A Comparative Study on Enhancing the Strength of the Concrete by using Rice Husk Ash and Precipitated Silica

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Abstract - *Concrete is defined as a composite mixture of cement, fine aggregate, coarse aggregate in definite proportion with water. The workability for the replacement and strength development with age depend upon the properties of the constituent material and their combined action. In this project, the materials like Rice Husk Ash (RHA) and Precipitated Silica (PS) is used as a partial replacement of cement at various percentages like 5%, 10%, 15% and 20%. The experimental investigations were carried out for M25 grade concrete with different percentage replacement and comparative analysis of both RHA and Precipitated Silica were made. While using RHA to the cement concrete at various percentage, 5% replacement of cement with Rice Husk Ash gives greater compressive strength and also the split tensile strength when compared to other percentages, likewise while using Precipitated Silica, 10% of replacement gives good target compressive strength, Split tensile and Flexural strength of the concrete.*

Keywords - ***Cement, Natural Sand (N-Sand), Manufactured Sand (M-Sand), Course Aggregate, Rice Husk Ash (RHA), Precipitated Silica (PS), Compressive Strength, Split Tensile Strength and Flexural Strength.***

I. INTRODUCTION

Concrete is the material of present as well as future. The wide use of it in structures, from buildings to factories, from bridges to airports, makes it one of the most investigated materials of the 21st century. Due to the rapid population explosion and the technology boom to cater to these needs, there is an urgent need to improve the strength and durability of concrete. Out of the various materials used in the production of concrete, cement plays a major role due its size and adhesive property. So, to produce concrete with improved properties, the mechanism of cement hydration has to be studied properly and better substitutes to it have to be suggested. Different materials known as supplementary cementitious materials are added to concrete to improve its properties. Some of these are fly ash, blast furnace slag, rice husk ash, silica fumes and even bacteria. Of the various technologies in use, technology looks to be a promising approach in improving the properties of concrete.

II. STUDY ON MATERIALS

A. Cement

Cement can be described as a crystalline compound of calcium silicates and other calcium compounds having hydraulic properties. The four major compounds that constitute cement are Tricalcium silicate, abbreviated as C3S, Dicalcium silicate (C2S), Tricalcium aluminate (C3A) and Tetracalcium aluminoferrite (C4AF). Where C stands for CaO, S stands for SiO_2, A stands for Al_2O_3 and F for Fe_2O_3. Tricalcium silicate and Dicalcium silicate are the major contributors to the strength of cement, together constituting about 70 % of cement.

Dry or anhydrous cement does not have adhesive property and hence cannot bind the raw materials together to form concrete. When mixed with water, chemical reaction takes place and is referred to as 'Hydration of Cement'. The products of this exothermic reaction are C-S-H gel and $Ca(OH)_2$. Calcium hydroxide has lower surface area and hence does not contribute much to the strength of concrete. On hydration of cement aluminates a product is formed known as Ettringite, which has needle like morphology and contributes to some early strength of concrete. C-S-H gel refers to Calcium Silicate Hydrates, making up about 60 % of the volume of solids in a completely hydrated cement paste. It has a structure of short fibers which vary from crystalline to amorphous form. Owing to its gelatinous structure it can bound various inert materials by virtue of Van der Waals forces. It is the primary strength giving phase in cement concrete.

B. Rice Husk Ash (RHA)

Rice Husk Ash (RHA) is used as a partial replacement for Ordinary Portland Cement (OPC) in concrete. OPC was replaced with RHA by weight at 5%, 10%, 15% and 20%. 0% replacement served as the control concrete. Compressive Strength test was carried out on hardened 100 mm concrete cubes after 7, 14, 21 & 28 days of curing samples in water. The results revealed that the Compacting factor decreased as the percentage replacement of OPC with RHA increased. The compressive strength of the hardened concrete also decreased with increasing OPC replacement with RHA. It is recommended that further studies be carried out to gather more facts about the suitability of partial replacement of OPC with RHA in concrete.

C. Precipitated Silica (PS)

Precipitated silica (PS) is also used as partial replacement for Ordinary Portland Cement (OPC) in concrete. OPC was replaced with Precipitated silica by at 5%, 10%, 15% and 20%. 0% replacement served as the control concrete. Compressive Strength test was carried out on hardened 100 mm concrete cubes after at days of curing samples in water. The results revealed that the Compacting factor decreased as the percentage replacement of OPC with Precipitated silica increased. It is recommended that further studies be carried out to gather more facts about the suitability of partial replacement of OPC with Precipitated silica in concrete.

