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PERFORMANCE OF HIGH STRENGTH CONCRETE – PARTIALLY REPLACING FINE AGGREGATE WITH MANUFACTURED SAND

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ABSTRACT - Concrete is a versatile engineering composite material made with cement, sand, fine & coarse aggregates and admixtures. Due to the day by day innovations and developments in construction field, the global consumption of natural aggregates is very high. As the infrastructural growth is at its peak in developing countries, large quantum of concrete is being utilized to cater the infrastructural requirement. Concrete plays a vital role in the construction industry. In the International forum about 50 years ago the High strength concrete label was applied to concrete having strength above 40 Mpa. More recently the threshold rose to 50 Mpa to 60 Mpa. In the world scenario however in the last 25 years concrete of very high strength more than 60 Mpa, entered the field of construction. High strength concretes differ from medium strength concretes in many ways. The cement paste matrix in high-strength concretes is dense owing to the absence of large capillary voids and a relative strong aggregate-cement paste interfacial zone, which has a much lower tendency for micro-cracking. High-strength concretes contain relatively high binder material content, a super plasticizer, and very low water content. They are capable of achieving a discontinuous capillary pore structure and low permeability within a few days of hydration of cement.

Extensive use of concrete leads to the scarcity of natural aggregates. Concrete industry is constantly looking for Alternative Materials. Because of this reason the Alternative Materials from the manufacturing Industries came into the picture to decrease the scarcity of natural basic aggregate. The aim is to study the suitability of Alternative Industrial Material such as Manufactured Sand in the concrete mix. In this project work, different mixes are cast into cubes, cylinders, & beams; fine aggregate is being partially replaced by Manufactured Sand. The project work is carried out by using M40 grade concrete with partial replacement of, 20%, 40% & 60% fine aggregates by Manufactured Sand and is carried out to determine the optimum percentage of replacement at which maximum compressive strength, split tensile strength, & flexural strength are achieved .There are several solutions for Alternative Industrial Materials, both at an experimental phase and in practical applications. In the last decade, construction industry has been conducting various researches on the utilization of Alternative Industrial Materials in concrete in order to reduce the utilization of natural resources. The study concerns mainly on the possible use of Alternative Industrial Materials, Manufactured Sand in construction industry, which would reduce both environmental impacts and the production cost. Manufactured sand is defined as a purpose made crushed fine aggregate produced from suitable source materials. Manufactured sand has been produced by variety of crushing equipments including cone crushers, impact crushers; roll crushers, road rollers etc. The raw material for M sand production is the parent mass of rock. It is based on the parent rock that the chemical, mineral properties, texture, composition of M sand would change.

INTRODUCTION

1.0 CONCRETE

Concrete is one of the commonly used construction material in the industry. Concrete is a composite material composed of coarse and fine aggregate bonded together with fluid cement which hardens over time. Most concretes used are lime-based concretes such as Portland cement concrete or concretes made with other hydraulic cements. In Portland cement concrete (and other hydraulic cement concretes), when the aggregate is mixed together with the dry cement and water, they form a fluid mass that is easily moulded into shape.

1.1 High Strength Concrete

In the International forum about 50 years ago the High strength concrete label was applied to concrete having strength above 40 Mpa. More recently the threshold rose to 50 Mpa to 60 Mpa. In the world scenario however in the last 25 years concrete of very high strength more than 60 Mpa, entered the field of construction. High strength concretes differ from medium strength concretes in many ways. The cement paste matrix in high-strength concretes is dense owing to the absence of large capillary voids and a relative strong aggregate-cement paste interfacial zone, which has a much lower tendency for micro-cracking. High-strength concretes contain relatively high binder material content, a super plasticizer, and very low water content to achieve the water to binder ratio below 0.30, by weight. They are capable of achieving a discontinuous capillary pore structure and low permeability within a few days of hydration of cement.

