Utilization of M-Sand & Basalt Fiber in Concrete: An Experimental Study on Strength and Durability Properties

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Abstract. The main aim of this project is to find a suitable alternative for the natural river sand, which is reaching maximum level of scarcity. M-sand is used along with the addition of natural basalt fibres in to the concrete. Mix design arrived for M25 using IS 10265 codal provisions. Initial properties test for fine aggregate (M-sand), coarse aggregate and cement were obtained in the laboratory. Basalt fibres are added in terms of volume fraction of 0%, 0.25%, 0.50% and 0.75% in to the concrete. Experimental investigations on fresh concrete were studied by conducting slump test, compaction factor test and Vee bee test. Also conducted experimental studies on strength and durability characteristics of basalt fibre reinforced concrete. For investigating strength test cubes and cylinders were casted for arriving compressive strength and split tensile strength. For durability studies, porosity tests (Water absorption test) were conducted. In the test, it is observed that, 0.75% volume fraction of basalt fibre reinforced concrete found optimum in terms of achieving strength and durability aspects. In our experimental studies, it found that M-sand can be effective alternative for the natural river sand.

1. Introduction
The biggest challenging issue, currently faced by the construction industry is the acute shortage and non availability of natural river sand [4]. The main reason behind this is the extreme mining on river beds to meet the rising demand for sand in the construction related activities [1]. This will lead to severe environmental injustice and imbalance to the nation. So, the government has taken some initiatives to prevent the depletion of the natural sources. The cost effective alternative to natural sand is manufacturing sand by crushing rocks/stones in various sizes and well. [2]. Sand produced by such means is known as manufactured /crusher/artificial sand. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers – each of them lends to varying distinct properties into the concrete matrix [3],[5]. Basalt fiber is an emerging fiber based polymer composites has enhanced strength characteristics and remarkably resistant to alkaline, acidic and salt nature [6],[7]. Few researches are only carried out by using basalt fiber and amongst the usage of the M-sand; an alternative resource for natural river sand has not initiated so far from our limited knowledge. So far from the review of past researches, it is concluded that there is a scope to conduct a study on various characteristics such as workability, strength and durability on basalt fiber reinforced M-25 grade concrete by using M-sand. The experimental works are preceded in that direction to fulfill the research gap identified based on the literature studies.

2. Materials Characteristics
Ordinary Portland Cement 53 grade with specific gravity of 3.14 with a initial setting time of 29 minutes. M-Sand (Fine Aggregate) used was locally procured and conformed to Indian Standard Specifications IS:383-1970 and this belong to grading zone III as per sieve analysis with a specific gravity of 2.65, fineness modulus of 2.76 with a moisture content of 1.1%. Coarse aggregate of size 20 mm with a specific gravity of 2.80 were used. Basalt fibers of length 24 mm with a diameter of 16 micron (aspect ratio of 1500) were used in this study. Portable water confirming to water of
concreting and curing according to drinking standards.

3. Mix Design and Methods
The mixture proportioning was done according to the IS 10262-2009. The mix ratio adopted for this study is 1:1.65:2.86. In order to get homogenous mix, the concrete materials were mixed thoroughly in dry state and water is added carefully to avoid segregation and bleeding. Moisture content were taken into consideration and appropriately subtracted from the water/cement ratio used for mixing. Basalt fibers with different percentages 0%, 0.25%, 0.50% and 0.75% are being used in this study in volume fraction. The freshly prepared basalt fibre reinforced concrete was tested for workability test such as slump cone test, compaction factor test and vee-bee test. Cubes (150 mm x 150 mm) and cylinders (100 mm x 120 mm) were casted, cured for 28 days and tested for finding compression strength, split tensile strength and water absorption test. For water absorption test, the specimens were kept in the hot oven and 100°C temperature is maintained till the period of 48 hours. Then the volume of pores can be arrived by the weight difference of specimens before and after kept in oven. The volume of pores expressed in terms of percentage.

4. Results and Discussions
4.1 Test on fresh concrete
4.1.1 Slump Test. The slump test is a measure of fluidity or consistency of workability. It refers to the reduction in height in the moulded basalt fiber composite concrete, when the mould is lifted up the cone having base diameter 200 mm, top diameter 100 mm and height 300 mm.

| S. No | Basalt fiber (%) | W/c | Slump value (mm) | Degree of workability |
|-------|------------------|-----|------------------|-----------------------|
| 1     | 0                | 0.5 | 95               | Medium                |
| 2     | 0.25             | 0.5 | 81               | Medium                |
| 3     | 0.50             | 0.5 | 67               | Medium                |
| 4     | 0.75             | 0.5 | 51               | Low                   |

From the table 1, it is understood that the slump value is ranging from 95 mm to 51 mm for the addition of 0 % to 0.75 %. For 0.75 % of fiber content, the degree of workability is low and fiber content upto 0.50 % it is medium. Slump value is getting reduced by the addition of fibers content and it affects the degree of workability in terms of bunching of fibers and non homogenous mixing. Figure 1 shows the increasing fiber content decreasing the degree of workability. The degree of workability is indirectly proportional to the fiber content.