D. M-Sand

Currently India has taken a major initiative on developing the infrastructures such as express highways, power projects and industrial structures etc., to meet the requirements of globalization, in the construction of building and other structures concrete plays the rightful role and a large quantum of concrete is being utilized. River sand (Natural Sand), which is one the constituents used in the production of conventional concrete, is not available now a days and it has become highly expensive and also scarce. In the backup of such a bleak atmosphere, there is large demand for alternative materials from waste. The utilization of Quarry dust which can be called as Manufactured sand (M-Sand) has been accepted as a building material in the industrially advanced countries of the west for the past three decades. As a result of sustained research and developmental works undertaken with respect to increasing application of this industrial waste, the level of utilization of Quarry Dust in the industrialized nations like Australia, France, Germany and UK has been reached more than 70% of its total production. The use of manufactured sand in India has not been much, when compared to some advanced countries.

E. Motivation of the Study

The increased use of cement is essential in attaining a higher compressive strength. But, cement is a major source of air pollution like dust and CO_2 greenhouse gases, reregister for global warming and climate changing. The use of materials by replacement of a proportion of cement can lead to a rise in the compressive strength of the concrete as well as a check to pollution.

Since the use of a proportion of RHA and Precipitated Silica can affect the properties of concrete largely, a proper study of its microstructure is essential in understanding the reactions and the effect of these materials. The existing papers show the use of admixtures in concrete mix. In the present study, no admixture has been used in order to prevent the effect of any foreign material on the strength of the concrete. This study is an attempt to explain the impact of RHA and Precipitated silica on the compressive strength of concrete by explaining its microstructure.

III. COLLECTION OF SUPPLEMENTARY MATERIALS

A. Rice Husk Ash

The Rice husk ash is obtained from burning protecting outer cover of rice husk ash. It is the control of non-crystalline silicon dioxide with high specific surface area and high pozzolanic reactivity. The Rice husk ash is found to be a natural material, by-product or industrial wastes and the chemical properties is so far closer to micro silica, silica fumes. The rice husk ash obtained was used in the concrete to caste test cubes. Further, researchers are continuing to improve the durability and sustainability of concrete and have realized significant increment in mechanical properties of cementitious materials by incorporating RHA. The Rice Husk Ash as shown in Fig. 1 was purchased from a rice mill of Kilkodungalore village, Vandavasi Taluk, Tiruvannamalai District and it was used in concrete to caste test cubes.

B. Precipitated Silica

Precipitated silica, a form of synthetic amorphous silicon dioxide, is derived from quartz sand, a crystalline form of silicon dioxide. The physical properties of precipitated silica can be manipulated during the manufacturing process to deliver products with a wide range of performance-enhancing features engineered for many different end-use applications. The precipitated silica as shown in Fig. 2 was purchased from Chennai and it is used in concrete to caste test cubes. Further, researchers are continuing to improve the durability and sustainability of concrete and have realized significant increment in mechanical properties of cementitious materials by incorporating Precipitated silica.

Fig. 1 Rice Husk Ash (RHA)

Fig. 2 Precipitated Silica (PS)

IV. MATERIAL PROPERTIES

The Materials used for preparing concrete are Cement, Natural Sand (N-Sand), Manufactured Sand (M-Sand), Coarse Aggregate, Rice Husk Ash (RHA) & Precipitated Silica (PS). The Physical Properties of the materials were given in the following Table I to V.

TABLE I

TEST RESULTS FOR CEMENT

Sl. No.	Physical Properties of Cement	Result	Requirements as per IS:8112-1989
1	Initial Setting Time	32 minutes	30 minutes Minimum
2	Final Setting Time	8 hours 30 minutes	10 hours Maximum
3	Specific Gravity	3.12	3.00 to 3.15
4	Normal Consistency	30 %	27 to 33 %

TABLE II

TEST RESULTS FOR NATURAL SAND

Sl. No.	Physical Properties of Sand	Result
1	Fineness Modulus	3.34
2	Specific Gravity	1.96
3	Density	1.76 g/cc
4	Percentage of Water Absorption	1.38 %

