

Table 3: Properties of Fine Aggregate (Natural Sand)

SL NO.	Properties	Results
1	Specific gravity	2.62
2	Sieve analysis	Zone II Table 4 of IS 383 (1970)
3	Water absorption	0.52%

Table 4: Properties of Coarse Aggregate

SL NO.	Properties	Results
1	Specific gravity	2.56
2	Sieve analysis	20mm Downsize Zone I Table 2 of IS 383 (1970)
3	Water absorption	nil
4	Aggregate Impact Value	24.86%

3.1.3 Basalt Fiber

16 mm length size Basalt fiber was used with apect ratio of 20. It helps to increases Compressive strength, tensile strength toughness as well as durability of concrete.

Figure 1: Basalt Fibers

Properties of Basalt Fiber

a) Physical Properties Color:-

- Available in golden brown in color.
- Diameter: - available in different diameter.
- Length: - Available in 6mm, 8mm, 12mm etc.
- Density:- 2.75 g/cm^3
- Coefficient of friction:- 0.42 to 0.50

b) Chemical Properties

- Basalts are more stable in strong alkalis.
- Weight loss occurs in boiling water,
- Alkali and acid is also significantly lower.
- Possess resistance to UV- Light & biologic and fungal contamination.

4. Experimental Investigation

4.1 Concrete Mix Design

Concrete mix design was done as per IS 456:2000 and IS 10262:2009. Mix proportion for M30 mix is given in table 5.

Table 5: Mix Proportion for fine Aggregate (for both manufactured Sand & natural sand)

S. No	Materials	Quantity(kg/m^3)
1	Cement	437.77 kg/m^3
2	Fine Aggregate	649.57 kg/m^3
3	Coarse Aggregate	1072.51 kg/m^3
4	Water	197 kg/m^3
5	Water cement ratio	
Mix Proportion(C:FA:CA:W)		**1:1.5:2.5:0.45**

5. Experimental Test Results & Discussions

5.1 Fresh Property Test

5.1.1 Slump Test

The results of slump tests for M-30 grade concrete with and without Basalt Fibers are shown in Figure 3 & Figure 4 respectively for mix with M sand & Natural Sand respectively.

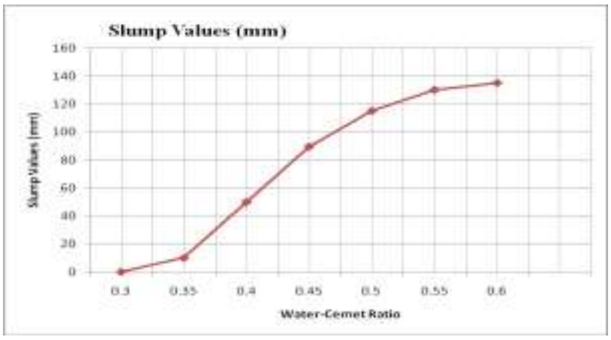

Figure 2: slump value vs. water cement ratio

5.1.2 Compaction factor test

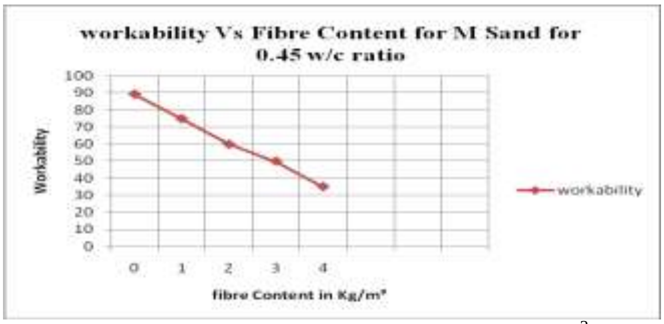

Figure 3: slump value vs. fiber content (in kg/m^3)

