PARTIAL REPLACEMENT OF CEMENT BY USING SILICA FUME IN CONCRETE

Nanabala jyosthna[1], A Naveen[2], J karimasif[3], M Subbireddy[4],L Ravi Kumar[5]

[1]Nanabala Jyoshna, Dept. of Civil Engineering, Kuppam Engineering College, Kuppam, AP
[2]A Naveen, Dept. of Civil Engineering, Kuppam Engineering College, Kuppam, AP
[3]J karimasif, Dept. of Civil Engineering, Kuppam Engineering College, Kuppam, AP
[4]M Subbireddy, Dept. of Civil Engineering, Kuppam Engineering College, Kuppam, AP
5L Rvai Kumar associate professor $ HOD, Kuppam Engineering Collage, Kuppam AP

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Abstract - This project reports the results of compressive strength obtained from the experiments where both conventional concrete and partial replacement of silica fume concrete are used. The physical properties of high strength silica fume concrete and their curing procedures were evaluated and compared with conventional concrete.. *The partially replacement of cement by silica fume the strength parameters of concrete have been studied. Silica fume were used to replace 0% to 15% of cement, by weight at increment of 5% for both cube and cylinder. The results showed that partial replacement of cement with silica fume had significant effect on the compressive strength of cube and split tensile strength cylinder. The strength of concrete increases rapidly as we increase the silica fume content and the optimum value of compressive strength is obtained at 10% replacement. After 10% its start decreasing under load condition of 4 KN and similarly the split tensile strength increases up to 10% and then start decreasing under the load condition of 2KN*

Key Words: Silica fume; cement; compressive strength; spilt tensile strength.

1.INTRODUCTION

Silica fume, also known as micro silica is an amorphous (non-crystalline) polymorph of silicon dioxide. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production. It is extremely fine with particles size less than 1 micron and with an average diameter of about 0.1 microns, about 100 times smaller than average cement particles. Its behaviour is related to the high content of amorphous silica (> 90%). The reduction of high-purity quartz to silicon at temperatures up to 2,000°C produces SiO_2 vapours, which oxidizes and condense in the low temperature zone to tiny particles consisting of non-crystalline silica.

During the last three decades, great strides have been taken in improving the performance of concrete as a construction material. Particularly Silica Fume (SF) and fly ash individually or in combination are indispensable in production of high strength concrete for practical application. The use of silica fume as a pozzolana has increased worldwide attention over the recent years because when properly used it as certain percent, it can enhance various properties of concrete both in the fresh as well as in hardened states like cohesiveness, strength, permeability and durability. Silica fume concrete may be appropriate in places where high abrasion resistance and low permeability are of utmost importance or where very high cohesive mixes are required to avoid segregation and bleeding.

Silica fume is a by-product from the production of elemental silicon or alloys containing silicon in electric arc furnaces. At a temperature of approximately 2000°C the reduction of high-purity quartz to silicon produces silicon dioxide vapor, which oxidizes and condenses at low temperatures to produce silica fume. The specific gravity of silica fume is generally in the range of 2.20 to 2.5. Portland cement has a specific gravity of about 3.15

2.OBJECTIVE

The objective of this study is to find the effect of partial replacement of silica fume on the workability, strength and durability characteristics of concrete. Three percentage levels of replacement i.e. 5, 10 and 15 percent are measured for partially replacing cement with silica fume. M25 concrete grade is initially designed without replacement and subsequently, cement is partially replaced with silica fume. Also, an attempt is made to find the optimum cement replacement level by silica fume for better strength and durability characteristics of High-Performance concrete.

3. LITERATURE REVIEW

Kumar & Dhaka (2016) write a Review paper on partial replacement of cement with silica fume and its effects on concrete properties. The main parameter investigated in this study M-35 concrete mix with partial replacement by silica fume with varying 0, 5, 9, 12 and 15% by weight of cement the paper presents a detailed experimental study on compressive strength, flexural strength and split tensile strength for 7 days and 28 days respectively.