TABLE III

TEST RESULTS FOR MANUFACTURED SAND

Sl. No.	Physical Properties of Sand	Result
1	Fineness Modulus	2.24
2	Specific Gravity	1.93
3	Density	1.58 g/cc
4	Percentage of Water Absorption	1.40 %

TABLE IV

TEST RESULTS FOR COARSE AGGREGATE

Sl. No.	Physical Properties of Coarse Aggregate	Result
1	Type	Crushed
2	Maximum Size	20 mm
3	Specific Gravity	2.67
4	Fineness Modulus	0.994
5	Water Absorption	0.81 %

TABLE V

TEST RESULTS FOR RHA & PRECIPITATED SILICA

Sl. No.	Physical Properties	Result
1	Loss on Ignition (LoI) for RHA	3.2 %
2	Moisture Content for Precipitated Silica	4.5 %

V. MIX PROPORTION

The Mix ratio as shown in Table VI has been designed based on **Indian Standard (IS)** recommended guidelines
IS 10262-2009.

TABLE VI

MIX RATIO FOR M 25 GRADE CONCRETE

Cement	Fine Aggregate	Coarse Aggregate	Water
465 kg/m³	630 kg/m³	1170 kg/m³	186 lit/m³
1	1.35	2.52	0.40

A mix proportion of **1: 1.35: 2.52** by weight of Cement, Fine Aggregate and Coarse Aggregate with supplementary materials like RHA and Precipitated Silica with a Water Cement ratio of **0.40** and 50% of fine aggregate (N-Sand) is replaced with M-Sand for casting all the test specimens.

VI. TEST PROCEDURES

A. Compressive strength Test for Cubes

According to Indian Standard specifications (IS: 516-1959), the compression tests on cubes as shown in Fig. 3 were conducted. Compressive strength of concrete is defined as the load, which causes the failure of a standard specimen divided by the area of cross section in uniaxial compression under a given rate of loading. The test of compressive strength should be made on 100 mm size cubes. Place the cube in the compression testing machine. When the load is applied gradually, the piston is lifted up along with the lower plate and thus the specimen application of the load should be 300 KN per minute and can be controlled by load rate control knob. Ultimate load is noted for each specimen.

The compressive strength of the specimen was calculated by using the formula.

$$F = P/A$$

Where,

F = Compressive stress in N/mm², P = Load at which specimen fails in N, A = Area over which the load is applied in mm²

Fig. 3 Compressive Strength Test on Cube

B. *Split Tensile strength Test for Cylinders*

A concrete cylinder of size 150 mm diameter x 300 mm height is subjected to the action of the compressive force along two opposite edges, by applying the force in this manner as shown in Fig. 4. The cylinder is subjected to compression near the loaded region and the length of the cylinder is subjected to uniform tensile stress. Direct measurement of tensile strength of concrete is difficult. One of the indirect tension test method is split tension test. The split tensile strength test was carried out on the compression testing machine. The casting and testing of the specimens were done as per IS 516:1959. The cylinders are kept in between the plates of split testing machine and load is given by means of rod. When the load is applied into the specimen it begins to form crack. The point at which the specimen begins to fail is noted.

$$\text{Horizontal tensile stress} = \mathbf{2P/\pi DL}$$

Where,

P = Compressive load on the cylinder in kN, L = Length of the cylinder in mm, D = Diameter of the cylinder in mm

Fig. 4 Split Tensile Strength Test on Cylinder

C. *Flexural strength Test for Prisms*

Flexural strength test was conducted as per recommendations IS: 516 - 1959. In flexural strength test, beams of size 10 ×10 ×50 cm were casted. The beams are kept in between the plates of flexural testing machine and load is given by means of rod as shown in Fig. 5. When the load is applied into the specimen it begins to form crack. The point at which the specimen begins to fail is noted.

$$\text{Flexure strength of prism} = \mathbf{pl/bd^2}$$

Where,

b = measured width in cm of the specimen, d = measured depth in cm if the specimen at the point of failure, l = length in cm of the span on which the specimen was supported and p = maximum load in kg applied to the specimen.

Fig. 5 Flexural Strength Test on Prism

VII. RESULTS & DISCUSSION

The following tables and figures shows the Experimental results of 7, 14 and 28th day Compressive Strength, Split Tensile Strength and Flexural Strength of Concrete Cubes, Cylinders and Prisms respectively.