![Slump value Vs Percentage of basalt fiber content](image)

4.1.2 Compaction factor Test. The compaction factor is the proportion of weights of partially compacted to fully compacted concrete. The compaction factor test is used for concrete which have low workability. The test is suitably susceptible to permit discrepancy in workability arising from the
initial process in the hydration of cement to be measured. In table 2, it is found to be 0.92 (high) compaction factor for without fibre content and the factor is around 0.74 for 0.75 % of fibre content. Similar to slump value, the compaction factor is affected by the increasing fibre content. For 0.75 %, the degree of workability is found low. In figure 2, it seems that the workability is medium up to 0.5% and further if it is increased to 0.75 %, the workability is low.

Table 2. Compaction Factor Value

| S. No | Basalt fiber (%) | W/c | Compaction factor | Degree of workability |
|-------|------------------|-----|-------------------|-----------------------|
| 1     | 0                | 0.5 | 0.92              | Medium                |
| 2     | 0.25             | 0.5 | 0.86              | Medium                |
| 3     | 0.50             | 0.5 | 0.81              | Medium                |
| 4     | 0.75             | 0.5 | 0.74              | Low                   |

Figure 2. Compaction factor value Vs Percentage of basalt fiber content

4.1.3 Vee-bee Test. It measures the properties of concrete under vibration which is intimately correlated to the process of placing in practice. Interestingly, it is found that for the addition of fibre content from 0%, 0.25%, 0.5% and 0.75% the vee-bee time arrived is 1 sec, 3 sec, 8 sec and 13 sec respectively from table 3 and figure 3. From different fiber content proportion, it ranges from all kind of degree of workability such as plastic, stiff plastic, stiff and very stiff. Very stiff workability is difficult to handle the concrete in terms of mixing and casting in to the mould. Generally for concreting it is preferred that around stiff nature.

Table 3. Vee-bee Test Value

| S. No | Basalt fiber (%) | W/c | Vee-bee Time (Sec) | Degree of workability |
|-------|------------------|-----|--------------------|-----------------------|
| 1     | 0                | 0.5 | 1                  | Plastic              |
| 2     | 0.25             | 0.5 | 3                  | Stiff Plastic        |
| 3     | 0.50             | 0.5 | 8                  | Stiff                |
| 4     | 0.75             | 0.5 | 13                 | Very Stiff           |
4.2 Test on hardened concrete

Hardened basalt fiber composite concrete was tested to evaluate the strength (Compressive Strength and Split Tensile Strength) and durability aspects (Porosity).

4.2.1 Compressive strength. The compressive test on hardened basalt fiber composite concrete was performed on a 2000kN capacity hydraulic compression testing machine in accordance to the relevant Indian standards. Three concrete cubes were tested for every compressive strength test and the average value is found for basalt fiber content 0 %, .25 %, 0.5 % and 0.75 % on the specimen 28 days age. In table 4, it is understood that, the compressive strength for the control specimen of 0 % basalt fiber reinforced composite content is found to be 24.35 %. The maximum compressive strength is 33.96 N/mm² for the fiber content of 0.75% of volume fraction. The percentage of fiber content is directly proportional to the compressive strength of the concrete as in figure 4. The results are found gradually increasing according to the increase in fiber content. The optimum percentage of basalt fiber intrusion in the concrete is found as 0.75 %, since the presence of basalt fibers filled the micro pores and cracks in the concrete. When comparing with control specimen the basalt fiber content of 0.75% increased 1.36 times of compressive strength.

