An Experimental Investigation of Partial Replacement of Cement and Sand by Silica Fume and Stone Dust in Concrete

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Abstract— The development of concrete technology can decrease the use of natural resources and energy sources and lessen the burden of pollutants on environment. The major benefit of supplementary cementitious material is their ability to return certain amount of cement and still capable to present cementitious property, as a result reducing the cost of using Portland Pozzolana cement. The waste materials which can be used as additional cementitious material like fly ash, silica fume, blast furnace, stone dust etc. From all these waste material the most successful cementitious material is silica fume and stone dust because it improves the strength and durability of concrete to such level that recent design rules also identify for the addition of silica fume and stone dust for design of high strength concrete. Silica fume is also known as micro silica; it is used as an artificial pozzolanic super plasticizer. Stone dust is a waste material obtained from crusher plants. It has potential to be used as partial replacement of natural river sand in concrete. Use of stone dust in concrete not only improves the quality of concrete but also conserve the natural river sand for future generations. Substitution of normal sand by stone dust will serve both solid waste minimization and waste recovery. To reduce the amount of cement and sand in concrete supplementary material are used. Silica fume and stone dust are most popular material used in the concrete to improve its compressive, flexural, split tensile strength and also increase its durability. For this purpose silica fume is partially replaced by 0%, 5%, 7.5%, 10%, 12.5% and 15% by the weight of cement and stone dust is partially replaced by 0%, 10%, 15%, 20%, 25% and 30% by the weight of sand. The design mix proportion of 1:1.55:3.44 at water cement ratio of 0.50 were used for M20 grade of concrete. Various tests were conducted in the research which showed the results of the above percentage for the time period of 3, 7, 14 and 28 days curing as a substitution of cement by silica fume and sand by stone dust on compressive strength, flexural strength, split tensile strength and durability. The results show the maximum increase in strength of concrete occurred when cement and sand were replaced by 10% silica fume and 20% stone dust.

Keywords: Silica Fume, Stone Dust, PPC, Compressive, Flexural, Split Tensile Strength and Durability

I. INTRODUCTION

Concrete is a most commonly used building material which is a mixture of cement, sand, coarse aggregate and water. It is used for construction of buildings, dams, road pavement, tanks, offshore structures, canal lining etc. The compressive strength of hardened concrete is commonly considered to be an index of its extra properties depends upon a lot of factors e.g. worth and amount of cement water and aggregates batching and mixing placing compaction and curing. The cost of concrete prepared by the cost of materials plant and labor and also cost of concrete is related to cost of materials essential to produce a minimum mean strength called characteristic strength that is specific by designer of the structures. This depends on the quality control measures but there is no doubt that quality control add to the cost of concrete. Nowadays engineers and scientists are trying to enhance the strength of concrete by adding the several other economical and waste material as a partial substitute of cement and sand or as a admixture fly ash, silica fume, steel slag, stone dust etc. are the few examples of these types of materials.

These materials are generally by-product from further industries for example silica fume is a by-product resulting from decrease of high purity quartz by coal or coke and wood chips in an electric arc furnace during production of silicon metal or ferrosilicon alloys and Stone dust is a waste material obtained from crusher plants. Now it has widely to be used as partial replacement of natural river sand in concrete. Use of stone dust in concrete not only improves the quality of concrete but also conserve the natural river sand for future generations. Substitution of normal sand by stone dust will serve both solid waste minimization and waste recovery. But now a day's silica fume and stone dust are used in large amount because it enhances the property of concrete. The use of micro silica as a pozzolanic material has enhanced in recent years and now a day's stone dust are used because when mixed in definite proportions it improves the properties of both fresh and hard concrete like durability, permeability, compressive strength, flexural strength and tensile strength etc.

A. Material used:

1) Cement (PPC):

Portland Pozzolana Cement of brand, Wonder Cement is used. The primary raw materials used for this cement manufacture are limestone ($CaCO_2$) and clay (SiO_2, AI_2O_3, and Fe2O3). It is an eco-friendly cement as the material used in the manufacture are made of natural recycled waste and reduces the carbon monoxide emission from the concrete. Pozzolana consists of silica material which makes it cheap and hence reduces the cost of the cement making it economical to use. Specific gravity of cement is 3.15 and fineness of cement is 3% (by sieve analysis).

2) Fine Aggregate (Sand):

The fine aggregate (sand) was passing through 150µ to 4.75 mm sieve are used. The grading zone of fine aggregate was found zone II as per Indian Standard specifications.