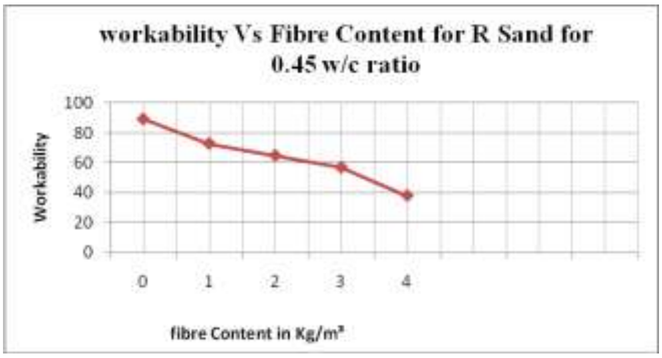

Figure 4: Workability (slump value) vs. fiber content (in kg/m^3)

From the experimental results it was observed that there is gradual decrease in the slump values with an increase in basalt fiber dose, which indicates that addition of Basalt Fibers content is associated with an increase in water demand.The compaction factor obtained for the mixes ranges from 0.8 to 0.90. Hence, the concrete is workable.

5.2 a) Durability Test

5.2.1 [Residual compressive Strength (in Bar graph) for HCL, NaSO4 & MgSO4]

5.2.1.1 Acid Resistance Test

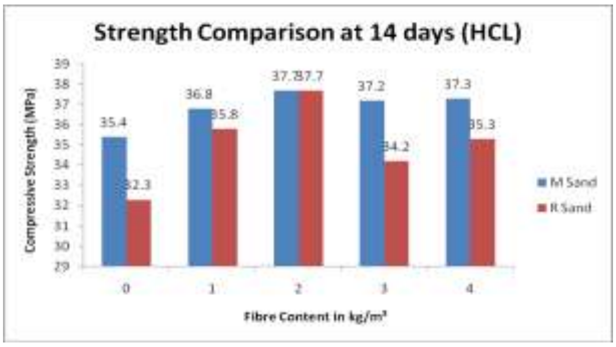

Figure 5: Residual Compressive Strength (in Mpa) vs. fiber content (in kg/m^3) at 14days for HCL

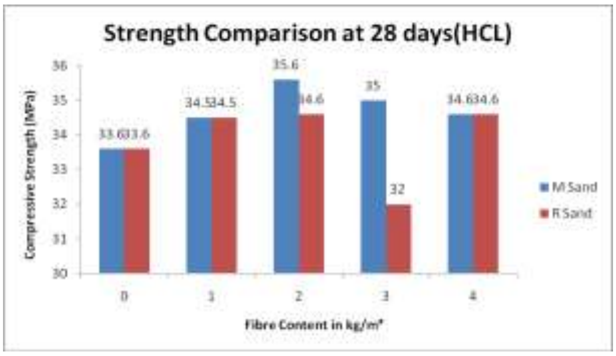

Figure 6: Residual Compressive Strength (in Mpa) vs. fiber content (in kg/m^3) at 28days for HCL

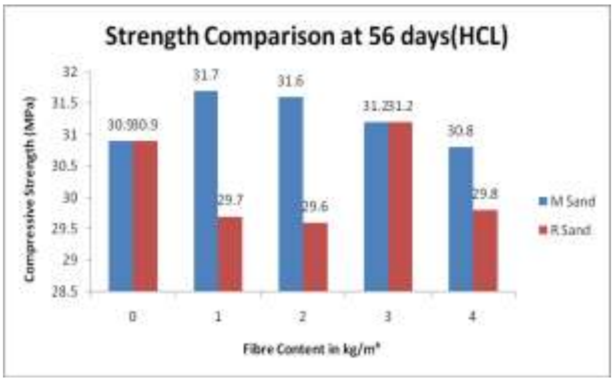

Figure 7: Residual Compressive Strength (in Mpa) vs. fiber content (in kg/m^3) at 56days for HCL

5.2.1.2 Chloride Resistance Test

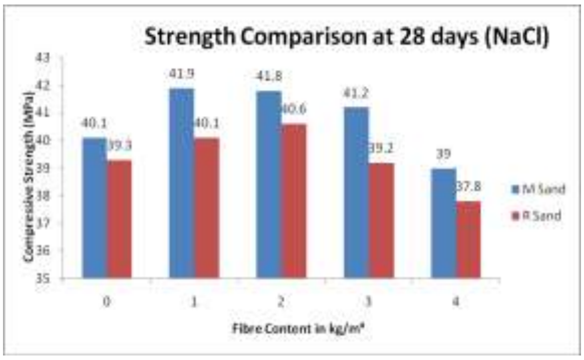

Figure 8: Residual Compressive Strength (in Mpa) vs. fiber content (in kg/m^3) at 28days for NaCl

