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STUDY ON EFFECT OF WATER CEMENTITIOUS RATIO ON HARDENED PROPERTIES OF SILICA FUME CONCRETE

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Abstract: The most crucial component of concrete is Portland cement, which is also a versatile and rather expensive substance. Cement manufacture on a large scale affects the environment negatively and depletes natural resources negatively. Researchers are now using industrial waste materials as an additional cementing element in concrete because of the damage they pose to the environment. The M30 grade of varied water cement ratios of 0.32, 0.35, and 0.38 is used to create high-strength concrete. Instead of increasing the cement content, mineral admixtures (additional cementitious ingredients) are employed.

In this study, M30 grade concrete with partial cement substitution by silica fume at levels of 5%, 10%, 15%, and 20%, with variable water cement ratios of 0.32, 0.35, and 0.38, is the key parameter under investigation. Compressive strength, flexural strength, and split tensile strength at ages of 7, 14, and 28 days are the subject of a thorough experimental research presented in this project. This article describes the findings of an experimental study on the impact of various silica fume (SF) and water to cement ratios (w/c) on standard concrete.

Index Terms – Industrial Wastes, Silica Fume.

1.INTRODUCTION

Any material that is not water, aggregates, hydraulic cements and additives (pozzolanas, slag, and/or fibre reinforcement) is referred to as an admixture, according to IS 9103: 1999.Both mineral and chemical admixtures perhaps utilized in concrete (additives) or chemical admixtures. Mineral admixtures, often known as additives, change the qualities of the fresh condition at a minimal cost. Depending on the addition employed, they may or may not have an impact on concrete's features in the hardened stage.

Through hydraulic or pozzolanic action, mineral admixtures modify the particulars of the hardened concrete. Natural pozzolans, involves the volcanic ash used in Roman concrete, fly ash, and silica fume, are cementitious substances known as pozzolans.

- Fly ash (FA)
- Silica fume (SF)
- Metakaolin (MK)
- Rice husk ash (RHA)

A certain amount of cement used to create concrete has grown in recent years. Silica fume be a pretext in concrete as an alternative for in part cement to reduce cement usage. In IS a code book, the employed with concrete crystalline silica as a as a part-time substitution for cement of up to 30% is permitted. High volume silica vapour concrete according to definition having a substantial volume consists of silica fumes (often exceeding 50%).

A by-product of making silicon metal or ferrosilicon alloys is silica mist. The most advantageous application is a dust of silica is in concrete. It is an extremely reactive pozzolan attributable to its chemical and physical characteristics. Silica fume-produced materials have the potential to be very durable and robust. When specified, a silica particle is readily available from providers of concrete admixtures and is merely added during the arranging of concrete. Titanium iron is produced in electrically heated burners and alloys. Wood chips, coal, and quartz make up the basic materials. Instead of being landfilled, the smoke that upon assembly boiler operation is collected and sold as silica vapour. Making advantage of this substance as a mineral additive in concrete is arguably its most significant application.

2. LITERATURE REVIEW

Kumar and Dhaka. et. al., [1] (2016): For M35 concrete mix with varied percentages of silico fume is 5, 9, 12, and 15% via means of cement, a case study was brought out to examine the impact of silica vapour replacement on the traits of the concrete. To be able to get the greatest compressive strength, it was discovered that 12% of SF substitution was ideal. 30.95 N/mm2 and 46.14 N/mm2 were determined being the greatest crushing strengths for seven days and 28 days, respectively.

Sasikumar and Tamilvanan. et. al., [2] (2016): SF fluctuation levels 50% or more were applied in an experimental evaluation for concrete of the M30 grade. For optimal tensile strength at ageing ages of 7 and 28, they discovered that silica fumes should be present at a maximum of 25%.