Sr. No.	Property	Average
1	Specific Gravity	2.70
2	Fineness Modulus	2.76
3	Water Absorption	2%
4	Surface Texture	Smooth
5	Particle shape	Angular

Table 1.1: Physical Properties of Fine Aggregate

3) Coarse Aggregate:

The coarse aggregates were available at college site from local quarry. Coarse aggregate are the crushed stone is used for making concrete. As per IS-383:1970, the maximum size of coarse aggregate are used 20 mm.

Sr. No.	Property	Average
1	specific gravity	2.95
2	fineness modulus	2.54
3	water absorption	0.5%
4	particles shape	Angular
5	crushing value	17.4
6	impact value	12.50

Table 1.2: Physical Properties of Course Aggregate

4) Silica Fume:

Silica fume used is a product from Nakoda Enterprises Indore (M. P.) Silica fume, also known as micro silica is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm.

Properties	Observed Values
Color	Dark grey
Specific gravity	2.2
Fineness modulus	20000 m^2/kg
Bulk Modulus	240 kg/m^3

Table 1.3: Physical Properties of Silica Fume

Properties	Observed value
SiO_2	90-96%
Al_2O_3	0.6 -3.0%
Fe_2O_3	0.3-0.8%
MgO	0.4-1.5%
CaO	0.1-0.6%
Na_2O	0.3-0.7%
K_2O	0.04-1.0%
C	0.5-1.4%
S	0.1-2.5%
Loss of ignition (C+S)	0.7-2.5%

Table 1.4: Chemical Properties of Silica Fume

5) Stone Dust:

Stone dust is a waste material obtained from crusher plants and was collected from locally available in area. The size of stone dust used is 150μ to 4.75mm.

Sr. No.	Property	Average
1	Specific Gravity	2.92
2	Fineness Modulus	2.67
3	Water Absorption	0.5%
4	Surface Texture	Rough
5	Particle Shape	Angular
6	Colour	Grey

Table 1.5: Physical Properties of Stone Dust

II. METHODOLOGY

Cubes, cylinders and beams are prepared to obtain the compressive strength, split tensile strength and flexural strength respectively. The specimens are casted and cured for 3, 7, 14 and 28 days and cured specimens are tested and the results are obtained.

- The compressive strength was conducted by the cube specimen of size 150 X 150 X 150 mm and the compressive strength was computed by the standard stress formula P/A, where P is the ultimate load in KN and A is the area in m^2.
- The split tensile strength was conducted by the cylinder specimen 150 X 300 mm and computed by using the expression ft = 2P/ πLD, where P is the ultimate load in KN, L is the depth of the cylinder in m and D is the diameter of the cylinder in m.
- The flexural strength was conducted by the beam of size 500 X 150 X 150 mm and computed by using the expression PL / bd^2, where P is the ultimate load in KN, L is the span between the rollers (40cm), b is the breadth of the beam in meter and d is the depth of the beam in meter.
- The durability test had done by using the cube specimen size 150 X 150 X 150 mm and immersed in sulphuric acid for 28 days and after that the compressive strength of these specimens are determine and also noted weight of these specimens. The percentage in loss of compressive strength and weights has found out and compare with conventional concrete cube specimens.

III. RESULTS AND DISCUSSION

Mix Proportions
Cement = 383 kg/m^3
Water = 191.6 lit/m^3
Coarse aggregate = 1317.97 kg/m^3
Fine aggregate = 594.10 kg/m^3
Mix proportion 1: 1.55: 3.44
Water Cement ratio = 0.50
Result of testing materials: From the above methodology the result of the testing material as shown in below:

A. Fresh Concrete:

1) Initial and Final Setting Time Test:

S. No	Setting Time (minutes)		Depth of penetration (mm)
	Initial	Final	
1.	37 minutes	10 hrs.	5 mm

Table 3.1: Initial and Final setting time test

Result:-1. The initial setting time of the cement sample is found to be 37 minutes
2. The final setting time of the cement sample is found to be 10 hrs

2) Consistency Test:

Weight of Cement (gm)	Quantity of Water (gm)	Penetration (mm)	% of Water (P)
400	120	15	0.30
400	132	8	0.33
400	144	6	0.36

Table 3.2: Consistency results of cement

Result: - The consistency of cement is 36%
3.1.3 Slump Cone test: Slump Value (mm) = 60 mm and w/c ratio = 0.50