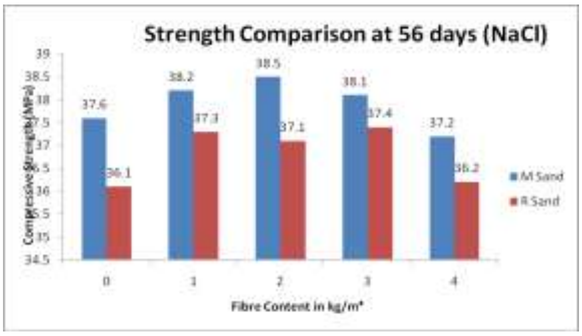

Figure 9: Residual Compressive Strength (in Mpa) vs. fiber content (in kg/m^3) at 56days for NaCl

5.2.1.3 Sulphate Resistance Test

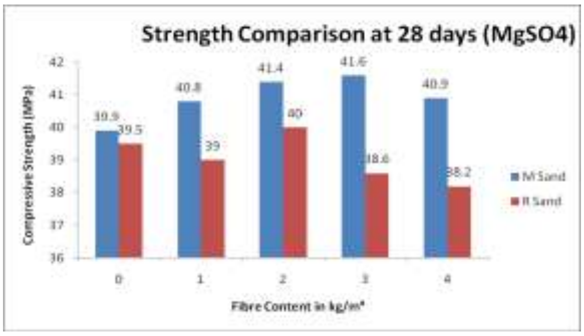

Figure 10: Residual Compressive Strength (in Mpa) vs. fiber content (in kg/m^3) at 28days for MgSo4

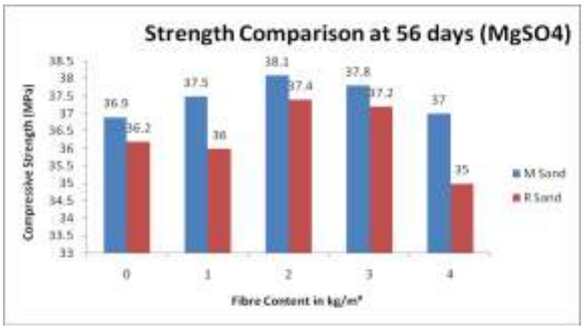

Figure 11: Residual Compressive Strength (in Mpa) vs. fiber content (in kg/m^3) at 56days for MgSo4

5.2 b) Durability Test

5.2.1[Residual compressive Strength (in line graph) for HCL, NaSO4 & MgSO4]

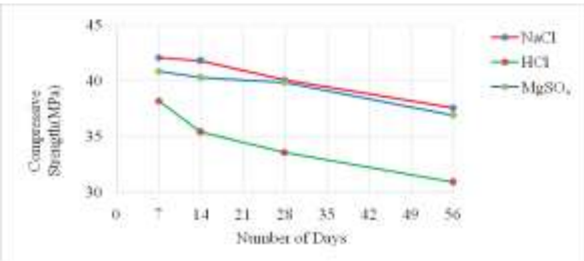

Figure 11: Residual Compressive Strength (in Mpa) vs. No of days for 0 kg/m^{3}Fiber content for M sand

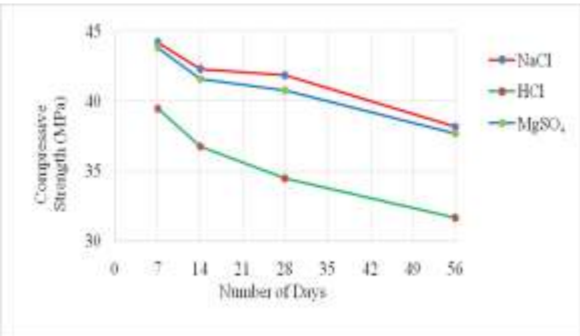

Figure 12: Residual Compressive Strength (in Mpa) vs. No of days for 1 kg/m^{3}Fiber content for M sand

