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Experimental Investigation of Properties of M20 Grade Concrete Using Crushed Sand and Silica Fume

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ABSTRACT: India is the second-largest cement manufacturer in the world. With more than 7% of the installed capacity worldwide. In FY 2027, it is anticipated that cement consumption would amount to 419.92 million tonnes. India's cement industry emissions have risen sharply in recent years, peaking at 144 million metric tonnes of carbon dioxide in 2019 (CO₂). It has become the need of the time to investigate the other alternative to natural sand as the demand supply ratio of natural sand cannot be fulfilled, which has further led to some ecological imbalances in the environment. The alternative to natural sand is manufactured sand (M-sand). Disposing of industrial by product has also become a tedious work, if these by product are not dispose properly, they cause environmental hazards. There are different types of by product such as fly ash, micro silica (silica fume), metakaolin, granulated blast furnace slag (GGBS) produced from different industries which can be made useful in civil engineering industries which will help in reducing the use of cement and lead to sustainability. In this experimental research partially replacement of cement with micro-Silica and 100% use of manufactured sand has been done. Concrete of grade M20 was casted from OPC 43 grade cement. The test was conducted on 28days, 56days, & 90days and comparative study has been performed using test results of Compressive Test, Split Tensile Test, Flexure Test, Shear Test, Acid Bath Test, Permeability Test, Rapid Chloride penetration Test (RCPT), between samples casted using 100% natural sand (M1), 100% manufactured sand (M2) and 100% Manufactured sand + 10% micro silica (M3). The result showed that the use of Silica fume with manufactured sand gives better result in flexure strength, resistance against chloride ion penetration, and acid attack

KEYWORDS: Natural sand, crushed sand (Manufactured Sand), Silica fume, Rapid chloride penetration test, Acid Bath, Compression Test, Split Tensile Test.

I. INTRODUCTION

Now a days lots of depletion of natural/ river sand has taken place, due to fast growth and need for infrastructure development, which has led to ecological imbalance in the environment. It is a high-quality white-gray sand that is utilized in masonry and concrete construction. Additionally, it can be used for RCC, brickwork, and plastering. This sand requires less moisture because water is already entrapped within its particles and has a superior grain form and smoother texture. It has a silt content of 5–20 percent. The alternative to natural sand came out to be manufactured sand. It is commonly known that manufactured sand is produced by mechanically crushing rock, in contrast to river sand that naturally occurs. Manufactured sand is different in terms of grading, shape and stone powder as compared to natural sand. As natural sand was used for long time in civil industries, we had all studies done on its properties (e.g., workability, mechanical properties), its effect on structure, its durability, etc. but for manufactured sand we are having less data compared to natural sand.

Pozzolanic materials like Silica fume, Granulated Blast furnace Slag (GGBS), Fly Ash, Metakaolin, etc. are some industrial by product which creates environmental hazards and hence to achieve sustainability we use these pozzolanic material with cement, either we add them or we partially replace them with cement. The amount of by-product materials produced by various industries, such as fly ash, GGBFS, metakaolin, rice husk ash, silica fume, etc., has grown enormously but isn't being used to its full potential. It is typically buried in landfills, which has negatively impacted numerous aquifers and freshwater sources and created a number of disposal issues. By partially substituting

with pozzolanic components, blended cements were launched in an effort to reduce the overall CO₂ emissions linked to ordinary Portland cement composites. Environmental challenges, sustainability issues, and high energy requirements are the three main issues with cement production. Due to the calcination of limestone and the burning of fossil fuels during the production of cement, almost the same amount of CO₂ is released into the atmosphere. It is necessary to do research regarding concrete made using manufactured sand because there is minimal data on this element of concrete using manufactured sand. The subsequent experiment was run in three stages.

All necessary materials were examined beforehand to determine their mechanical and physical characteristics. Following the determination of the concrete sample, the concrete mix design was created before the actual casting of concrete specimens.