Alok (2016) write A Research Paper on Partial Replacement of Cement in M-30 Concrete from Silica Fume and Fly Ash. Replacement levels of OPC by Silica Fume were 0%, 2.5%, 5%and 7.5% where replacement levels of Ordinary Portland cement by Fly Ash were 0%, 5%, 10% and 15% by weight. 1% super-plasticizer was used in all the test specimens for better workability at lower water cement ratio and to identify the sharp effects of Silica Fume and Fly Ash on the properties of concrete. Water-cement ratio was kept 0.43 in all cases.43.1 N/mm2 was the maximum compressive strength which was obtained at replacement level of 7.5% by weight of SF and 20% by weight of FA with cement.6.47 N/mm2 was the maximum flexural strength which was obtained at replacement level of 7.5% by weight of SF and 20% by weight of FA with cement.2.573 N/mm2 was the maximum split tensile strength which was obtained at replacement level of 7.5% by weight of SF and 20% by weight of FA with cement.

Jain &. Pawade (2015) studied the Characteristics of Silica Fume Concrete. The physical properties of high strength silica fume concretes and their sensitivity to curing procedures were evaluated and compared with reference Portland cement concretes, having either the same concrete content as the silica fume concrete or the same water to cementitious materials ratio. The experimental program comprised six levels of silica-fume contents (as partial replacement of cement by weight) at 0% (control mix), 5%, 10%, 15%, 20%, and 25%, with and without superplasticizer. It also included two mixes with15% silica fume added to cement in normal concrete. Durability of silica fume mortar was tested in chemical environments of sulphate compounds, ammonium nitrate, calcium chloride, and various kinds of acids.

Ghutke& Bhandari (2014) examine the Influence of silica fume on concrete. Results showed that the silica fume is a good replacement of cement. The rate of strength gain in silica fume concrete is high. Workability of concrete decreases as increase with % of silica fume. The optimum value of compressive strength can be achieved in 10% replacement of silica fume. As strength of 15% replacement of cement by silica fume is more than normal concrete. The optimum silica fume replacement percentage varies from 10 % to 15 % replacement level.

4. METHODOLOGY

All the works which are necessary for our project had been executed in concrete Technology Laboratory inkuppam Engineering College. Mix design is very important to make the cubes and cylinder for good results. Mix design for M25 grade concrete is done by using IS10262:2019 and concrete design code IS 456:2000. In this project, we had done in 3 stages. First phase is testing of materials, second phase is making of cubes as normal concrete and third phase is replacing of material with cubes. After casting of cubes, we have to check the compressive strength and split tensile strength at 7, 14 and 28 days

5.MIX DESIGN (IS 10262:2019)

1. STIPULATIONS FOR PROPORTIONING
1. Grade designation : M25
2. Type of cement : OPC 43 GRADE
3. Type of mineral admixture : Silica fume
4. Maximum nominal size of aggregate : 20 mm
5. Workability : 100 mm (slump)
6. Method of concrete placing : Chute (not pumping)
7. Degree of supervision : Good
8. Type of aggregate : Crushed angular aggregate
9. Maximum cement content : As per IS 456

2.TEST DATA FOR MATERIALS
1. Cement used : OPC 43 GRADE
2. Specific gravity of cement : 3.15
3. Specific gravity of Silica fume : 2.25
4. Specific gravity of
   1) Coarse aggregate : 2.68
   2) Fine aggregate : 2.65
5. Water absorption
   1) Coarse aggregate : 0.5 percent
   2) Fine aggregate : 1.0 percent
6. The coarse and fine aggregates are wet and their total moisture content is 2 percent and 5 percent respectively. Therefore, the free moisture content in coarse and fine aggregate shall be as shown in
7. below j) Free (surface) moisture

Coarse aggregate: Free moisture = Total moisture content – Water absorption
= 2.0 – 0.5 = 1.5 percent

Fine aggregate: Free moisture = Total moisture content – Water absorption
= 5.0 – 1.0 = 4.0 percent

3.TARGET STRENGTH FOR MIX PROPORTIONING

$f'ck = fck + 1.65\ S$ or

$f'ck = fck + X$ whichever is higher.

In code book 10262 From Table 2, standard deviation, S = 4 N/mm^2.

that is, a) $f'ck = fck+1.65\ S$

$= 25 + 1.65 \times 4$

$= 31.6\ N/mm^2$

Therefore, target strength will be 31.6 N/mm^2

4. APPROXIMATE AIR CONTENT
In code book 10262 From Table 3, the approximate amount of entrapped air to be expected in normal (non-air-entrained) concrete is 1.0 percent for 20 mm nominal maximum size of aggregate.