High Strength High Performance Concrete (HSHPC)

What was known as high strength concrete in the late 1970s is now referred to as high performance concrete (HPC) because it has been found to be much more than simply stronger. High performance concrete has one or more of the properties like as low shrinkage, low permeability and high modulus of elasticity or high-strength. ACI defines high performance concrete as concrete that meets special performance and uniformity requirements that cannot always be achieved routinely by using only conventional materials and normal mixing, placing and curing practices. The requirements may involve enhancement of placement and compaction without segregation, long term mechanical properties, early age strength, toughness, volume stability or service life in severe environments. As per Indian Standard, the concrete having strength 60 MPa or more are known as high strength concrete.

1.3 Manufactured Sand

Manufactured sand is defined as a purpose made crushed fine aggregate produced from suitable source materials. Manufactured sand has been produced by variety of crushing equipments including cone crushers, impact crushers; roll crushers, road rollers etc. The raw material for M sand production is the parent mass of rock. It is based on the parent rock that the chemical, mineral properties, texture, composition of M sand would change. Concrete has been a leading construction material for over a century: its global production is about 3.8 billion cum roughly 1.5 tones per capita – according to Portland Cement Association data (Portland Cement Association). The high cost of concrete depends on the cost of the constituent materials. The cost of concrete can be reduced through the use of locally available alternative material, to the conventional ones.

1.4 Use of Manufactured Sand in Concrete

Today we are facing with an important consumption and a growing need for aggregates because of the growth in industrial production, this situation has led to a fast decrease of available resources. Therefore, it has become necessary to use the Manufactured Sand particularly in the manufacture of concrete products for construction purposes. The main goal of this study is to demonstrate the possibility of using Manufactured Sand as a substitute rather than natural aggregates in concrete production.

LITERATURE REVIEW

2.1 General

River sand is costly due to transportation, large scale depletion of resources and enforcement regulations. Manufactured Sand can be used as an alternative to the river sand. Cost analysis shows that there is 40% savings if Manufactured Sand is partially replaced with natural river sand. Manufactured Sand is one of the substitute materials for the natural river sand. In recent years there were many attempts have been made to study the properties of Manufactured Sand as a partial replacement for sand in concrete.

2.2 Review of Literature

Syam Prakash. V (2007)

In this study physical and mechanical properties of M Sand and ready mixed concrete prepared using M Sand are presented. Experimental results shows that the quality of M Sand is better than the river sand in many respects, such as cleanliness, grading, strength, angularity, flakiness, elongation etc. Design of RMC and its experimental investigation reveals that the use of M Sand in RMC imparts better properties for RMC in its fresh state and hardened state. Test results on RMC in its fresh and hardened state are also presented. The study concludes that M Sand is a suitable and viable substitute to river sand and could be effectively used in RMC which provides adequate strength and durability for the concrete.

Priyanka A. et al (2012)

The effect of water cement ratio on fresh and hardened properties of concrete with partial replacement of natural sand by manufactured sand was investigated. Concrete mix design of M20 grade was done according to Indian Standard code (IS: 10262). Concrete cube, cylindrical, and beam specimens were tested for evaluation of compressive, split tensile and flexural strength respectively. Workability was measured in terms of slump and compacting factor. The concrete exhibits excellent strength with 60% replacement of natural sand, so it can be used in concrete as viable alternative to natural sand.

Adams Joe. M et al (2013)

"Experimental Investigation on The Effect of M-Sand in High Performance Concrete" AJER, e-ISSN: 2320-0847 p-ISSN: 2320-0936 Volume-02, Issue-12, pp-46-51 www.ajer.org

The purpose of this research is to experimentally investigate the effect of M-Sand in structural concrete by replacing river sand and develop a high performance concrete. It is proposed to determine and compare the differences in properties of concrete containing river sand and M-sand. The investigations were carried out using several tests which include workability test, compressive test, tensile test, and flexural test.