This paper presents a comparison of an experimental study that was conducted on M20 grade concrete prepared using natural sand and natural aggregate (M1), Crushed sand and natural aggregate (M2), and crushed sand and 10% replacement of cement with silica fume (M3) and cured up to 28, 56 and 90 days. Material properties such as specific gravity, % water absorption, and mechanical properties like crushing value, impact value, and abrasion value are also determined and compared. Moreover, the properties of fresh concrete, like workability, and properties of hardened concrete like compressive strength, tensile strength, and shear strength are determined. Additionally, durability test including Rapid Chloride Penetration Test (RCPT), water permeability test, and acid bath test was also conducted and compared.

II. MATERIAL AND METHODS

The natural sand used in the mix was obtained from the Krishna River basin. The crushed sand used was obtained from Vertical Shaft Impact (VSI) crusher. The parent rock in the manufacturing of crushed sand was basalt. The same rock was used in the manufacturing of normal coarse aggregate used in the mix. Ordinary Portland Cement (OPC) conforming to IS 8112: 1989 [9] was used in all mixes with standard consistency of 34 %, Initial Setting Time (IST) of 40 minutes, Final Setting Time (FST) of 390 minutes Fineness of 4%.

1. Particle size distribution: This is the most important property of Fine aggregate as it affects the particle packing. After conducting a sieve analysis of natural sand and crushed sand, the particle size distribution curve obtained is as shown in fig. 1
2. Specific gravity: The specific gravity of aggregate was found using the pycnometer method as specified in IS 2386: 1963 (Part III) [10]. After carrying out the standard procedure, the specific gravity of natural sand, crushed sand, normal aggregates were found as given in table 1.
3. Water absorption: Water absorption of aggregate is an important property in the concrete mix design. The water absorption of natural sand, crushed sand, normal aggregate was found as per IS 2386: 1963 (Part III) [10], and the results obtained after the test are shown in table 1.
4. Silt content: The % silt content of natural sand was determined as per IS 2386: 1963 (Part II) [11] and was found to be 4.05%.
5. Crushing, Impact, and Abrasion value: The Crushing value, Impact value, and abrasion value are the most important mechanical properties in accessing coarse aggregate quality. The test on normal aggregate was conducted as per IS 2386: 1963 (Part IV) [12], and the results of the test are shown in table 2.

Silica Fume: The silica fume was purchased from “Elkem South Asia pvt. ltd.” Located at Vashi NaviMumbai. Following are the properties of silica Fume.



Table 01. Chemical Properties of Silica Fume

Parameters	Limitation	Values
SiO ₂ (%)	Min. 85	87.88
Moisture Content (%)	Max. 3	0.72
Loss Of Ignition (%)	Max. 6	1.29

Table 02. Physical Properties of Silica fume

Parameters	Limitation	Values
Particle Size >45Micron (%)	Max. 10	0.16
Pozzolanic activity Index(7d) (%)	Min. 105	127
Specific Surface (m ² /g)	Min. 15	18.5
Bulk Density (Kg/m ³)	500-700	617

Properties of fresh concrete: For preparing the concrete, the coarse aggregate passing through a 20mm IS sieve and retained on a 10 mm IS sieve were used. The natural sand and crushed sand used were passed through 4.75 mm and retained on 150 microns IS sieve. While mixing ingredients for the preparation of concrete normal weigh batching was done for mixes M1, M2 and M3. The mixing is done in 2 stages, firstly the mixing is done in dry state and secondly mixing is wet mixing after addition of water. After the production of concrete, the workability of fresh concrete was checked using the slump cone apparatus. The workability of concrete mix M1 was found to be 100mm while that of mix M2 and mix M3 was found to be 90mm and 100mm respectively.