5. SELECTION OF WATER-CEMENT RATIO
In code book 10262 From Fig. 1, the free water-cement ratio required for the target strength of 31.6 N/mm2 is 0.45 for OPC 43 grade curve. This is lower than the maximum value of 0.45 prescribed for 'severe' exposure for reinforced concrete as per Table 5 of IS 456 hence O.K.

6. SELECTION OF WATER CONTENT
In code book 10262 From Table 4, water content = 186 kg (for 50 mm slump)

for 20 mm aggregate.

Estimated water content for 100 mm slump (increasing at the rate of 3 percent for every 25 mm slump)

$= \frac{186+6}{100X186}$

= 197.16 kg

Hence the arrived water content = 197.16

≈ 200 kg.

7. CALCULATION OF CEMENT CONTENT
Water-cement ratio= 0.45
Cement content = 200/0.45
= 444.4 kg/m^3
≈ 450 kg/m^3

OTE —
This illustrative example is with increase of 10 percent cementitious material content. Cementitious material content = 450 × 1.10

= 495 kg/m^3

Water content = 200 kg/m^3
So, water-cementitious ratio = 200/495=0.40
Silica Fume @15 percent of total cementitious material content
= 495 ×15 percent
=74.25 kg/m^3
Cement (OPC)
= 495-74.25

= 420.75 kg/m^3

From Table 5 of IS 456, minimum cementitious content for 'severe' exposure condition = 320 kg/m^3
420.75kg/m^3> 320 kg/m^3, hence O.K

8. PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGRAGETE CONTENT

In code book 10262 From Table 5, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.5 = 0.62. The corrected proportion of volume of coarse aggregate for the water-cementitious ratio of 0.45
= 0.62 + 0.01
= 0.63
Therefore,
volume of coarse aggregate = 0.63m^3.
Volume of fine aggregate content = 1 – 0.63
= 0.37 m^3

9. MIX CALCULATIONS
The mix calculations per unit volume of concrete shall be as follows:

a) Total volume = 1 m^3
b) Volume of entrapped air in wet concrete = 0.01 m^3
c) Volume of cement = Mass of cement /Specific gravity of cement*1/ 1 000
= 396/3.15X1/1000
= 0.12 m^3

d) Volume of Silica Fume = Mass of Silica Fume /Specific Gravity of
Silica Fume X1/1000
= 99/2.25X1/1000
= 0.044 m^3
e) Volume of water = Mass of water /Specific Gravity of water
X1/1000
= 200/1X1/1000 = 0.2

f) Volume of all in aggregate
= [(a-b)-(c+d+e)]
= [(1-0.01) -(0.12+0.044+0.200)]
= 0.624 m^3
g) Mass of coarse aggregate
= f × volume of coarse aggregate × Specific gravity of coarse aggregate × 1 000
= 0.624 × 0.63× 2.86 × 1 000
= 11254 kg
h) Mass of fine aggregate
= f × Volume of fine aggregate × Specific gravity of fine aggregate
× 1 000
= 0.624 × 0.37 × 2.65 × 1 000
= 611.8 kg

- Silica Fume @ 0 percent of total cementitious material content

= 0
Cement (OPC)= 495-0
= 495 kg/m^3

- Silica Fume @ 5 percent of total cementitious material content

= 495 × 5 percent
= 24.75 kg/m^3

Cement (OPC)= 495-24.75
= 470.25 kg/m^3

- Silica Fume @10 percent of total cementitious material content

= 495 × 10 percent
= 49.5 kg/m3
Cement (OPC) = 495-49.5
= 445.5 kg/m3

- Silica Fume @15 percent of total cementitious material content

= 495 x 15 percent
= 74.25 kg/m^3
Cement (OPC) = 495-74.25
= 42075 kg/m^3

6. EXPERIMENTAL WORK

COMPRESSIVE STRENGTH TEST

Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. A material under compression tends to reduce the size, while in tension, size elongates. The cubes at 7, 14&28 days of curing were taken for test.

Remove the specimen from water after specified curing time and wipe out excess water from the surface. Clean the bearing surface of the testing machine. Place the specimen in the machine in such a manner that the load shall be applied to the opposite of the cubes cast. Rotate the movable portion gently by hand so that it touches the top surface of the specimen. Apply the load gradually till the specimen fails. Record the maximum load. Fig Indicate finding compressive strength in CTM.

Compressive strength $= \frac{ultimate\ load}{cross\ section\ area}$

Finding compressive strength in CTM

SPLIT TENSILE TEST

The concrete is very weak in tension due to its brittle nature. Hence, it is not expected to resist the direct tension. Concrete develops cracks when tensile forces exceed its tensile strength. It is necessary to determine the tensile strength of concrete to determine the load at which the concrete member may crack.