From the results it is concluded that the M-Sand can be used as a replacement for fine aggregate. It is found that 50% replacement of fine aggregate by M-Sand give maximum result in strength and durability aspects than the conventional concrete. The results proved that the replacement of 50% of fine aggregate by M-Sand induced higher compressive strength, higher split tensile strength, higher flexural strength.

Senthil kumar. V. et al (2013)

"Optimization of fully replacement of natural sand by m-sand In high performance concrete with nanosilica" IJETAE, Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 11, November 2013).

This paper presents the optimization of fully replacement of manufactured sand by natural sand with Nano silica in high performance concrete. The ordinary Portland cement is partially replaced with nanosilica by 0.75% and natural sand is fully replaced with manufactured sand. The studies reveal that the increase in percentage of partial replacement of nano silica increased the compressive, tensile and flexural strength of concrete.

Prakash. P. et al (2013)

"Strength of Concrete by Partially Replacing the Fine aggregate using M-Sand" (SJET) ISSN 2321-435X Sch. J. Eng. Tech., 2013; 1(4):238-246

In this present experimental investigation M25 concrete is used as control mix with M-sand and super plasticizer and glass fiber in various percentages. Strength of modified concrete is compared with normal concrete. The results show that the significant improvement in the strength and workability of modified concrete. M Sand is satisfying the requirements of fine aggregate such as strength, gradation, shape, Angularity etc. The dwindling sources of natural sand and its high cost could encourage the adoption of M-sand by 50% replacement of natural sand.

Praveen Kumar. K. et al (2015)

"Strength and Workability of Cement Mortar with Manufactured Sand", IJRET, eISSN: 2319-1163 | pISSN: 2321-7308; Volume: 04 Special Issue: 01, NCRTCE-2014 | Feb-2015, Available @ http://www.ijret.org 186.

This research presents a study on replacement of natural sand in cement mortar by M-sand at different percentages. Strength and workability characteristics of 1:6 cement mortar using natural sand and M-sand as fine aggregate at various replacement levels were evaluated and compared. The workability of the cement mortar increases with the increase in M-sand content up to certain level, whereas the strength increases with the increase of manufactured sand. Hence M-sand can be recommended for the replacement of natural river sand in cement mortar.

Prince Arul raj .G. et al (2015)

"Experimental Investigation on High Performance Concrete with Partial Replacements of Fine Aggregate by M-Sand and Cement by Fly Ash, IJETS, ISSN (P): 2349-3968, ISSN (O): 2349-3976, Volume 2 Issue 2, February 2015In this project, investigations were carried out on strength properties such as compressive strength, split tensile strength and flexural strength of M75 grade of HPC mixes with different replacement levels. The HPC mix, grade M75 concrete is designed as per ACI 211.4R-08. Mechanical characteristics like Compressive strength, Split-tensile strength, Flexural strength were examined. The result of these investigations demonstrates the strength characteristics of M-Sand and the properties of fly ash based concrete mixes. Based on the results obtained, the replacement of 50% M- Sand and 20% fly ash with 1.2% of super plasticizer with superior characteristics was arrived.

Saravanan. S.S. et al (2015)

This study presents the performance of compressive strength of M40 Grade artificial sand concrete with partial replacement of river sand to manufactured/Artificial sand. Investigation carried out by varying 0 to 100% replacement of natural sand with manufactured sand in M40 mix. The compressive strength was determined at 7, 14 and 28 days. M 40 Grade concrete using complete manufactured sand yielded an excesses strength of 7.65%, 7.76% and 2.71% compared to conventional concrete for 7 days, 14 days and 28 days respectively, with a reduction of 25-37% in slump. To improve the workability 0.5% of Cera-Chem plasticizer as admixture is recommended. Hence M40 Grade concrete with manufactured sand was found to increase the compressive strength of concrete on all ages when compared to conventional concrete with river sand.

Manjunatha .M. et al (2016)

"Durability Studies on Concrete by Replacing Natural Sand with M-Sand – A Review", www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 6, Issue 3 According to these persons, various researchers have conducted research work to study only the mechanical properties of concrete with M-sand. The durability of concrete is the ability to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Need of hour is to focus more on durability properties of concrete with M-sand for severe exposure conditions to study the behavior and residual strength properties.