Figure.1. Particle Size Distribution Curve

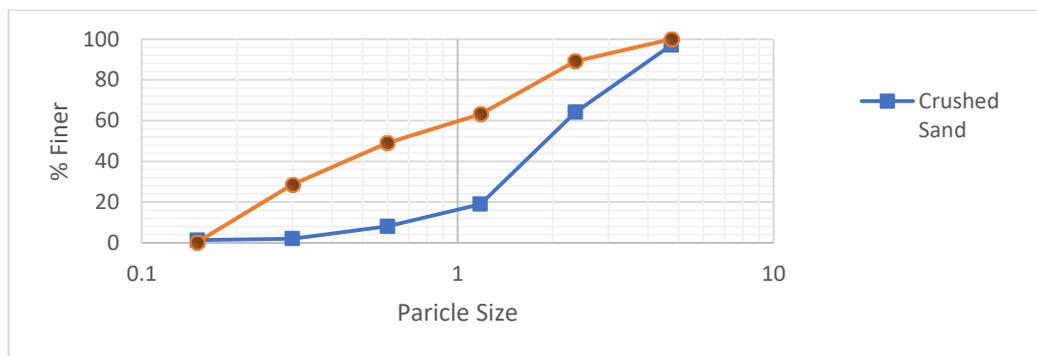


Table 04. Mechanical Properties of Coarse Aggregates

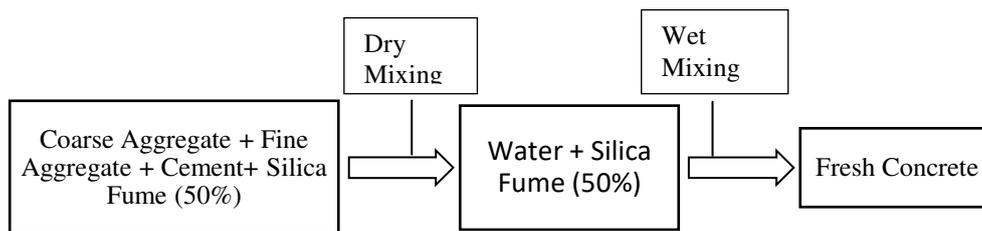
Properties	Normal Aggregate
Crushing Value	12.65
Impact Value	5.97
Abrasion Value	21.32



Table 05. Physical Properties of Fine and Coarse Aggregates

Properties	Natural sand	Crushed sand	Normal Aggregate
Specific Gravity	2.95	3.21	2.95
Water Absorption	3.1	1.43	0.7
Silt content(%)	4.05	-	-

Figure 2 Mixing Process



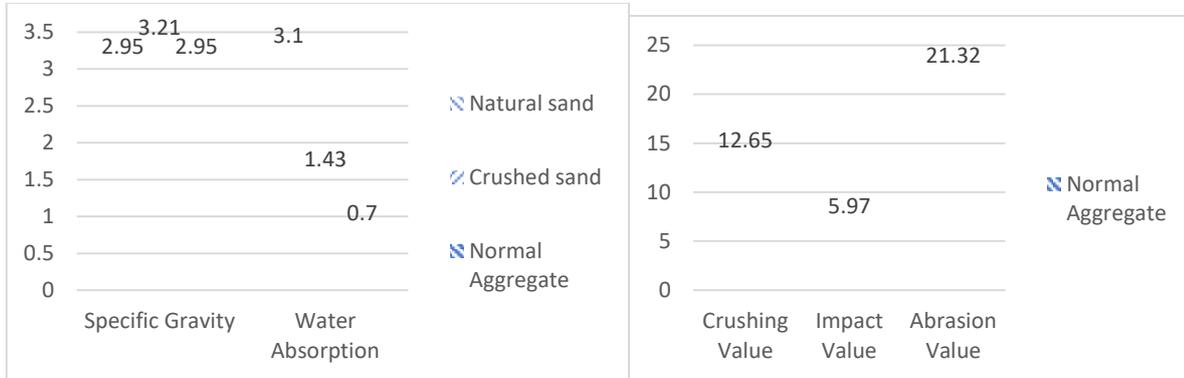
III. RESULTS AND DISCUSSION

The specific gravity of natural sand was found to be 2.95 while that of crushed sand was found to be 3.21. As crushed sand is produced after crushing rock, the number of organic impurities present in the crushed sand is less. Due to this, the specific gravity of crushed sand is more as compared to natural sand. On the other hand, the specific gravity of natural coarse aggregate is 2.95.