B. Hardened Concrete:

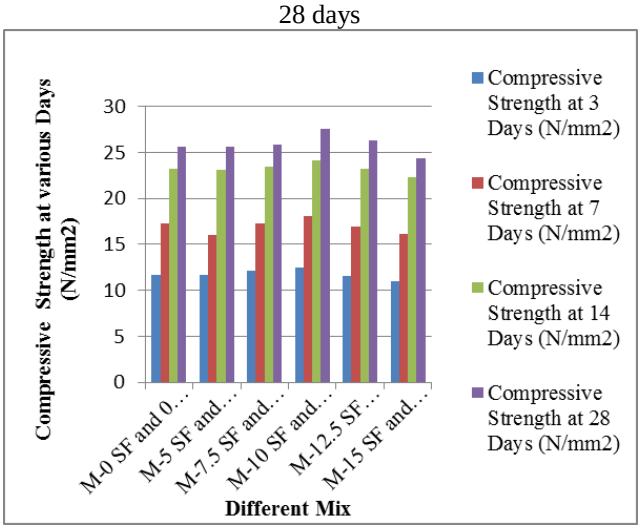
1) Compressive Strength Test Result:

Sr. No.	Composition	Notations
Mix-01	No replacement	M-0 SF and 0 SD
Mix-02	Replacement 5% silica fume and 10% stone dust	M-5 SF and 10 SD
Mix-03	Replacement 7.5% silica fume and 15% stone dust	M-7.5 SF and 15 SD
Mix-04	Replacement 10% silica fume and 20% stone dust	M-10 SF and 20 SD
Mix-05	Replacement 12.5% silica fume and 25% stone dust	M-12.5 SF and 25 SD
Mix-06	Replacement 15% silica fume and 30% stone dust	M-15 SF and 30 SD

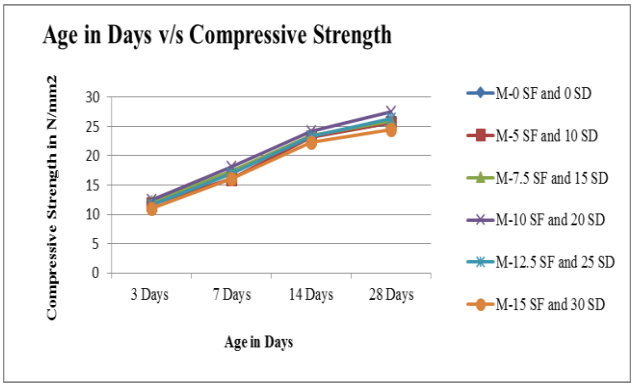
Table 3.3: Composition and Notations

Different Mix	Compressive Strength at 3 Days (N/mm^2)	Compressive Strength at 7 Days (N/mm^2)	Compressive Strength at 14 Days (N/mm^2	Compressive Strength at 28 Days (N/mm^2)
Mix-01	11.70	17.29	23.26	25.7
Mix-02	11.70	16.07	23.11	25.66
Mix-03	12.15	17.33	23.48	25.85
Mix-04	12.51	18.07	24.15	27.55
Mix-05	11.62	16.96	23.26	26.36
Mix-06	10.96	16.15	22.29	24.44

Table 3.4: Compressive Strength in N/mm^2 at 3, 7, 14 and 28 days



Graph 3.1: Compressive Strength in N/mm2 at various age (Days)



Graph 3.2: Variation of 3, 7, 14 and 28 days Compressive Strength with variation of % of SF and SD

a) Discussions:

1) As shown in graph 3.2: The age in days v/s Compressive strength of concrete cubes with 0% to 15% Silica Fume (SF) and 0% to 30% Stone Dust (SD) replacements are shown in above curves.