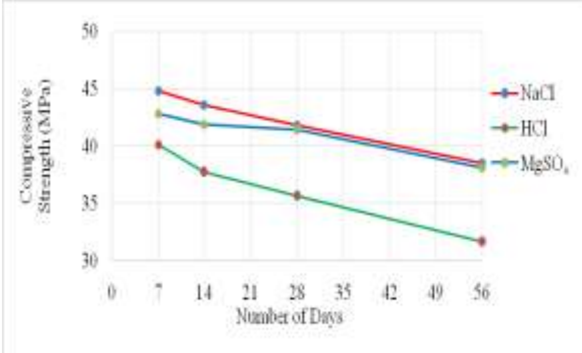

Figure 13: Residual Compressive Strength (in Mpa) vs. No of days for 2 kg/m^3 Fiber content for M sand

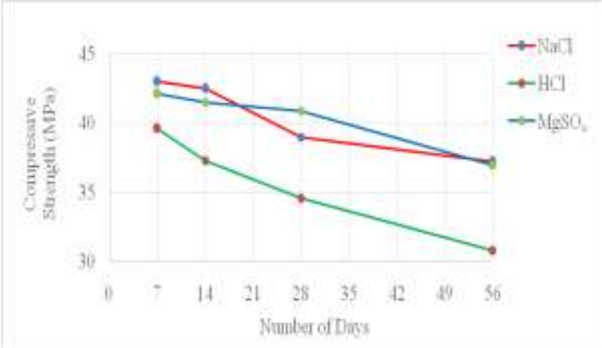

Figure 14: Residual Compressive Strength (in Mpa) vs. No of days for 3 kg/m^{3}Fiber content for M sand

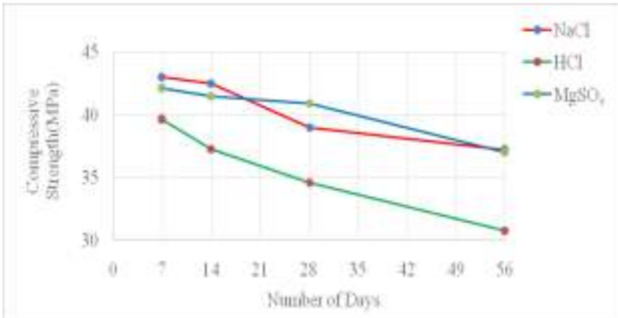

Figure 14: Residual Compressive Strength (in Mpa) vs. No of days for 4 kg/m^3 Fiber content for M sand

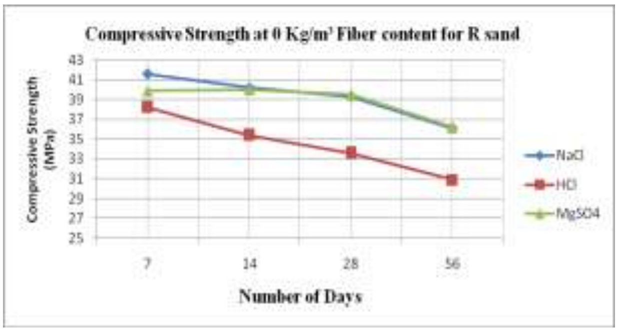

Figure 15: Residual Compressive Strength (in Mpa) vs. No of days for 0 kg/m^3 Fiber content for R sand

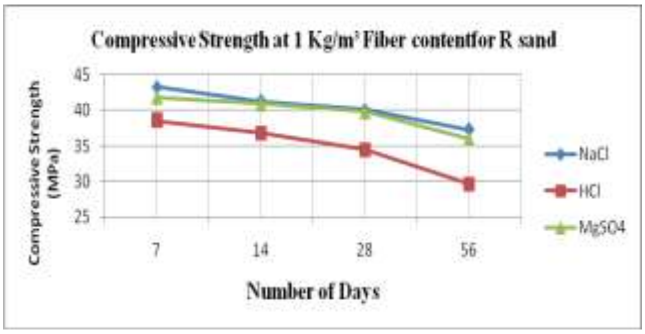

Figure 16: Residual Compressive Strength (in Mpa) vs. No of days for 1 kg/m^3 Fiber content for R sand