Hanumesh. et. al., [3] (2015): By using a fume of silica as a substitute for cement (5, 10, 15 or 20%), concrete's elastic attributes were tested. By replacing 10% or less of the silica-containing cement fume; they were able to verify a decreasing trend in tensile stiffness strength, that which is level over which it tends to increase. For the concrete's of M20 grade, it was discovered that 10 percent cement should be replaced by silica fume.

Amarkhail. et. al., [4] (2015): In this investigation, SF five, ten, and fifteen levelsof substitution and 20% they served for the 7- and 28-day curing periods, respectively, at varied w/c ratios of 0.36 and 0.30. Both have discovered increased flexure strength for 15% of ideal substitution for silica fume.

Amudhavalli and Mathew. et. al.,[5] (2012): the replacement amount of consisted of particles of silica taken as 5, 10, 15, and 20%, in addition to how silica fume affects you on concrete strength was looked into applying a constant w/c ratio of 0.36.For 7 and 28 days, highest strength when compressed is 38.3 and 47.3 Mpa, respectively, and 15% discovered to be the ideal replacement percentage for silica fume.

Katkhuda. et. al., [6] (2009): By substituting 5, 10, 15, 20 and 25% of SF with w/c ratios ranging from 0.26 to 0.42, The repercussions of asbestos fumes on high strength, light weight concrete was examined. For 0.26 and 0.30 w/c ratios, they identified an optimal percentage of 15%, however 20% was discovered for 0.34, 0.38, and 0.42 w/c ratios as the optimal replacement.

Wong. et. al., [7] (2005): investigated defining qualities of freshly blended concrete using three different w/c ratios of 0.27, 0.30, and 0.33. A different amount of fume from silica was harnessed in place of cement at each w/c ratio: 0, 5, 10, and 15%. an adaptation of Slump with varying levels of replacement at a particular w/c ratio. The investigation came to the conclusion that the cause of the wide range in workability among mixes was the relied of a fixed quantity of super plasticizer for mixtures possessing the same w/c ratio.

M.H. Zhang. et. al., [8] (2003): This experiment looked at how much SF and OPC concrete shrank on their own. The results were compared to those of the concrete exempler dried at 65% relative humidity after an initial moist curing of 7 days, which included drying shrinkage and one of the autogenous shrinkage. The tested concrete had a water-to-cementitious materials (w/c) ratio of 0.26 to 0.35, and its SF concentration ranged from zero percentage to ten percentages by cement weight.

3. OBJECTIVES AND METHODOLOGY

3.1 Objectives

1. To gather the materials and examine their fundamental characteristics.
2. Using IS 10262: 2019 for concrete mix design, M30 grade
3. Workability of concrete as determined by the slump test technique.
4. To investigate the qualities freshly installed and strengthened concrete whensilica exhaust is used in place of cement at various percentages.
5. To ascertain the ideal amount of silica fume utilisation in concrete.
6. To thoroughly assess the impact of silica fume on the compression, flexural and tensile strength of split of high-strength concrete and identify the ideal dosage.
7. Additionally, the impact of physicochemical effects of silica fume characteristicslike density was identified.

3.2 Methodology

The approach has been used to investigate the hardened characteristics incorporating plaster silica fume at various water cement ratios, including 0.32, 0.35, and 0.38. The study work involves the subsequent steps. Consequently, the codalrequirements of IS 10262-2009, the M30 grade was created. The total amount of silica fume used in various percentages by volume in relation to the concrete mixes varies. The produced mixtures' toughened characteristics were examined.

Below is a representation of the experimental work's technique.

- Gathering of materials
- Running initial testing on materials.
- Mix design for concrete of grade M30 in accordance with IS 10262:2019.
- Calculating the amount of materials needed for beams, cylinders, and cubes.
- Casting samples and storing them for cure at 7 and 28 days.
- Slump test for fresh concrete's workability.
- Testing of specimens, including workability of test, water absorption test, compressive strength tests, split tensile strength tests and flexural strength tests.
- Results.
- Conclusions

4 MATERIAL CHARACTERIZATION

4.1 Materials Used for Conventional Concrete

Materials used for customary concrete are:

- Cement
- Aggregate
- Water
- Silica fume
- Superplasticizers

4.2 Silica Fume

It's like adding silica smoke cement, it works as a pozzolan, chemically combining with calcium hydroxide to create calcium silicate hydrate, just as much as a chemically inert filler, improving the physical structure.