In the case of natural sand, the water absorption was found to be 3.1% while that of crushed was found to be 1.3%. As stated earlier the percentage of silt and other organic impurities is almost zero in crushed sand, the percentage of water absorbed by it is less compared to natural sand.

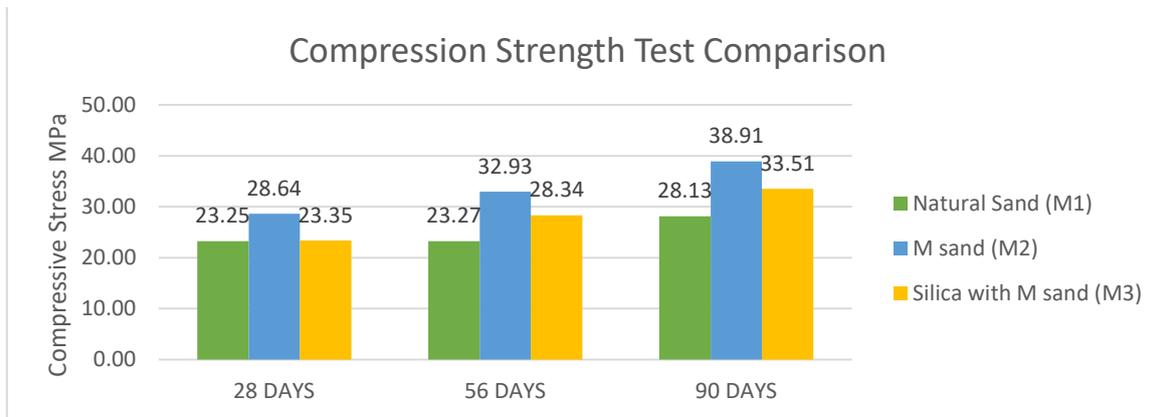


Graph 01. Comparison Of Physical Properties of Aggregate Graph 02. Comparison Of Mechanical Properties of Coarse Aggregate

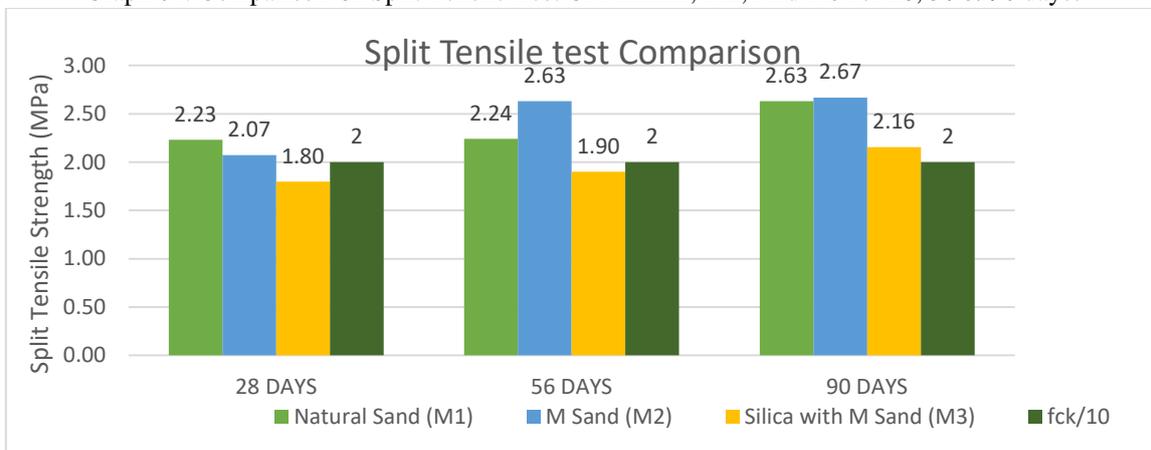


The workability of fresh concrete produced using natural sand and natural aggregate was 100mm, while that of crushed sand and natural aggregate was 90mm. The decrease in workability in concrete containing crushed sand was due to the presence of more angular particles. The natural sand contains spherical particles which enhances the ability of concrete to flow. Mix M3 containing crushed sand and 10% Silica fume, which has a workability of 100mm