A. *Compressive strength Test Results for Concrete Cubes*

TABLE VII

COMPRESSIVE STRENGTH OF CONVENTIONAL AND RHA REPLACED CONCRETE CUBES

Sl. No.	% Replacement of RHA	Compressive Strength of Cubes in N/mm^2		
		7^{th} day	14^{th} day	28^{th} day
1	0%	25	30	33
2	**5%**	**30**	**35**	**39**
3	10%	20	25	31
4	15%	19	28	30
5	20%	18	25	29

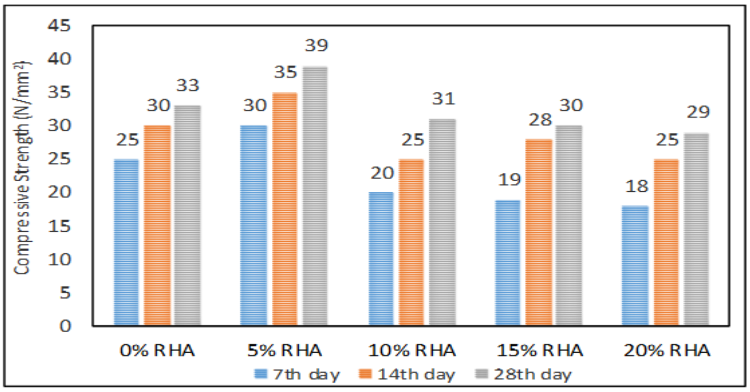

Fig. 6 Compressive Strength of Conventional and RHA Replaced Concrete Cubes

From the Table VII & Fig. 6, it was clearly shown that 5% of Rice Husk Ash (RHA) replaced concrete cubes give good Target Compressive Strength when compared to other percentage replacement.

TABLE VIII

COMPRESSIVE STRENGTH OF CONVENTIONAL AND PRECIPITATED SILICA REPLACED CONCRETE CUBES

Sl. No.	% Replacement of Precipitated Silica	Compressive Strength of Cubes in N/mm^2		
		7th day	14th day	28th day
1	0%	25	30	33
2	5%	35	50	52
3	**10%**	**30**	**42**	**45**
4	15%	28	30	35
5	20%	20	20	25

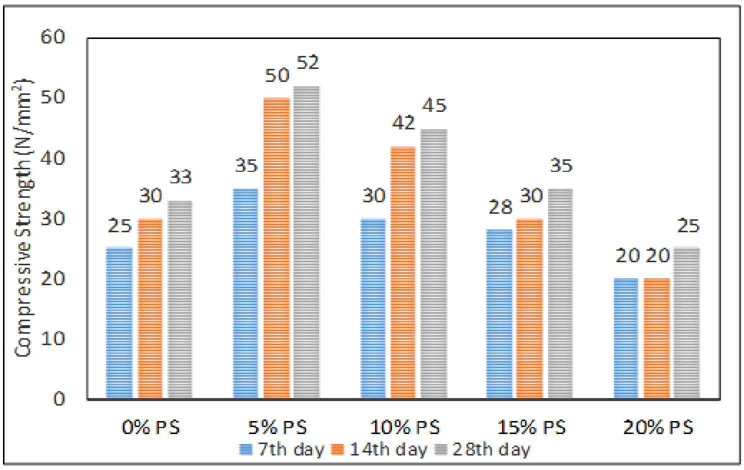

Fig. 7 Compressive Strength of Conventional and Precipitated Silica Replaced Concrete Cubes

From Table VIII & Fig. 7, it was clearly shown that 10% of Precipitated Silica (PS) replaced concrete cubes give good Target Compressive Strength when compared to other percentage replacement.

From the above results, it was clearly understood that 5% of RHA or 10 % of PS can be used as partial replacement of cement in concrete, which gives the 28th day Target compressive strength. While increasing the percentage of RHA and PS, the compressive strength values decreases further. So, as a result the other

Strength characteristics of the concrete were tested only for the above said percentage to check the design values.