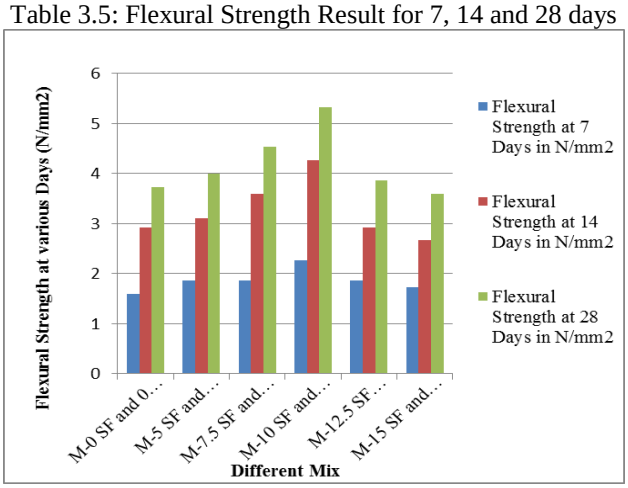
- The Compressive strength of concrete cubes in 3, 7, 14 and 28 days of controlled specimen (i.e., M-0 SF and 0 SD) is found as 11.7 N/mm^2, 17.29 N/mm^2, 23.26 N/mm^2 and 25.70 N/mm^2 respectively.
- For 5% Silica Fume and 10% Stone Dust remolded specimen (i.e., M-5 SF and 10 SD), the Compressive strength is decreased up to 0%, 7.05%, 0.65% and 0.2% respectively.
- For 7.5% Silica Fume and 15% Stone Dust remolded specimen (i.e., M-7.5 SF and 15 SD), the Compressive strength is increased up to 6.83%, 0.23%, 0.95% and 0.6% respectively.
- For 10% Silica Fume and 20% Stone Dust remolded specimen (i.e., M-10 SF and 20 SD), the Compressive strength is increased up to 6.9%, 4.5%, 3.83% and 7% respectively.
- For 12.5% Silica Fume and 25% Stone Dust remolded specimen (i.e., M-12.5 SF and 25 SD), the Compressive strength is decreased up to 0.7%, 1.9%, 0% and 5.2% respectively.
- For 15% Silica Fume and 30% Stone Dust remolded specimen (i.e., M-15 SF and 30 SD), the Compressive strength is decreased up to 6.3%, 6.6%, 4.2% and 5% respectively.
- Thus, it is observed from the above discussions that an increase in Compressive strength at 3, 7, 14 and 28 days with replacement of 10% Silica Fume and 20% Stone Dust remolded specimen give 6.9%, 4.5%, 3.83% and 7% (i.e., 12.51 N/mm^2, 18.07 N/mm^2, 24.15 N/mm^2 and 27.55 N/mm^2) more Compressive strength as compared with controlled concrete specimen without replacement of Silica Fume and Stone Dust (i.e., 11.7 N/mm2, 17.29 N/mm^2, 23.26 N/mm^2 and 25.7 N/mm^2).

2) Flexural strength Test Result:

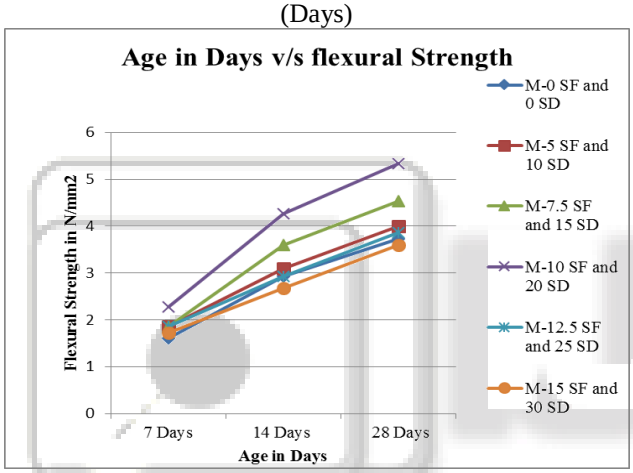
Different Mix	Flexural Strength at 7 Days (N/mm^2)	Flexural Strength at 14 Days (N/mm^2	Flexural Strength at 28 Days (N/mm^2
Mix-01	1.60	2.93	3.73
Mix-02	1.86	3.10	4.00
Mix-03	1.86	3.60	4.53

Mix-04	2.27	4.27	5.33
Mix-05	1.86	2.93	3.86
Mix-06	1.73	2.67	3.60

Table 3.5: Flexural Strength Result for 7, 14 and 28 days



Graph 3.3: Flexural Strength in N/mm2 at various age (Days)



Graph 3.4: Variation of 7, 14 and 28 days Flexural Strength with variation of % of SF and SD

a) Discussions:

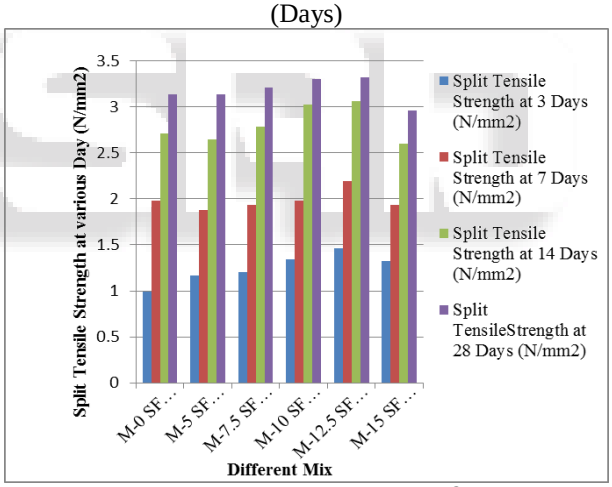
2) As shown in graph 3.4: The age in days v/s Flexural strength of concrete beams with 0% to 15% Silica Fume (SF) and 0% to 30% Stone Dust (SD) replacements are shown in above curves.