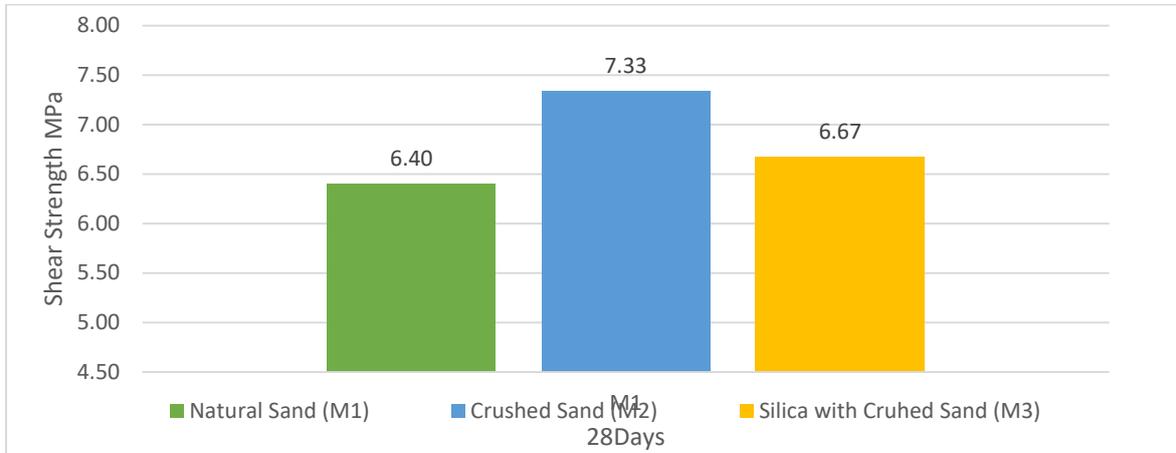
Graph03 Comparison Of Compression Test Of Mix M1, M2, And M3 for 28, 56 & 90 days.



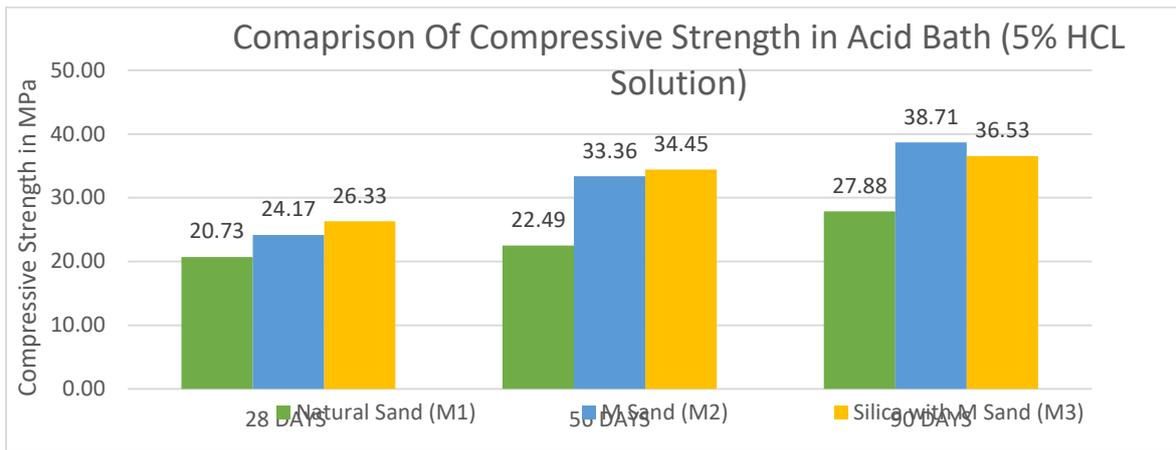
Graph 04. Comparison Of Split Tensile Test Of Mix M1, M2, And M3 for 28, 56 & 90 days.