Taken out the wet specimen from water after 7, 14&28 of curing or any desired age at which tensile strength to be estimated. Then, wipe out water from the surface of specimen. Specimen should be placed such a manner load shall be applied uniformly. Rotate the movable portion gently by hand so that it touches the top surface of the specimen. Apply the load continuously without shock at a rate within the range 0.7 to 1.4 Mpa/min (1.2 to 2.4 Mpa/min based on

IS 5816 - 1999. Finally, note down the breaking load (P). Fig Indicates split tensile test in CTM.

Split tensile strength $= \frac{2p}{\pi DL}$

Split Tensile test in CTM

7. TEST RESULTS

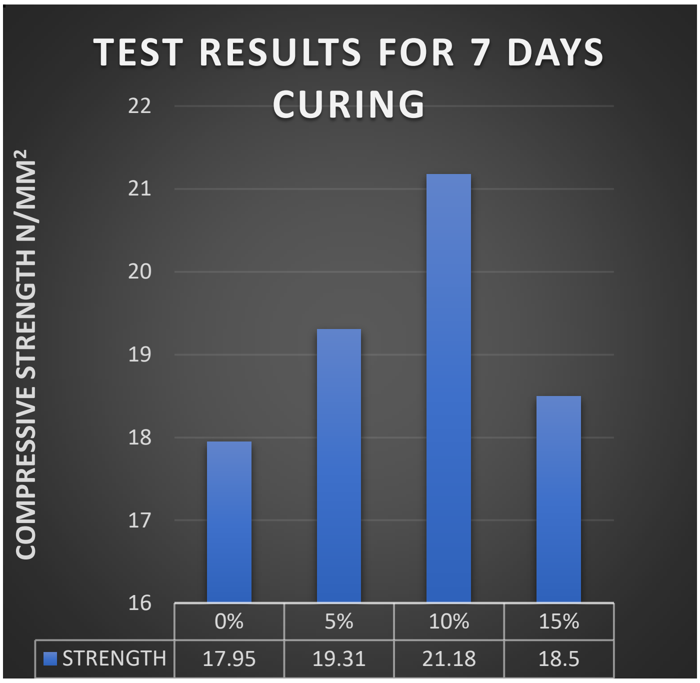
COMPRESSIVE STRENGTH

The cubes at 7, 14, and 28 days of curing were taken for test. The compressive strength conventional concrete and new proportion such as 95% cement and 05%SF, 90% cement and 10% SF, 85% cement and 15% SF constant as total project.

8.1.1 TEST RESULTS FOR 7 DAYS CURING

Table No: 8.1 Test Results for 7 Days Curing

S No	Mix (%)	Compressive strength (N/mm^2)		Average
		Trail 1	Trail 2	
1	0%	17.5	18.4	17.95
2	5%	18.68	19.93	19.31
3	10%	21.4	20.95	21.18
4	15%	18.6	18.4	18.5



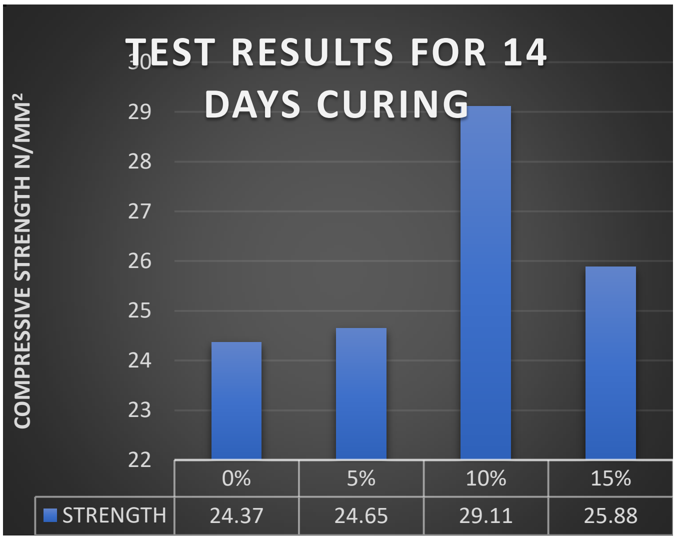
Test Results for 7 days Curing

TEST RESULTS FOR 14 DAYS CURING

Test Results for 14 days Curing

S No	Mix (%)	Compressive strength (N/mm²)		Average
		Trail 1	Trail 2	
1	0%	24.15	24.5	24.37
2	5%	24.28	25.01	24.65
3	10%	29.05	29.18	29.11
4	15%	25.38	26.39	25.88