Fig. 4.1: Silica Fume

Table 4.1: Physical Properties of Silica Fume

Sl No.	Properties	Values
1	Appearance	Grey powder
2	Specific Gravity	2.2
3	Average practical size	0.1μ
4	Practical size	0.1μ-0.5μ

Table 4.2: Chemical Properties of Silica Fume

Sl No.	Chemical properties	Mass %
1	Silica (SiO_2)	90.2
2	Al_2O_3	1.7
3	CaO	0.4
4	Fe_2O_3	2.1
5	SO_4	1.7
6	K_2O	0.7

4.3 Superplasticizers

Super plastifiers are a key component in reducing concrete's yield stress. To attain the intended workability of concrete, superplasticizers of polycarboxylicether (PCE) condensates kinds were purchased from a reputable company. Superplasticizers are additives that enable the achievement of a specified level of workability at a lowerwater/cement ratio.

5 RESULTS AND DISCUSSIONS

5.1 Compressive Strength Test

Strength test by Compression according to IS 516: 1959 were carried out on grade M30 concrete made with and varying silica fume, cement to water ratio is not present of 0.32, 0.35 and 0.38 were determined 7 days, 14 days and 28 days. The test results of concrete M30 are given in table. The gain in compression energy has been detected in silica fume as compared to normal mix at 7days, 14 days at the same time as at 28 days with 5% replacement level.

Table 5.1: Compressive Strength Test for Water Cement Ratio 0.32 at 7, 14 and 28 days

Mix	% Replacement	Average Compression strength in N/mm² 7 days	Average Compression strength in N/mm² 14 days	Average Compression strength in N/mm² 28 days
M0	0	21.50	28.32	37.02
M1	5	28.44	34.15	40.08
M2	10	36.85	41.52	44.84
M3	15	32.84	38.14	42.94
M4	20	30.44	35.84	36.07

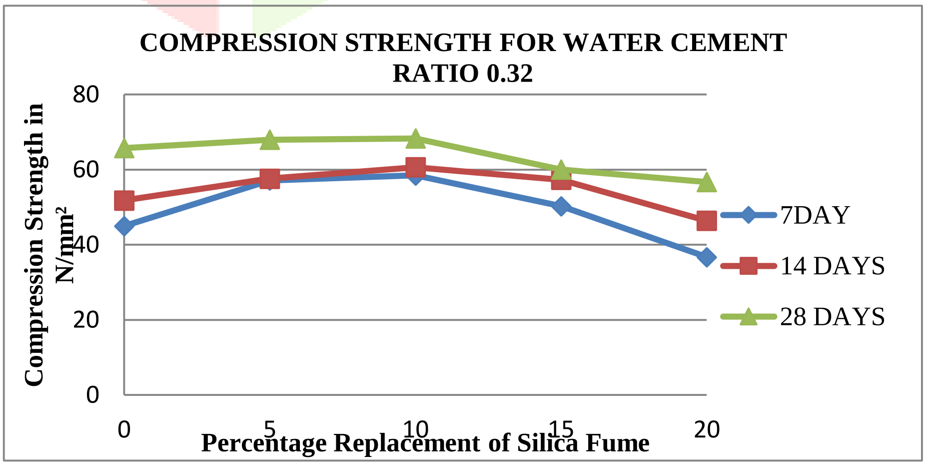


Fig. 5.1 : Compressive Strength of Concrete

Table 5.2: Compressive Strength Test for Water Cement Ratio 0.35 at 7, 14 and 28 days.