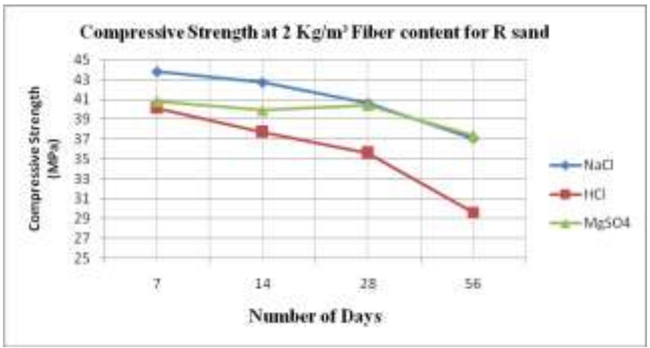

Figure 17: Residual Compressive Strength (in Mpa) vs. No of days for 2 kg/m^3 Fiber content for R sand

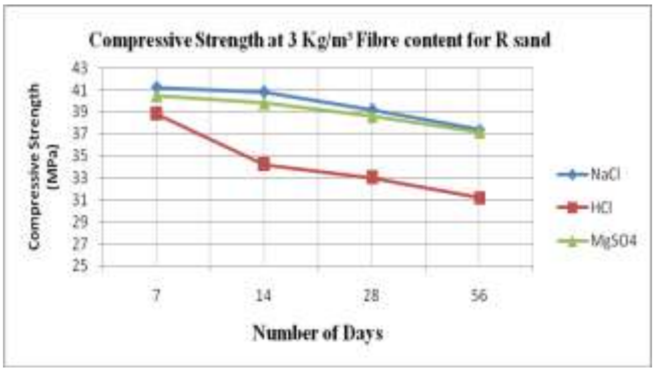

Figure 18: Residual Compressive Strength (in Mpa) vs. No of days for 3 kg/m^3 Fiber content for R sand

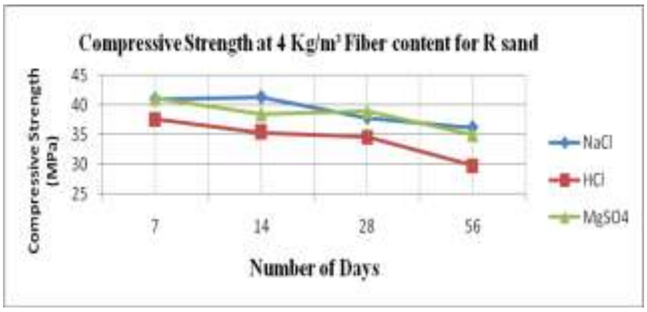

Figure 19: Residual Compressive Strength (in Mpa) vs. No of days for 4 kg/m^3 Fiber content for R sand

5.2.2 Weight loss of Mix with Manufactured Sand

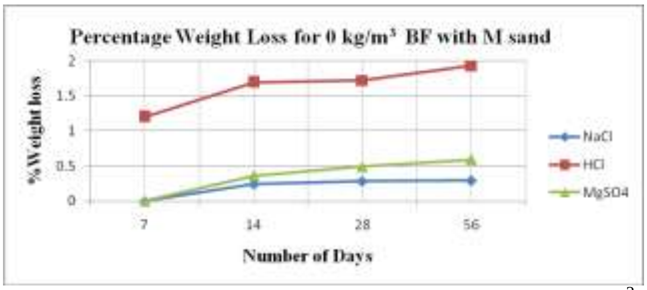

Figure 20: Weight Loss (in %) vs. No of days for 0 kg/m^3 Fiber content for M sand

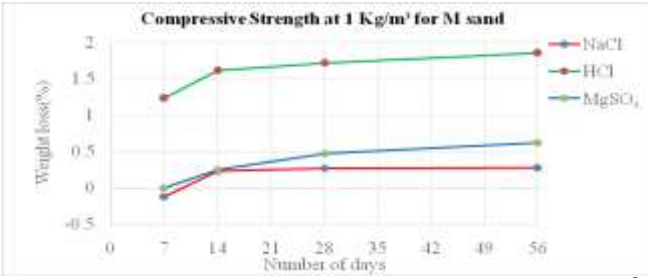

Figure 21: Weight Loss (in %) vs. No of days for 1 kg/m^3 Fiber content for M sand