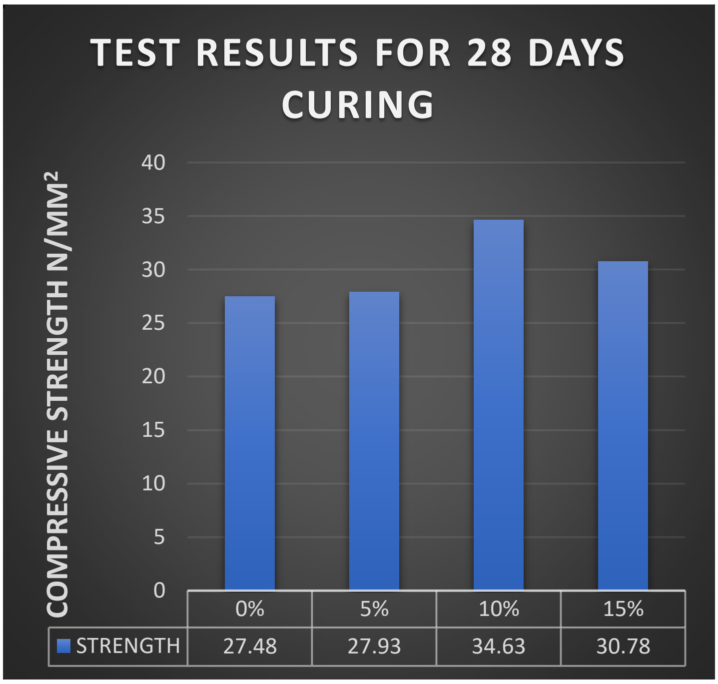
Test Results for 14 Days Curing



TEST RESULTS FOR 28 DAYS CURING

Test Results For 28 Days Curing

S No	Mix (%)	Compressive strength (N/mm²)		Average
		Trail 1	Trail 2	
1	0%	27.6	27.3	27.48
2	5%	27.85	28.01	27.93
3	10%	34.5	34.96	34.63
4	15%	31.4	30.15	30.78

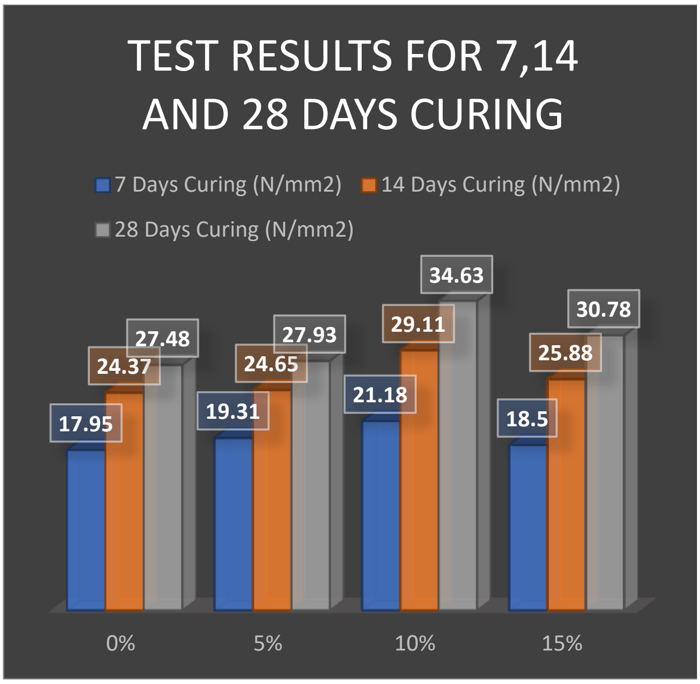


Test Results For 28 days Curing

COMPARISION TEST RESULTS FOR 7, 14 AND 28-DAYS CURING

Test Results for 7, 14 and 28-Days curing

S. No	Mix %	7 days curing (N/mm²)	14 days curing (N/mm²)	28 days curing (N/mm²)
1	0%	17.95	24.37	27.48
2	5%	19.31	24.65	27.93
3	10%	21.18	29.11	34.63
4	15%	18.5	25.88	30.78