Mix	% Replacement	Average Compression strength in N/mm^2 7 days	Average Compression strength in N/mm^2 14 days	Average Compression strength in N/mm^2 28 days
M0	0	25.60	32.14	38.30
M1	5	29.72	35.70	41.29
M2	10	38.14	42.80	47.30
M3	15	34.13	40.42	46.76
M4	20	31.76	37.72	43.73

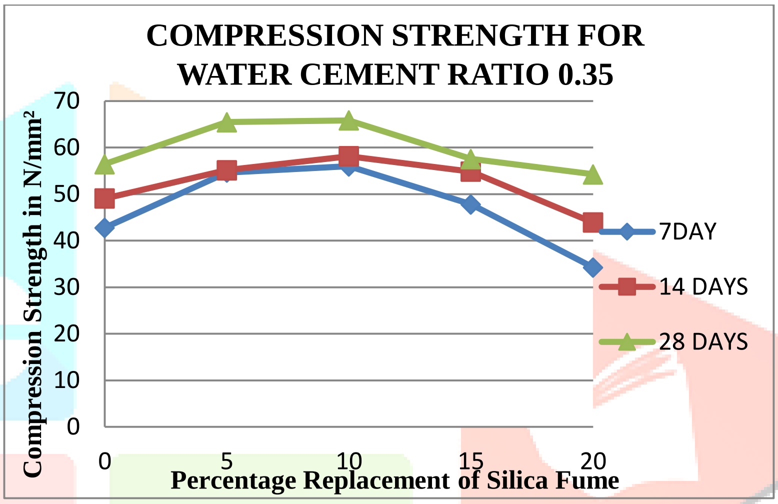
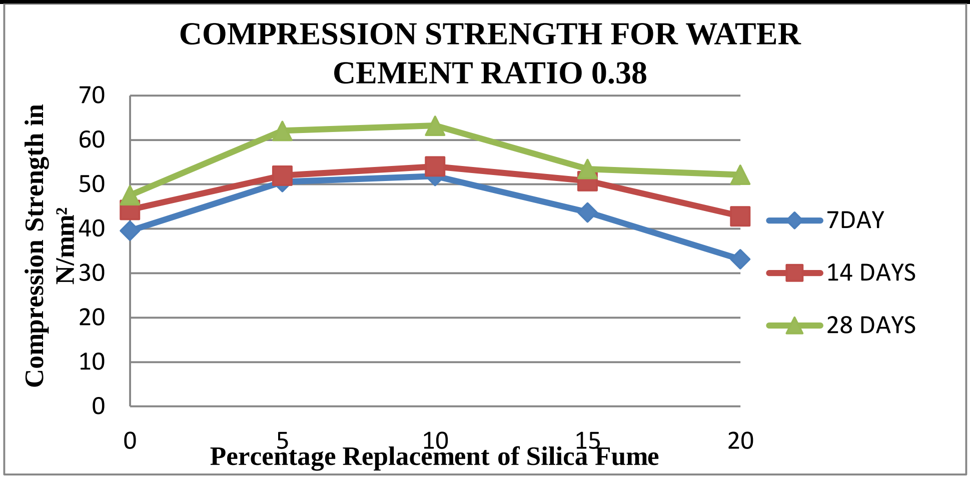


Table 5.3: Compressive Strength Test for Water Cement Ratio 0.38 at 7, 14 and 28 days.

Mix	% Replacement	Average Compression strength in N/mm^2 7 days	Average Compression strength in N/mm^2 14 days	Average Compression strength in N/mm^2 28 days
M0	0	20.30	25.60	32.98
M1	5	26.24	31.68	38.61
M2	10	34.65	39.32	42.37
M3	15	30.64	35.94	40.74
M4	20	28.24	33.64	34.00



Comparing the impact of silica fumes and water cement ratios on the concrete's compressive strength after days of 7, 14, and 28 appears in the figures. When the silica haze concentration is increased by 5 to 20% for water-cement ratiosof 0.32, 0.35 and 0.38 it has been revealed that the concrete becomes stronger. Beyond that, silica fume substitution of more cement reduces the ability to cater for concrete.