By various durability tests, they came to know that the penetration of water into concrete decreases by increasing proportions of M-sand in concrete.

Much research work is necessary to study the durability properties of concrete with M-sand and to investigate the performance of M-sand when the concrete subjected to severe environmental exposure condition.

Boopathi.Y et al (2016)

"Study on M-sand as a partial replacement of fine aggregate in concrete", IJARTET Vol. 3, Special Issue 2. Page 746 – 749. In this study, natural river sand is replaced by manufactured sand by various proportions such as 0%, 20%, 40%, 60% and 80%. For these various replacement percentages, a suitable proportion is selected for a particular grade of concrete to get optimum strength. Hardened concrete tests such as Compressive strength test and Split tensile strength test were performed. The test results showed that there is a gradual increase in strength when using manufactured sand up to 60%.

Krishna Rao. S. et al (2016)

"Experimental Studies in Ultrasonic Pulse Velocity of Roller Compacted Concrete containing GGBS and M. - Sand" ARPN JEAS, www.arpnjournals.com VOL. 11, NO. 3, FEBRUARY 2016 SSN 1819-6608

This study presents the experimental investigation results of Ultrasonic Pulse Velocity (UPV) testing conducted on Roller Compacted Concrete (RCC) containing Ground Granulated Blast furnace Slag (GGBS) as mineral admixture and manufactured sand (M-sand) as partial replacement of fine aggregate (50%). The UPV was determined at the age of 24 hours, 3 days, 7 days, 14 days, 28 days and 90 days for seven RCC mixtures using cube specimens of plain and GGBS Roller Compacted Concrete (GRCC). The amount of OPC replaced by GGBS was varying from 0% to 60%. The UPV of GRCC was found to be lower for all mixtures at 24 hours in comparison with control mix concrete. But at 3, 7,28and 90 days the Ultrasonic pulse velocities were significantly improved for all the mixes. Relationships between compressive strength of GRCC and UPV and Dynamic Elastic Modulus were proposed. A new model is proposed to determine the Dynamic Elastic Modulus of GRCC as a function of age of concrete and percent replacement of GGBS by Ultrasonic Method. The quality of Roller Compacted Concrete with GGBS at early ages is found to be good for all concrete mixtures, but at later ages i.e. from 3 days to 90 days, quality of RCC has been improved from good to excellent.

PROPERTIES OF THE MATERIALS

3.0Properties of the Materials

3.1 Properties of Cement

All the properties of cement were determined by referring IS-12269-1987. The specific gravity of cement is 3.15.

Initial Setting Time of Cement

The initial setting time of cement was found using Vicats apparatus. The initial setting time of the cement used was found out to be 1 hour & 20 minutes.

Final Setting Time of Cement

Final setting time of cement was found using Vicats apparatus. Initial setting time of the cement used was found out to be 430 minutes. Standard consistency of cement was 34%.

3.2 Properties of Fine Aggregate

Fine aggregate is defined as a material that will pass 4.75 mm sieve and will be for the most part, be retained on 75 micron sieve. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.

The natural river sand has a specific gravity of 2.65, bulk density of 1793 Kg/m3, fineness modulus of 3.177, Void ratio 0.55, Density 1.63, Uniformity coefficient of 3.33, coefficient of curvature of 0.948, water absorption of 1.0 %, & Round Particle Shape, & nil surface moisture.

3.3 Properties of Coarse Aggregate

The natural Coarse Aggregate has a specific gravity of 2.68, bulk density of 1603 Kg/m3, fineness modulus of

2.65, Crushing value of 15.9%, Impact value of 6.67%, Water absorption of 0.5% Uniformity coefficient of 1.479 & coefficient of curvature of 1.201, & flaky Particle Shape, & nil surface moisture.