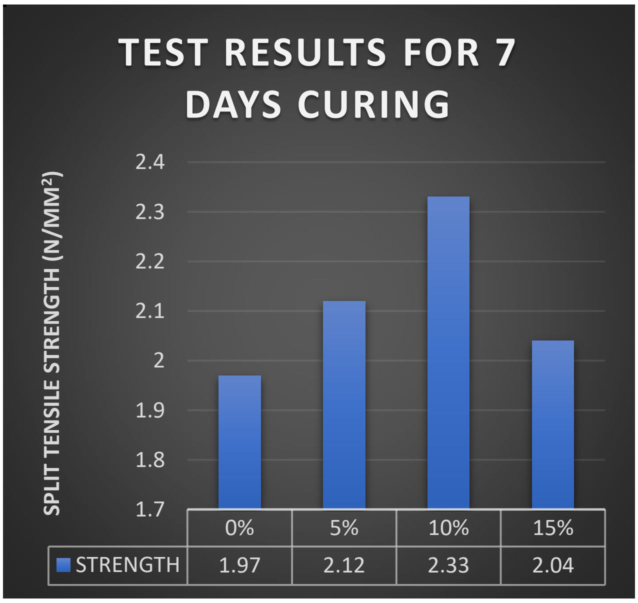
Graph N0: 8.4 Test Results for 7,14 and 28-Days Curing

AVERAGE SPLIT TENSILE STRENGTH

Test Results for 7 Days curing

Test Results for 7 days curing

S No	Mix (%)	Split tensile strength (N/mm²)		Average
		Trail 1	Trail 2	
1	0%	1.79	2.02	1.97
2	5%	2.05	2.19	2.12
3	10%	2.35	2.30	2.33
4	15%	2.05	2.02	2.04

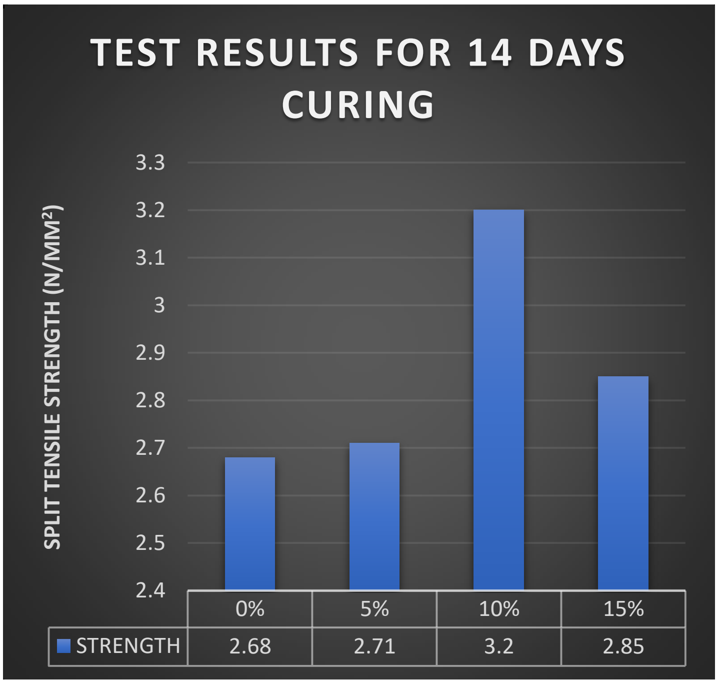


Test results for 7 Days Curing

Test Results for 14 Days Curing

Test Results for 14 Days Curing

S No	Mix (%)	Split tensile strength (N/mm²)		Average
		Trail 1	Trail 2	
1	0%	2.66	2.7	2.68
2	5%	2.67	2.75	2.71
3	10%	3.2	3.21	3.2
4	15%	2.79	2.9	2.85