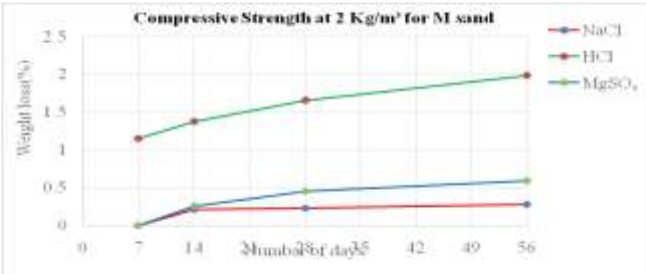

Figure 22: Weight Loss (in %) vs. No of days for 2 kg/m^3 Fiber content for M sand

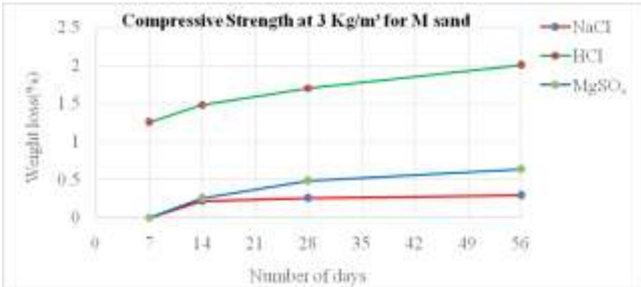

Figure 23: Weight Loss (in %) vs. No of days for 3 kg/m^3 Fiber content for M sand

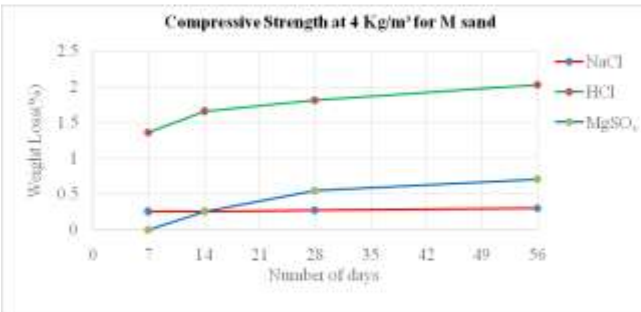

Figure 24: Weight Loss (in %) vs. No of days for 4 kg/m^3 Fiber content for M sand

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5.3 Water Absorption Test

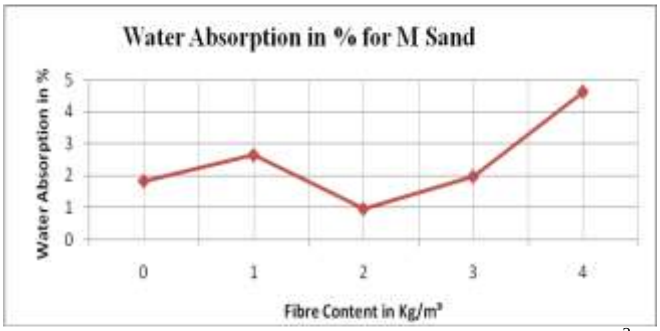

Figure 25: Water Absorption vs. Fiber Content (in kg/m^3) for M sand

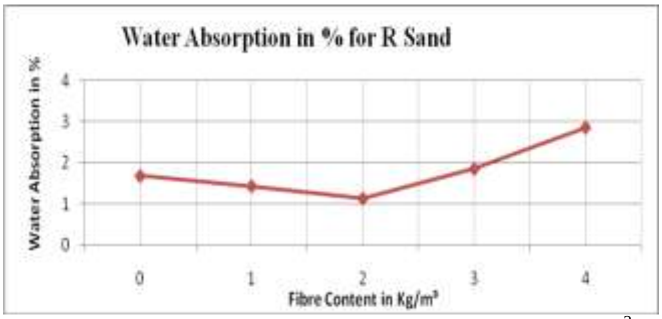

Figure 26: Water Absorption vs. Fiber Content (in kg/m^3) for R sand

5.4 Elevated Temperature Test

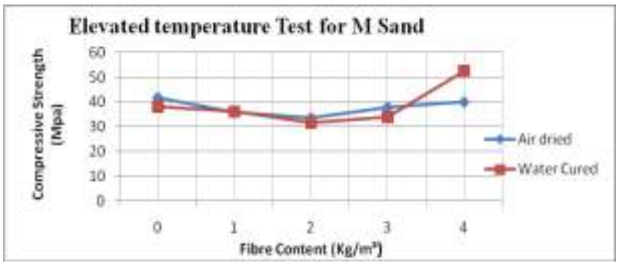

Figure 27: Residual Compressive Strength (in Mpa) vs. Fiber content (in kg/m^3) for M sand