– The Flexural strength of concrete beams with 7, 14 and 28 days of controlled specimen (M-0 SF and 0 SD) is found as 1.6 N/mm^2, 2.93 N/mm^2 and 3.73 N/mm^2.
– For 5% Silica Fume and 10% Stone Dust remolded specimen (i.e., M-5 SF and 10 SD), the Flexural strength is increased up to 16.25%, 5.8% and 7.24% respectively.
– For 7.5% Silica Fume and 15% Stone Dust remolded specimen (i.e., M-7.5 SF and 15 SD), the Flexural strength is increased up to 16.25%, 22.87% and 21.45% respectively.
– For 10% Silica Fume and 20% Stone Dust remolded specimen (i.e., M-10 SF and 20 SD), the Flexural strength is highly increased up to 41.9%, 45.73% and 43% respectively.
– For 12.5% Silica Fume and 25% Stone Dust remolded specimen (i.e., M-12.5 SF and 25 SD), the Flexural strength is increased up to 16.25%, 0% and 3.5% respectively.
– For 15% Silica Fume and 30% Stone Dust remolded specimen (i.e., M-15 SF and 30 SD), the Flexural strength is increased up to 8.1%, 8.8% and 3.48% respectively.
– Thus, it is observed from the above discussions that an increase in Flexural strength at 7, 14 and 28 days with replacement of 10% Silica Fume and 20% Stone Dust remolded specimen give 41.9%, 45.73% and 43% (i.e., 2.27 N/mm^2, 4.27 N/mm^2 and 5.33 N/mm^2) more Flexural strength as compared with controlled concrete specimen without replacement of Silica Fume and Stone Dust (i.e., 1.6 N/mm^2, 2.93 N/mm^2 and 3.73 N/mm^2).

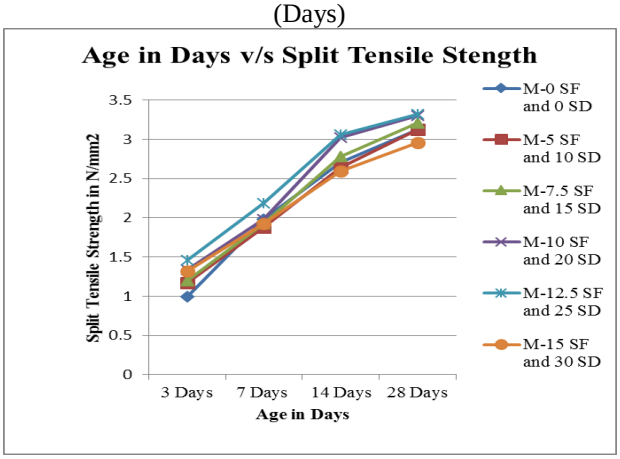
3) Split Tensile Strength Test:

Different Mix	Split Tensile Strength at 3 Days (N/mm^2)	Split Tensile Strength at 7 Days (N/mm^2)	Split Tensile Strength at 14 Days (N/mm^2)	Split Tensile Strength at 28 Days (N/mm^2)
Mix-01	0.99	1.98	2.71	3.13
Mix-02	1.32	1.93	2.64	2.96
Mix-03	1.46	2.19	2.78	3.32
Mix-04	1.34	1.98	3.02	3.30
Mix-05	1.20	1.93	3.06	3.21
Mix-06	1.17	1.88	2.60	3.13

Table 3.6: Split Tensile Strength in N/mm^2 at various age (Days)



Graph 3.5: Split Tensile Strength in N/mm^2 at various age (Days)



Graph 3.6: Variation of 3, 7, 14 and 28 days Split Tensile Strength with variation of % of SF and SD

a) Discussions:

1) As shown in graph 3.6: The age in days v/s Split tensile strength of concrete cylinders with 0% to 15% Silica Fume (SF) and 0% to 30% Stone Dust (SD) replacements are shown in above curves.