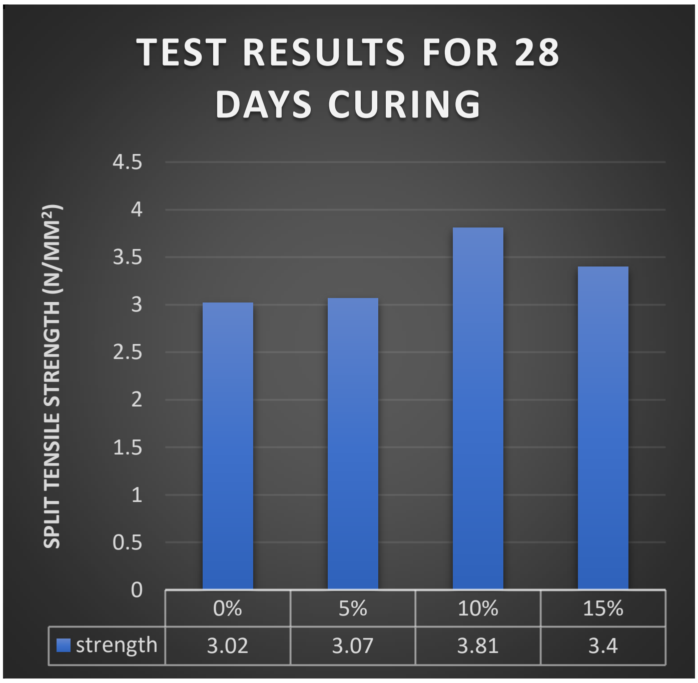
Test Results for 14 Days Curing

TEST RESULTS FOR 28 DAYS CURING

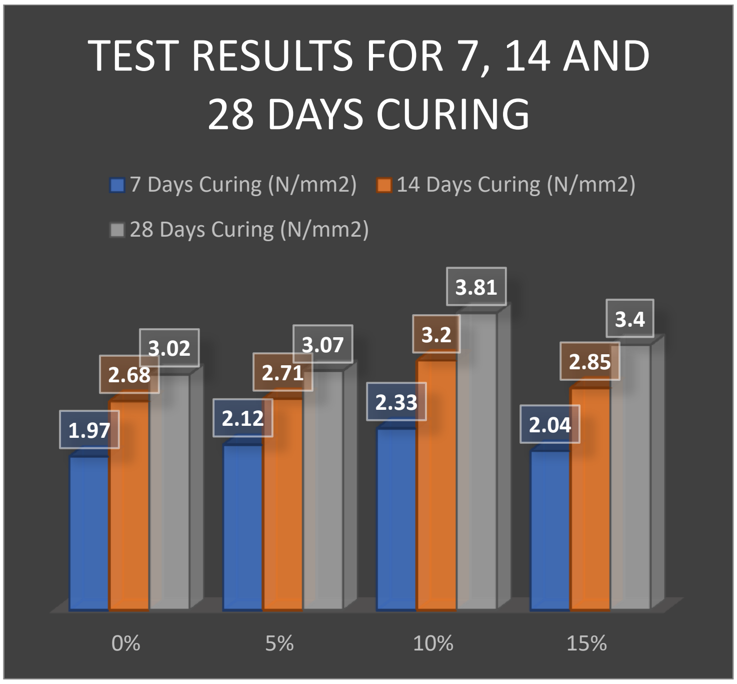
Test Results for 28 Days curing

S No	Mix (%)	Split tensile strength (N/mm²)		Average
		Trail 1	Trail 2	
1	0%	3.04	3	3.02
2	5%	3.06	3.08	3.07
3	10%	3.80	3.85	3.81
4	15%	3.45	3.32	3.40

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 06 | June 2021 www.irjet.net p-ISSN: 2395-0072



Test Results for 28 Days curing



Test Results for 7, 14 and 28-Days Curing

SPILT TENSILE TEST RESULTS FOR 7, 14 AND 28-DAYS CURING

Test Results for 7, 14 and 28-Days curing

S. No	Mix %	7 days curing (N/mm²)	14 days curing (N/mm²)	28 days curing (N/mm²)
1	0%	1.97	2.68	3.02
2	5%	2.12	2.71	3.07
3	10%	2.33	3.2	3.81
4	15%	2.04	2.85	3.40

8. CONCLUSIONS

In this project, an experimental study has been conducted on concrete by varying the percentage of silica fume as 0%, 5%,10% and 15% respectively to study the increase in the compressive strength of concrete. Based on the experimental investigation, the compressive strength was found to increase at 10% addition of silica fume in the concrete. The compressive strength was found to gradually decrease after 10% addition in the concrete. After performing the test and analyzing their result, the following conclusions have been derived: The results achieved from the existing study shows that silica fume is great potential for the utilization in concrete as replacement of cement.

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BIOGRAPHIES

NANABALA JYOTHSNA

A NAVEEN

J KARIMASIF

M SUBBIREDDY

L RAVI KUMMAR