B. *Split Tensile strength Test Results for concrete Cylinders*

TABLE IX

SPLIT TENSILE STRENGTH OF CONVENTIONAL AND RHA REPLACED CONCRETE CYLINDERS

Sl. No.	**% Replacement of RHA**	**Split Tensile Strength of Cylinders in N/mm^2**		
		7th day	**14th day**	**28th day**
1	0%	1.95	2.00	2.80
2	**5%**	**1.96**	**2.01**	**2.98**
3	10%	1.45	1.64	2.13

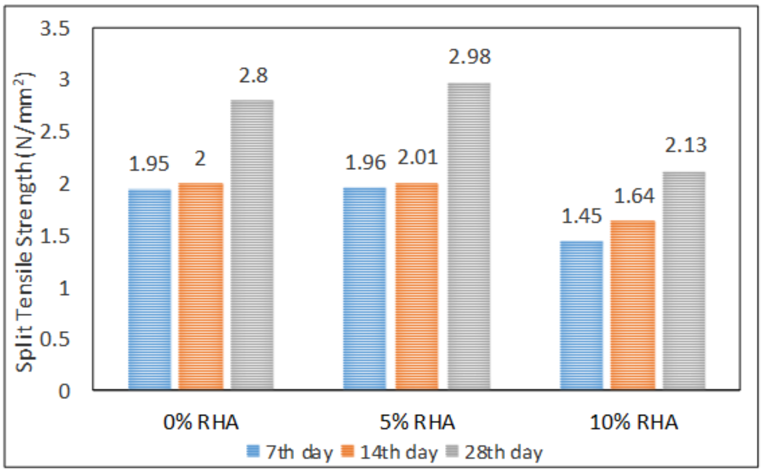

Fig. 8 Split Tensile Strength of Conventional and RHA Replaced Concrete Cylinders

As said earlier, from the Table IX & Fig. 8, 5% of RHA replaced concrete cylinders gives good design Split Tensile Strength. When the percentage increases further, the strength value decreases.

TABLE X

SPLIT TENSILE STRENGTH OF CONVENTIONAL AND PRECIPITATED SILICA REPLACED CONCRETE CYLINDERS

Sl. No.	**% Replacement of Precipitated Silica**	**Split Tensile Strength of Cylinders in N/mm^2**		
		7th day	**14th day**	**28th day**
1	0%	1.95	2.00	2.80
2	5%	1.50	2.20	2.85
3	**10%**	**1.99**	**2.22**	**3.12**

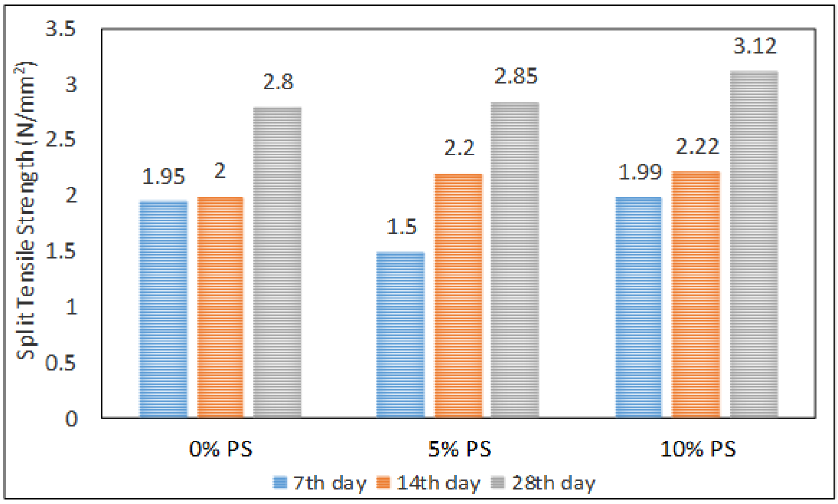

Fig. 9 Split Tensile Strength of Conventional and Precipitated Silica Replaced Concrete Cylinders

As said earlier, from the Table X & Fig. 9, 10% of PS replaced concrete cylinders gives good design Split Tensile Strength.