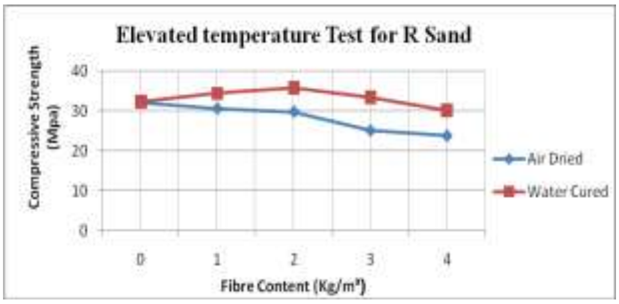

Figure 28: Residual Compressive Strength (in Mpa) vs. Fiber content (in kg/m^3) for R sand

6. Conclusions

1) In the slump test, workable slump of 85mm was obtained for water-cement ratio of 0.45 which is in accordance with IS 10262 taken in mix design.
2) From the test result, it is noted that strength reduction of concrete cubes is more with increase in days of specimen immersion in chemicals. It can also be seen that the reduction in compressive strength was maximum in case of acid resistance test and minimum in the case of Chloride resistance test.
3) In Acid resistance test, it was found that resistance to loss in compressive strength of concrete specimens was maximum at 3kg/m^3 for both M Sand and R Sand but comparatively M Sand has greater resistance to loss in strength than R Sand .There was a significant weight loss in the initial 7 days. Thereafter the percentage weight loss increased progressively till 56 days with minimum percentage weight loss at 2kg/m^3 to 3kg/m^3 of fibers content.
4) In Chloride resistance test the resistance to loss in compressive strength of the specimens were found to be maximum for 4 kg/m^{3}fiber content in both the concrete cubes with M Sand & R Sand but comparatively M Sand has greater resistance to loss in strength than R Sand. There was a weight gain in some specimens in the initial 7 days. Thereafter percentage weight loss was found to be increasing till 56 days with minimum weight loss at 2 kg/m^3 of basalt fibers content.
5) In Sulphate resistance test the resistance to loss in compressive strength of the specimens were found to be maximum for 4 kg/m^{3}fiber content in both the concrete cubes with M Sand & R Sand but comparatively M Sand has greater resistance to loss in strength than R Sand. There was no loss of weight in the specimens in the initial 7 days. Thereafter the percentage weight loss increased progressively till 56 days with minimum percentage weight loss at 2 kg/m^{3}fiber content.
6) In Water Absorption Test, water Absorption of concrete cubes decreased initially from 1.68 for 0 kg/m^{3}fiber content to 1.13% for 2 kg/m^3 and then increased to 4.02% for the 4 kg/m^{3}fiber content for concrete cubes with R Sand. And water Absorption of concrete cubes decreased initially from 1.83 for 0 kg/m^{3}fiber content to 0.965% for 2 kg/m^3 and then increased to 4.61% for the 4 kg/m^{3}fiber content for concrete cubes with M Sand. Thus, permeability is minimum for cubes with M Sand than R Sand for same 2 kg/m^3 of basalt fiber content.
7) Hence, it can be concluded that M Sand can be used as an effective substitute of natural sand with 2 kg/m^3 of basalt fiber content with respect to strength, workability and durability properties.

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Author Profile

Suman Luitel received the BE civil Engineering degree with First Class with Distinction from Visveswaraya Technological University. He has University Highest marks on Design of Prestress Concrete & Structures Subject & has been proposed for Gold Medal. He has a keen interest on Research on Concrete, Prestress Concrete, and Structures & Material Science.

Seema Thapa.k received the BE civil Engineering degree with First Class with Distinction from Visveswaraya Technological University. She has a interest on Concrete, Material Science, Environmental Engineering & diverse fields on civil Engineering.