4.2.2 Split tensile strength. The cylindrical specimen was tested in compression testing machine of capacity of 300kN to compute the tensile strength in the indirect way of the load is applied on the circumference area of the cylinder. The cylinder is then subjected to loading and then the strength is calculated by applying load until is subjected to failure.

| Basalt fiber content (%) | Compressive Strength (N/mm²) | Average Compressive Strength (N/mm²) | Split tensile Strength (N/mm²) | Average Split tensile Strength (N/mm²) |
|--------------------------|------------------------------|-------------------------------------|-----------------------------|-------------------------------------|
| 0 %                      | 24.48                        | 25.02                               | 1.95                        | 1.99                                |
|                          | 24.73                        |                                     | 2.04                        |                                     |
|                          | 25.84                        |                                     | 1.99                        |                                     |
| 0.25 %                   | 28.08                        | 27.24                               | 2.19                        | 2.24                                |
|                          | 26.44                        |                                     | 2.28                        |                                     |
|                          | 27.21                        |                                     | 2.24                        |                                     |
| 0.50 %                   | 29.77                        | 31.02                               | 2.57                        | 2.60                                |
|                          | 32.08                        |                                     | 2.71                        |                                     |
|                          | 31.20                        |                                     | 2.52                        |                                     |
| 0.75 %                   | 33.20                        | 33.96                               | 3.08                        | 3.08                                |
|                          | 34.84                        |                                     | 3.15                        |                                     |
|                          | 33.86                        |                                     | 3.02                        |                                     |
In table 4 and figure 5, it is understood that, the split strength for the 0 %, 0.25 %, 0.50 % and 0.75 % of basalt fiber reinforced composite content is found to be 1.99 N/mm², 2.24 N/mm², 2.60 N/mm² and 3.08 N/mm² respectively. It is also found that; percentage of basalt fiber content is directly proportional to the split tensile strength. The presence of basalt fibers yields performs better in improving split tensile strength up to 1.54 times of control specimen of 0 % of fiber content.

4.2.3 Water absorption test. The water absorption tests were conducted on the companion cube specimens. The specimens were placed in a hot air oven at 100 degree temperature for 24 hours and the dry weight of specimens is weighted, then the specimens were immersed in water for 24 hours and then weight is noted. The differences of above two weights are expressed in percentage over the dry weight. Thus the percentage of water was determined for basalt fiber composite concrete. From table 6, it is understood that, volume of pores is reduced from 7.32 % to 5.04 % from 0 % to 0.75 % basalt fiber content. Therefore the percentage of reduction of pores reduced up to 31%. The presence of fibers intruded into the micro pores and therefore volume of pores drastically reduced as seen in figure 6. The increase in fibers content is directly proportional to the reduction of pores. Once the pores are reduced, the durability of concrete may gets increased.

| Sl.No. | Basalt fiber content (%) | Volume of pores (%) | Percentage of Reduction of pores |
|-------|--------------------------|---------------------|---------------------------------|
| 1     | 0 %                      | 7.32                | 0 %                             |
| 2     | 0.25 %                   | 6.1                 | 16 %                            |
| 3     | 0.5 %                    | 5.58                | 23 %                            |
| 5     | 0.75 %                   | 5.04                | 31 %                            |
4.3 Regression analysis

Based on the experiment result, the model is developed to validate based on regression analysis. The model 1 will able to arrive the compressive strength ($f_{ck}$) for the specimens at 28 days once if the volume fractions of basalt fibers are known.

$$F_{ck} = 13.04\, v_f + 24.25 \quad \text{(1)}$$

The model 2 will able to find the split tensile strength ($f_s$) for the specimen if volume fractions of basalt fibers are known.

$$F_{s} = 1.452\, v_f + 1.933 \quad \text{(2)}$$

For relating, estimating pores ($P$) and volume fraction of basalt fibres, model 3 can be used.

$$P = 40\, v_f + 0.025 \quad \text{(3)}$$

All the models are correlating with each other with the validation of 10% to 15% accuracy.

5. Conclusions

From the workability test, it is observed that the degree of workability varies from medium to low, when the volume of basalt fibers increased to 0.75%. The slump value ranges from 95 mm to 51 mm when the volume of basalt fibers 0% to 0.75%. Similarly the compaction factor ranges from 0.92 to 0.74. In the Vee-bee test, it is understood that, the workability classified from plastic to very stiff category. If any admixtures added, the workability can be improved to some extent. The compressive strength of concrete found increase by 9% for 0.25% of basalt fibers, 20% for 0.50% of basalt fibers and 26% for 0.75% of basalt fibres. The split tensile strength of concrete found increase by 12% for 0.25% of basalt fibres, 21% for 0.50% of basalt fibres and 35% for 0.75% of basalt fibres. In water absorption test, volume of pores reduced up to 31%, when the fibres added up to 0.75%. Addition of basalt fibre into the concrete resulted in significant increase in strength in terms of compressive and split tensile strength. From the experimental results, it is found that, M-sand will be a suitable alternative for natural river sand in terms of achieving strength and durability characteristics. Developed models are well correlating the experimental results.

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