C. Flexural strength Test results for Concrete Prisms

TABLE XI

FLEXURAL STRENGTH OF CONVENTIONAL AND RHA REPLACED CONCRETE PRISMS

Sl. No.	**% Replacement of RHA**	**Flexural Strength of Prisms in N/mm^2**		
		7th day	**14th day**	**28th day**
1	0%	2.5	3.3	4.5
2	**5%**	**2.9**	**3.5**	**4.9**
3	10%	2.1	2.9	3.1

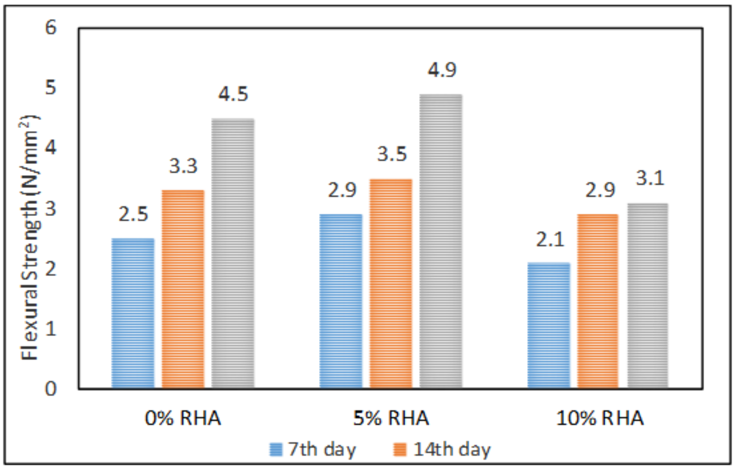

Fig. 10 Flexural Strength of Conventional and RHA Replaced Concrete Prisms

From the Table XI & Fig. 10, it was clearly shown that 5% of Rice Husk Ash (RHA) replaced concrete Prisms gives higher Flexural Strength when compared to other percentage replacement.

TABLE XII

FLEXURAL STRENGTH OF CONVENTIONAL AND PRECIPITATED SILICA REPLACED CONCRETE PRISMS

Sl. No.	**% Replacement of Precipitated Silica**	**Flexural Strength of Prisms in N/mm²**		
		7th day	**14th day**	**28th day**
1	0%	2.5	3.3	4.5
2	5%	4.2	4.5	4.9
3	**10%**	**5.0**	**5.2**	**5.5**

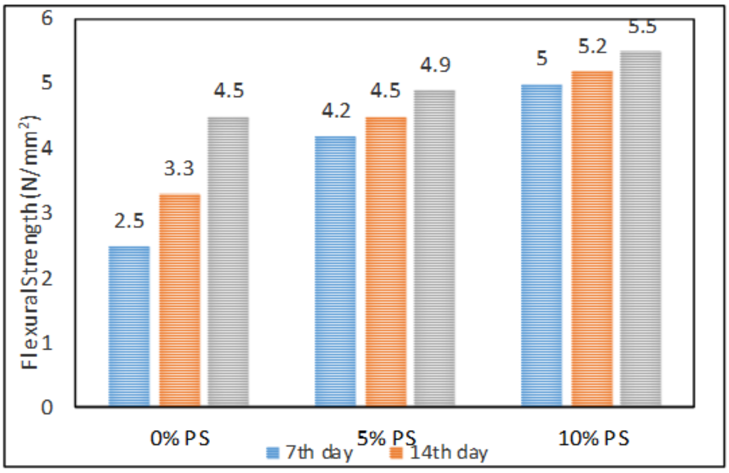

Fig. 11 Flexural Strength of Conventional and Precipitated Silica Replaced Concrete Prisms

From the Table XII & Fig. 11, again 10% of PS replaced concrete Prisms gives higher Flexural Strength when compared to normal conventional concrete.

VIII. CONCLUSION

The Rice husk ash is used in the experimental investigation to increase the strength of concrete. But the rice husk ash having an amount of unburnt carbon this leads to the decrease or reduction of the strength of concrete, so that's why we can use Precipitated silica getting from Rice husk ash. The precipitated silica used to cast the cubes, cylinders and prisms. It will increase the strength of concrete compared to rice husk ash strength and also when we use silica fume in concrete, it will further increases the strength of the concrete. M-Sand is used as a replacement of river sand as fine aggregate. The following results have been obtained from the compression, split tensile and flexural strength test.

- At the water/cement ratio of 0.40, slump flow test results were found to be satisfactory and the workability of concrete is good.
- Addition of Rice husk ash and precipitated silica gives more compressive strength than conventional concrete.
- 5% replacement of cement with RHA gives the highest value of compressive strength when compared to other percentages.
- When the cement is replaced by 10% Precipitated silica, it gives comparatively greater strength than the conventional concrete.
- 50 % Replacement of river sand as fine aggregate by M-Sand will also observed to give better results.
- Thus the overall test results of compressive, split tensile and flexural tests are satisfactory based on the proper mix design of the concrete.

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