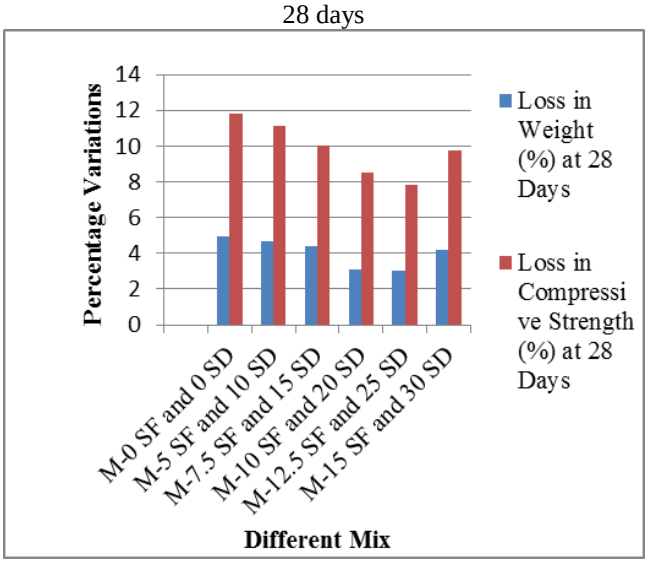
- The Split tensile strength of concrete cylinders at 3, 7, 14 and 28 days of controlled specimen (M-0 SF and 0 SD) is found as 0.99 N/mm^2, 1.98 N/mm^2, 2.71 N/mm^2 and 3.13 N/mm^2 respectively.
- For 5% Silica Fume and 10% Stone Dust remolded specimen (i.e., M-5 SF and 10 SD), the Split tensile strength is increased up to 18.2% at 3 days, decreased up to 5% and 2.6% at 7 and 14 days and there is no variation in strength at 28 days.
- For 7.5% Silica Fume and 15% Stone Dust remolded specimen (i.e., M-7.5 SF and 15 SD), the Split tensile strength is increased up to 21.2% at 3 days, decreased up to 2.5% at 7 days and again the strength is increased up to 2.6% at both 14 and 28 days.
- For 10% Silica Fume and 20% Stone Dust remolded specimen (i.e., M-10 SF and 20 SD), the Split tensile strength is increased up to 35.4%, 0%, 11.44% and 5.43% respectively.
- For 12.5% Silica Fume and 25% Stone Dust remolded specimen (i.e., M-12.5 SF and 25 SD), the Split tensile strength is increased up to 47.5%, 10.6%, 13% and 6.1% respectively.
- For 15% Silica Fume and 30% Stone Dust remolded specimen (i.e., M-15 SF and 30 SD), the Split tensile strength is increased up to 33.3% at 3 days and decreased up to 2.5%, 4.1% and 5.43% at 7, 14 and 28 days respectively.
- The percentage increase in Split tensile strength at 3, 7, 14 and 28 days of 12.5% & 25% replacement of silica fume and stone dust give 47.5%, 10.6%, 13% and 6.1% (i.e., 1.46 N/mm^2, 2.19 N/mm^2, 3.06 N/mm^2 and 3.32 N/mm^2) more Split tensile strength as compared with conventional concrete specimen without replacement of Silica Fume and Stone Dust (0.99 N/mm^2, 1.98 N/mm^2, 2.71 N/mm^2 and 3.13 N/mm^2) but the split tensile strength with 12.5% silica fume and 25% stone dust remolded specimen (i.e., 3.32 N/mm^2) and the strength for 10% silica fume and 20% stone dust remolded specimen (i.e., 3.30 N/mm^2) is almost same at 28 days.
- Thus, it is observed that the Split tensile strength is increases up to 10% silica fume 20% stone dust replacement level.

4) Durability Test Results:

This test was carried out on cube samples of dimensions 150* 150 * 150 mm. These test specimens were cured and tested for 28-days and tested in compressive testing machine.

Different Mix	Loss in Weight (%) at 28 Days	Loss in Compressive Strength (%) at 28 Days
M-0 SF and 0 SD	4.98	11.8
M-5 SF and 10 SD	4.7	11.1
M-7.5 SF and 15 SD	4.39	10
M-10 SF and 20 SD	3.1	8.5
M-12.5 SF and 25 SD	3.04	7.86
M-15 SF and 30 SD	4.2	9.77

Table 3.7: Loss in Weight and Compressive Strength (%) at 28 days



Graph 3.7: Durability Test results on Concrete Cube at 28 days

a) Discussions:

As shown in graph 3.7: The action of acids on concrete is the change of calcium compounds into calcium salts of the attacking acid. These reactions destroy the concrete structure. The percentage loss in compressive strength at 28 days was found to be 11.80% without replacement of silica fume and stone dust and replaced with silica fume and stone dust were found to be 11.1%, 10%, 8.5%, 7.86% and 9.77% respectively. Thus the strength of concrete cube found to be with silica fume and stone dust replaced specimen is greater than conventional concrete specimen. The percentage loss in weight of concrete cube at 28 days was found to be 4.98% without replacement and 4.7%, 4.39%, 3.1%, 3.04%, and 4.2% were found to be with silica fume and stone dust replaced concrete specimen. Thus replacement of silica fume and stone dust concrete specimen are found to have less affected from weathering agencies.