3.4 Properties of Manufactured Sand -- Physical Properties of Manufactured Sand

The Manufactured Sand has an appearance of light brown solid, odorless, negligible solubility of < 0.1%. Manufactured Sand has a specific gravity of 2.76, and fineness modulus of 6.598 & nil surface moisture, Water absorption of 0.5%, Impact value of 24.68, Crushing value 36.8, Abrasion value 12.36, P^H value 8 – 9, melting point of 845° C. etc.

Table No. 1. Chemical composition of Manufactured Sand

Constituent	Manufactured sand (%)	Natural sand	Test method
SiO_2	62.48	80.78	
AL_2O_3	18.72	10.52	IS : 4032-1968
FE_2O_3	6.54	1.75	
CaO	4.83	3.21	
MgO	2.56	0.77	
NNa_2O	Nil	1.37	
K_2O	3.18	1.23	
TiO_2	1.21	Nil	
Loss of ignition	0.48	0.37	

3.5 Properties of Water

Water used for mixing and curing was potable tap water free from injuries, amounts of oil acids, alkyls salts organic matter or other substances that may be harmful to concrete as per clause 5.4 of IS 456-2000. Density of water is 1gm/cc, PH value of portable water used was found to be 7.1 as per 10500:2012. The turbidity of portable water used was found to be 1 NTU as per 10500:2012

3.6 Properties of Admixtures

Super plasticizer is the high range water reducing admixture. The super plasticizer should be constantly or intermittently in contact with water & to achieve high resistance to water ingress. It significantly improving the site mixed and precast concrete without increasing water demand. Minimizes segregation and bleeding and improve pump ability.

CONCRETE MIX DESIGN

4.0 Concrete Mix Design

The process of selecting suitable ingredients of concrete and determining their relative quantities with the objective of producing a concrete of the required strength, durability, and workability as economically as possible, is termed the concrete mix design. Based on the results of tests on individual material such as cement, fine aggregate, coarse aggregate, Manufactured Sand, and water, the quantities required for design mix of M40 grade concrete were calculated based on the procedure given in IS code method in IS: 2009.

The final mix ratio was 1 : 1.4413 : 2.8935 : 0.40, with water cement ratio of 0.40. The measurement of materials was done by weight in electronic weighing machine. Water was measured in liters.

Fine Aggregate

4.75 mm down size (zone-2 according to IS: 383 – 1970) was taken Specific Water absorption – 1% Specific gravity value - 2.65 Surface moisture – 0%

Coarse Aggregate

20mm down size coarse aggregates was taken. Specific Surface moisture - nil Specific gravity value – 2.68; Water Absorption –0.5%

Manufactured Sand

Water absorption – 0.5% Specific gravity – 2.6

Percentages of Partial replacement

The percentages of the partial replacement of Manufactured Sand are 20%, 40%, 60% by the weight of the fine aggregates.

4.1 Grade of the Concrete

In this project work, high strength concrete of M 40 grade has been adopted. A high strength concrete of grade 40 MPa has been designed with conventional aggregates.

4.2 Method of Mix design

The mix design is done according to the IS design method

4.3 Water Cement Ratio

The water cement ratio of 0.40 has been adopted.

4.4 Methodology

Percentage of replacement 0% to 60%
Maximum size of aggregates 20 mm
Number of days for compressive strength – 7days, 14 days, 21 days and 28 days
Proportion ratio – 1 : 1.4413 : 2.8935 : 0.40

Concrete Mix Design

The Concrete Mix Design was carried out according to IS: 10262 – 1982 Grade of concrete