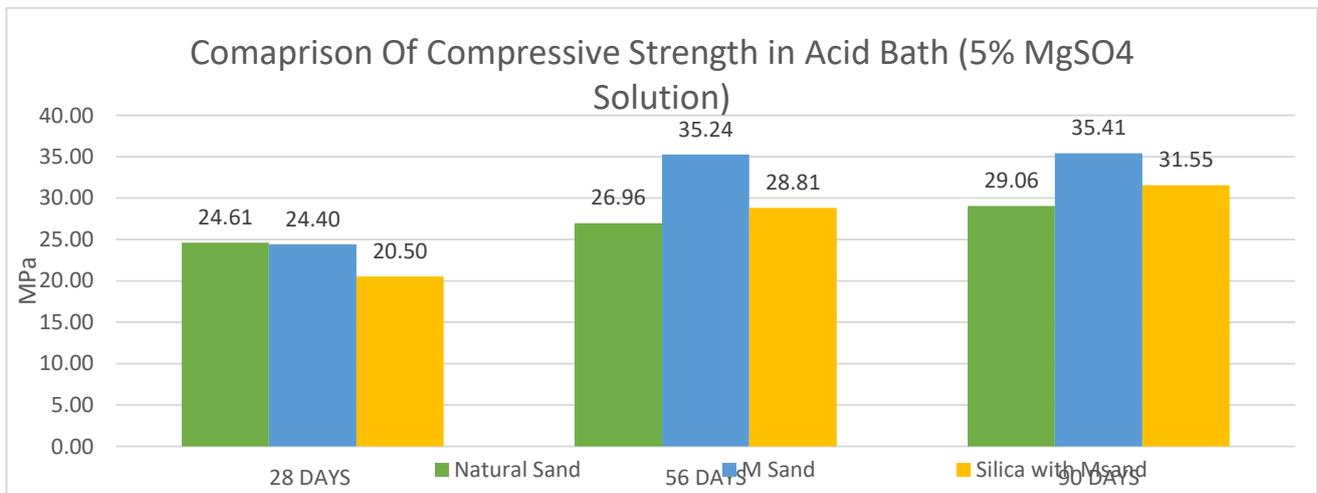
Graph 06. Comparison of Shear Strength of concrete



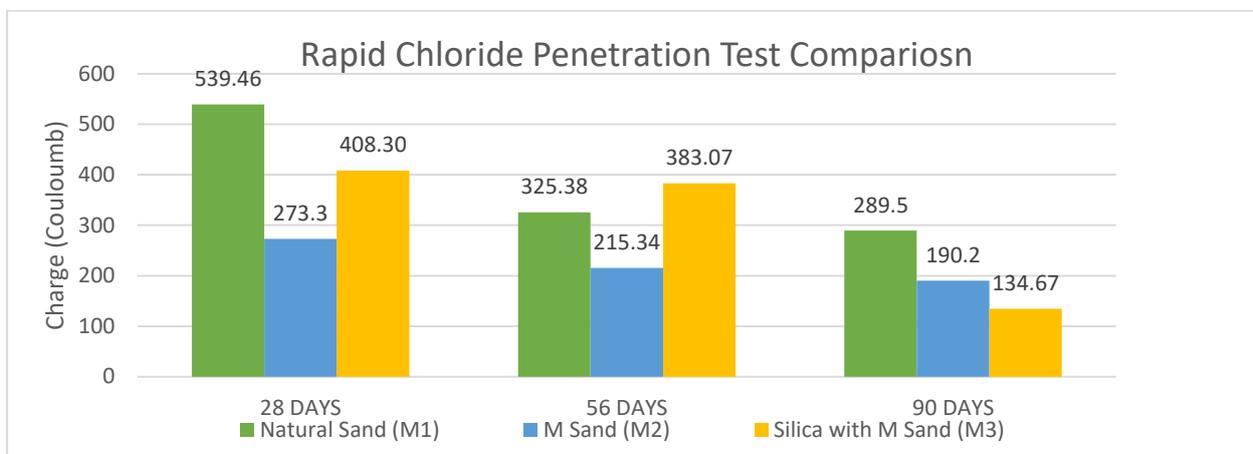
Graph 07. Comparison Of Acid Bath Test (HCL Soln.) Of Mix M1, M2, And M3 for 28, 56 & 90 days.