Thus replacement of silica fume and stone dust concrete specimen are found to have increased the durability against acid attack and the optimum percentage of replacement with SF and SD are 12.5% and 25%.

IV. CONCLUSION

The Compressive strength, Flexural strength, Split tensile strength and Durability test of concrete mixes made with and without silica fume and stone dust has been determined at 3, 7, 14 and 28 days of curing. The strength gained has been determined of silica fume and stone dust added concrete with 0%, 5%, 7.5% 10%, 12.5% & 15% and 0%, 10%, 15% 20%, 25% & 30% respectively for M20 grade as partial replacement of cement and sand in conventional controlled concrete. From the results, it is concluded that the silica fume and stone dust are superior replacement of cement and sand

up to 10% and 20%. Silica fume has high silicon dioxide (90-96%) content. The cement in concrete releases hydroxide throughout the hydration process. The silicon oxide fume reacts with the hydroxide to make further binder material. The provision of binder and rocky structure of stone dust keep bond formation between the concrete particles, ensuing improved strength properties and sturdiness of concrete. Additionally silicon oxide fume fill the voids between the cement particles and results in increase within the durability. The decrease in strength properties of concrete with increase in the silica fume and stone dust content beyond 10% and 20% are due to the over generation of binder which increases the brittleness of concrete in the presence of high content of silica fume. When activity all the tests and analyzing their result, the subsequent conclusions are derived:

- The results achieved from the existing study shows that silica fume and stone dust are great potential for the utilization in concrete as partial replacement of cement and sand.
- The percentage increase in compressive strength at 3, 7, 14 and 28 days with 10% silica fume and 20% stone dust replacement concrete give 6.9%, 4.5% 3.83% and 7% (i.e., 12.51 N/mm^2, 18.07 N/mm^2, 24.15 N/mm^2 and 27.55 N/mm^2) more strength as compared with conventional concrete mix without replacement of Silica Fume and Stone Dust (i.e., 11.7 N/mm^2, 17.29 N/mm^2, 23.26 N/mm^2 and 25.7 N/mm^2).
- The percentage increase in Flexural strength at 7, 14 and 28 days with 10% silica fume and 20% stone dust replacement concrete give 41.9%, 45.73% and 43% (i.e., 2.27 N/mm^2, 4.27 N/mm^2 and 5.33 N/mm^2) more Flexural strength as compared with conventional concrete mix without replacement of Silica Fume and Stone Dust (i.e., 1.6 N/mm^2, 2.93 N/mm^2 and 3.73 N/mm^2).
- The percentage increase in Split tensile strength at 3, 7 and 28 days of 12.5% & 25% replacement of silica fume and stone dust give 47.5%, 10.6% and 6.1% (i.e., 1.46 N/mm^2, 2.19 N/mm^2, 3.06 N/mm^2 and 3.32 N/mm^2) more Split tensile strength as compared with conventional concrete mix without replacement of Silica Fume and Stone Dust (0.99 N/mm^2, 1.98 N/mm^2, 2.71 N/mm^2 and 3.13 N/mm^2) but the Split tensile strength with 12.5% silica fume and 25% stone dust remolded specimen (i.e., 3.32 N/mm^2) and the strength for 10% silica fume and 20% stone dust remolded specimen (i.e., 3.30 N/mm^2) is almost same at 28 days.
- Thus, it is observed that the Split tensile strength is increases up to 10% silica fume 20% stone dust replacement level.
- The percentage of loss in Weight and compressive strength at 28 days found to be 3.04%, 4.98% and 7.86% and 11.8% with and without replacement of cement and sand by Silica Fume (12.5%) and Stone Dust (25%). Thus replacement of silica fume and stone dust are found to have increased the durability against acid attack.
- From the results, it is concluded that the Silica Fume and Stone Dust are superior replacement of Cement and Sand up to 10% and 20%.