Stipulations for Proportioning

Grade designation: M 40
Type of Cement: OPC 53 grade confirming to IS 8112: 2013
Maximum Nominal Size of Aggregate: 20mm
Minimum Cement Content: 400 kg confirming to IS 456:2000
Maximum water cement Ratio: 0.40
Workability: True Slump
Exposure Condition: Moderate
Degree of Supervision: Good
Type of Aggregate: Crushed Angular Aggregate
Maximum Cement Content: 450 kg
Test Data for Aggregate
Cement used: OPC 53 Grade confirming to IS 8112:2013
Brand: Ultra Tech
Specific gravity of Cement: 3.15
Specific Gravity of Coarse Aggregate (20 mm): 2.68
Coarse Aggregate (12.5mm): 2.5
Specific gravity of Fine Aggregate: 2.65
Water Absorption: Coarse Aggregate (20 mm): 0.5%.
Coarse Aggregate (12.5mm): 0.5%.
Fine Aggregate: 1.0%

4.5 Mix Design Calculations

Standard deviation (s) = 5% (for 20 mm size coarse aggregates.)
Target strength Fck = fck + 1.65 s = 40 + (1.65 * 5) = 48.25 N/mm2.
Water cement ratio = 0.40. From table - 2 of IS 10262: 2009 maximum water content = 186 kg for 20 mm grade size aggregates. Estimated water content for 100 mm slump =186 + (6 / 186) x 100 = 197 litre
As super plasticizer is used, the water content has been reduced up to 15%. Hence, the arrived water content, W = 197 x 0.85 = 167.45 litre. W/c = 0.40.

Cement content, c = 167.45 / 0.4 = 418.625 kg/m3.
Cement required per cubic meter of concrete = 418.625 kg.
Absolute volume of concrete in one m3 = 1 - 0.02 = 0.98 m3

4.6 Quantities of the materials

Cement = 418.625 kg/m3.
Fine aggregates = 603.383 kg/m3
Coarse Aggregates =1211.281 kg/m3.
Water = 167.45 kg. W/C =0.40.
Cement : Fine aggregates : Coarse aggregates : water
418.625 : 603.383 : 1211.281 : 167.45
1 : 1.4413 : 2.8935 : 0.40

4.7 Actual Proportion of the Mix

M 40 Grade concrete having mix proportion of
1 : 1.4413 : 2.8935 : 0.40

TESTS ON FRESH CONCRETE

5.0 Tests on Fresh Concrete (Laboratory Tests – 2)

5.1 Workability Test

5.1.1 Slump Cone Test

The concrete slump test is an empirical test that measures the workability of fresh concrete. "True Slump" had been got for the present research project work.

5.1.2 Compaction factor test

Compacting factor of fresh concrete is done to determine the workability of fresh concrete by compacting factor test as per IS: 1199 – 1959. According to this test, the workability may be defined as the amount of applied work required to compact the concrete to its maximum density. Compacting factor = weight of partially compacted concrete / Weight of fully compacted concrete. Compaction factor of the concrete for the present project work is 0.9.

TESTS ON HARDENED CONCRETE

6.0 Tests on Hardened Concrete (Laboratory Tests – 3)

The cast specimens were tested on their respective schedules of testing. Cubes were tested for compression in Compression Testing Machine. Cylinders were tested for Split tension in Compression Testing Machine and Beams were tested for Flexural strength in universal testing machine.

The concrete Cubes, cylinders sand beams for M40 grade concrete with different percentages of replacement with Manufactured Sand for 7 days, 14 days, 21 days and 28 days have been tested for compression strength, split tensile strength and flexural strength.

6.1 Compression Strength Test

The compression test is carried out on cubical specimen. The cube specimen is of size 150 mm × 150 mm × 150 mm. Compression Strength Test is conducted for concrete cubes of 0%, 20%, 40%, & 60% replacement of sand by Manufactured Sand for M 40 grade concrete mixes.

The cube specimen was tested for compressive strength at the end of 7 days, 14 days, 21 days and 28 days of curing. The specimen was tested after the surface gets dried. The load was applied on the smooth sides without shock and increased continuously till the specimen failed. The mean compressive strength is calculated and tabulated.

Fig. No. 9. Compression Strength Test

6.2 Split Tensile Strength Test

Split tensile test is also referred as "Brazilian Test". Placing a cylindrical specimen horizontally between the loading surfaces of a compression-testing machine and the load is applied till the cylinder failed along the vertical diameter. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete.