Graph 11. Comparison Of Acid Bath Test (MgSO₄ Soln.) Of Mix M1, M2, And M3 for 28, 56 & 90 days



Graph 15. Comparison Of Rapid Chloride Penetration Test Of Mix M1, M2, And M3 for 28, 56 & 90 days



Based upon the results obtained after experimental investigation of mix M1 (natural sand + normal aggregates), M2 (crushed sand + normal aggregates) and M3 (crushed sand + 10% Silica Fume) it was concluded that:

- At 28 days, mix M3 shows 0.43% more compressive strength than mix M1, while mix M2 shows 22.65% more strength than that of mix M3. At 56 days, mix M3 shows 21.78% more compressive strength than mix M1, while mix M2 shows 16.19% more strength than that of mix M3. For 90 days, mix M3 shows 19.12% more compressive strength than mix M1, while mix M2 shows 16.11% more strength than that of mix M3. This shows that the use of crushed sand in concrete has proved to be effective in its compressive strength development. This shows that partial replacement of 10% silica fume in cement gives better strength than natural sand.
- The split tensile strength of mix M3 is less than 2 N/mm² for 28 and 56 days. Also mix M3 had less split tensile strength than mix M2 and M3 by 23.88%, 15% respectively for 28 days and 17.9%, 38.42% respectively for 56 days. Hence it can be concluded that the use of Silica fume in concrete does not give sufficient split tensile strength. However, mix M3 value has been increased by 7.4% in 90 days, from this it is concluded that the value of split tensile increases over a period.
- When cubes were immersed in 5% HCl solution, it is seen that the compressive strength increased by 27.01%, 53.17% at 28 & 56 days respectively as compared to mix M1 and 8.9%, 3.26% at 28 & 56 days as compared to M2 respectively.
- At 28, 56, and 90 days mix M1 shows 0.69%, 0.81%, and 1.7% decrease weight respectively. While mix M2 showed 0.22%, 0.22% and 0.33% decrease in weight at 28, 56, and 90 days respectively. Similarly mix M3 showed 0.67%, 0.55% and 1.14% decrease in weight at 28, 56, and 90 days respectively.
- when cubes were immersed in 5% MgSO₄ solution, the 28 days compressive strength of mix M1 and M2 is almost same and more than 20% & 19.02% respectively as that of mix M3. But at 56 & 90 day mix M2 have 30.71%, 22.31% & 21.85%, 12.23% respectively as that of mix M1 and M3.
- At 28, 56, and 90 days mix M1 shows 0.3%, 0.3%, and 0.34% decrease weight respectively. While mix M2 showed 0%, 0.1% and 0.1% decrease in weight at 28, 56, and 90 days respectively. Similarly mix M3 showed 1%, 0.22% and 0.9% decrease in weight at 28, 56, and 90 days respectively.
- In Rapid Chloride Penetration Test (RCPT) all the mixtures M1, M2 & M3 have chloride ion penetration in between 100-1000 coulomb and hence it is very low according to ASTM 1202 guidelines. Also, in mix M3 there was decrease in charge value by 6.18% between 28 to 56 days and 64.84% between 56 to 90 days.
- The Modulus of elasticity after 28 days for manufactured sand was 25288.55 N/mm² and that of manufactured sand with 10% silica fume was 24456.27 N/mm².

IV. CONCLUSION

Finally, it can be concluded that performance of partial replacement of silica fume with crushed sand in concrete mix is better compared to the river sand and crushed Sand where acid attack is prone to structures. Also, in case of flexure, durability, silica fume with crushed sand gives better results. Silica fume with crushed sand can be used in marine environment or where sea water wetting takes place.

Silica fume with crushed sand at M20 grade concrete does not give enough compressive strength as compared to the concrete of same grade casted using only crushed Sand. In split tensile test, strength of silica fume was gained at 90day above 2 N/mm²

Future scope is use of silica fume for different grades of concrete can be done and tested for compression strength. Also, test for durability can be done for more duration that is 120, 180 and 365 days.

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