A. Future Scope: Recommendations for Future Research

From this research, there are few recommendations to develop, to extend and to explore the usage of silica fume and stone dust in concrete:

- Define the effect of Silica Fume and Stone Dust on concrete with the replacement of mixture of coarse and fine aggregate by volume method.
- Replacement of cement and sand with Silica Fume and Stone Dust in different water cement ratio and grade of concrete.
- Selected few samples of concrete with different percentage of Silica Fume & Stone Dust and conclude the most suitable percentage of usage to achieve the optimum compressive strength.
- Study on effect of concrete with and without replacement of Silica Fume and Stone Dust and also compare their cost.

REFERENCES

[1] K. Perumal R. Sundaranjan (2004): Effect of partial replacement of cement with silica fume on the strength and durability characteristics of high performance concrete 29 conference on our world in concrete and structures: 25-26 August 2004, Singapore article Online Id: 100029050.

[2] N. K. Amudhavalli, Jeena Mathew (2012): Effect of SF on Strength & Durability Parameters of Concrete International Journal of Engineering Sciences & Emerging Technologies, Aug 2012. ISSN: 2231–6604, Vol.3, Issue1, pp: 28-35.

[3] Dilip Kumar Singha Roy, Amitava Sil (2012): Effect of Partial Replacement of Cement By Silica Fume On Hardened Concrete International Journal Of Emerging Technology And Advanced Engineering, Aug 2012, ISSN 2250-2459, Volume 2, Issue 8.

[4] Vikas Srivastava, V.C. Agarwal And Rakesh Kumar (2012): Effect Of SF On Mechanical Properties Of Concrete J. Acad. Indus. Res., Sept 2012, Issn: 2278-5213, Vol. 1, Issue 4.

[5] Dr. P.B.Sakthivel, C.Ramya, M.Raja (2013): An Innovative Method of Replacing River Sand by Quarry Dust Waste in Concrete for Sustainability, International Journal of Scientific & Engineering Research Volume 4, Issue 5, May-2013 ISSN 2229-5518

[6] Chandana Sukesh, Katakam Bala Krishna, P.Sri Lakshmi Sai Teja, S.Kanakambara Rao(2013): Partial Replacement of Sand with Quarry Dust in Concrete,International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-2, Issue-6, May 2013

[7] Prof. Vishal S. Ghutke, Prof. Pranita S.Bhandari (2014): Influence Of Silica Fume On Concrete Iosr Journal Of Mechanical And Civil Engineering (Iosr - Jmce), E-Issn: 2278-1684, P-ISSN: 2320-334.

[8] Amar Devendra Shitole, Sandhya Mathapati (2014): The Use of Micro-Silica to Improve the Compressive and Flexural Strength of Concrete. International Journal of Mechanical and Production Engineering, Aug.-2014, ISSN: 2320-2092, Volume- 3, Issue-6.

[9] J. Karthick, T.Rama, IIIN.Mani Bharathi (2014): An Experimental study on Usage of Quarry Rock Dust as Partial Replacement for Sand in Concrete. International Journal of Advanced Research in Education Technology (IJARET) Vol. 1, Issue 1 (July - Sept. 2014)
[10] Poonam , Anoop Bishnoi , Manju Bala (2015): Effect of Quarry Dust as Partial Replacement of Sand in Concrete, International Journal of All Research Education and Scientific Methods (IJARESM) ISSN: 2455-6211, Volume 3, Issue 6, June- 2015
[11] S Sundararaman and S Azhagarsamy (2015): A Study on Performance of Concrete by Partial Replacement of Cement with Rice Husk Ash and Silica Fume ISSN: 2394 - 658X, Volume 4, Issue 1.
[12] Pranshu Saxena (2015): Experimental Study on Mechanical Properties of M30 Concrete with Partial Replacement of Cement and Fine Aggregate with Silica Fume. IJRET: International Journal of Research in Engineering and Technology, ISSN: 2319-1163, ISSN: 2321-7308 Volume 4, Issue 7.
[13] Anurag Jain, P. Y. Pawade (2015): Characteristics of Silica Fume Concrete International Journal of Computer Applications, ISSN: 0975-8887, Volume 7, Issue 5.
[14] B Anusha Priya and U.Vamsi Mohan (2015): Experimental Studies on the Effect of Silica Fume and Quarry Dust in Concrete. International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization) Vol. 4, Issue 9, September 2015
[15] Sasikumar, A. (2016): Experimental Investigation on Properties of Silica Fumes as a Partial Replacement of Cement. International Journal of Innovative Research in Science, 5 (3), 4392-4395.