The concrete cylinders of size 150 mm x 300 mm of M40 grade concrete with different percentages of replacement, 0%, 20%, 40% and 60% with Manufactured Sand have been tested for split tensile strength test after 7 days, 14 days, 21 days and 28 days of curing.

6.3 Flexural Strength Test

The flexural strength of the concrete was determined by using loading frame. The loading is done using hydraulic jack on the beam and the load applied is measured using the proving ring. The span of the beam adopted is 450 mm and central concentrated load was applied.

Flexural strength is the one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 500 mm x 100 mm x 100 mm concrete prisms with a span length at least three times the depth. The flexural strength is expressed as Modulus of Rupture (MR) in (N/mm2) and is determined by standard test methods confirming to IS 516: 1959.

The concrete beams of size 100 mm x 100 mm x 500 mm of M40 grade concrete with different percentages of replacement, 0%, 20%, 40% and 60% with Manufactured Sand have been tested for flexural strength test after 7 days, 14 days, 21 days and 28 days of curing.

TEST RESULTS & TABULATIONS

7.0 Analysis of Test Results

7.1 Test Results of Compression Strength

Mix Combination	7th Day strength	14th Day Strength	21st Day Strength	28th Day Strength
0% M-Sand	3.21	4.42	4.56	4.83
20% M-Sand	3.53	4.81	4.99	5.28
40% M-Sand	4.1	5.44	5.61	5.96
60% M-Sand	4.21	5.63	5.78	6.14

7.2 Test Results of Split Tensile Strength Test

Mix Combination	7th Day strength (Mpa)	14th Day strength (Mpa)	21th Day strength (Mpa)	28th Day strength (Mpa)
0%	32.56	44.48	46.73	48.37
20%	33.88	46.36	48.96	51.58
40%	34.69	47.16	50.25	52.46
60%	35.97	48.01	51.11	53.18

7.3 Test Results of Flexural Strength Test

Mix Combination	28th Day Strength
0% M-Sand	4.86
20% M-Sand	5.4
40% M-Sand	6.1
60% M-Sand	6.4

CONCLUSIONS

1. From the above test results it has been found that natural fine aggregates can be replaced with Manufactured Sand up to 60% individually.

2. It is observed that the compressive strength value is increased up to 60% replacement with Manufactured Sand when compared to that of natural fine aggregate concrete specimen.

3. It is observed that the Split tensile strength values are increasing for all the percentages of replacements of Manufactured Sand when compared to that of natural fine aggregate concrete specimen.

4. It is observed that the Flexural strength values are increasing for all the percentages of replacements of Manufactured Sand when compared to that of natural fine aggregate concrete specimen.

5. Manufactured sand is free from chemical impurities such as sulphates and chlorides which improves the properties of concrete like strength and durability.

6. Manufactured sand contains no organic impurities; hence it gives increased strength of Concrete with same cement content. And does not harm the environment in any way. No wastage since Sand is already sieved in the required size (below 4.75 mm).

7. Manufactured sand is economical as compared to natural river sand.

8. M - Sand is satisfying the requirements of fine aggregate such as strength, gradation, shape, Angularity etc.

9. M - Sand can be produced to fall in the desired Zone according to our requirement. This can definitely ensure the quality of concrete.

10. Compressive strength obtained for conventional concrete cubes and concrete cast using M - Sand indicates that the strength properties of M Sand are adequate.

11. The dwindling sources of natural sand and its high cost could encourage the adoption of M - Sand by 60% replacement of natural sand.

12. Upon cost analysis result Manufactured Sand concrete proves more economical than concrete made with conventional fine aggregate.

13. Utilization of Manufactured Sand in concrete reduces use of natural fine aggregate which reduces mining of natural fine aggregate, & which results in reduced environmental contamination.

14. Manufactured Sand reduces depletion of conventional fine aggregates from environment and also enables to produce Green Concrete.

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