A 10% replacing ratio of silica fume to water in cement of 0.35 at 7 days, 14 days and 28 days resulted in maximum crush strengths of 48.98%, 33.16% and 23.49% respectively.

When silica fume is added, the 28-day compressive strength is really improved by 5% and when the volume of silica vapour reaches 10% the crush strength grows even more, reaching its maximum strength. In contrast, silica fume at rates of 15% and 20% reduces the 28-day strength for all water-cement ratios.

5.1 Flexural Strength Test

Strength test for bending as per IS 516: 1959 were conducted on M30 grade of concrete made additional to and without a fume of silica, along with variations in waterto cement ratios of 0.32, 0.35 and 0.38 were determined 7 days, 14 days and 28 days. The evaluation the outcomes of concrete M30 are given in table. The gain in bending resistance has been recorded in silica fume in comparison with normal mix at 7days, 14 days also at 28 days. with 5% replacement level.

Table 5.4: Flexural Strength Test for Water Cement Ratio 0.32 at 7,14 and 28 days.

Mix	% Replacement	Average Flexural Strength in N/mm² 7 days	Average Flexural Strength in N/mm² 14 days	Average Flexural Strength in N/mm² 28 days
M0	0	4.33	4.68	5.33
M1	5	6.03	6.35	6.58
M2	10	6.38	6.82	6.90
M3	15	5.98	6.10	6.42
M4	20	5.88	6.00	6.32

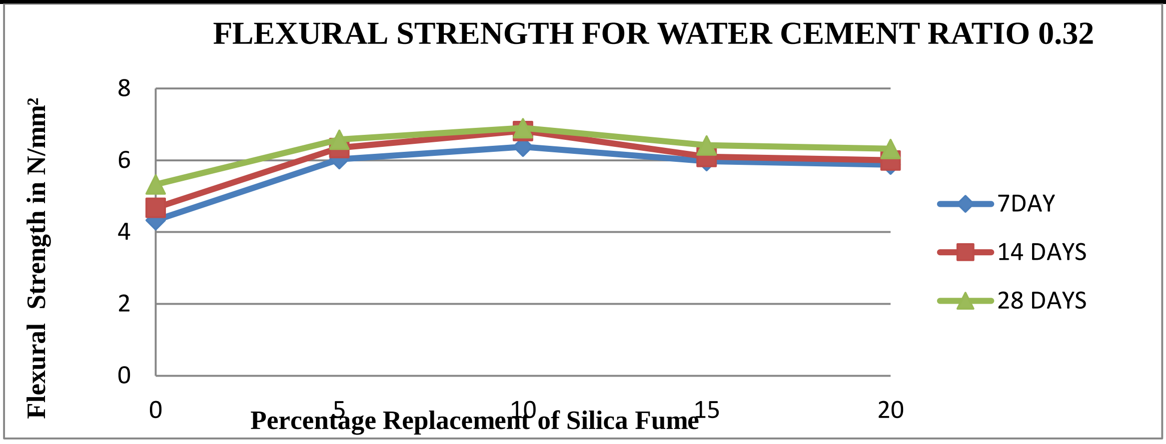


Table 5.5: Flexural Strength Test for Water Cement Ratio 0.35 at 7,14 and 28 days.

Mix	% Replacement	Average Flexural Strength in N/mm² 7 days	Average Flexural Strength in N/mm² 14 days	Average Flexural Strength in N/mm² 28 days
M0	0	4.68	5.03	5.68
M1	5	6.45	6.77	7.00
M2	10	6.80	7.24	7.32
M3	15	6.40	6.52	6.84
M4	20	6.30	6.42	6.74

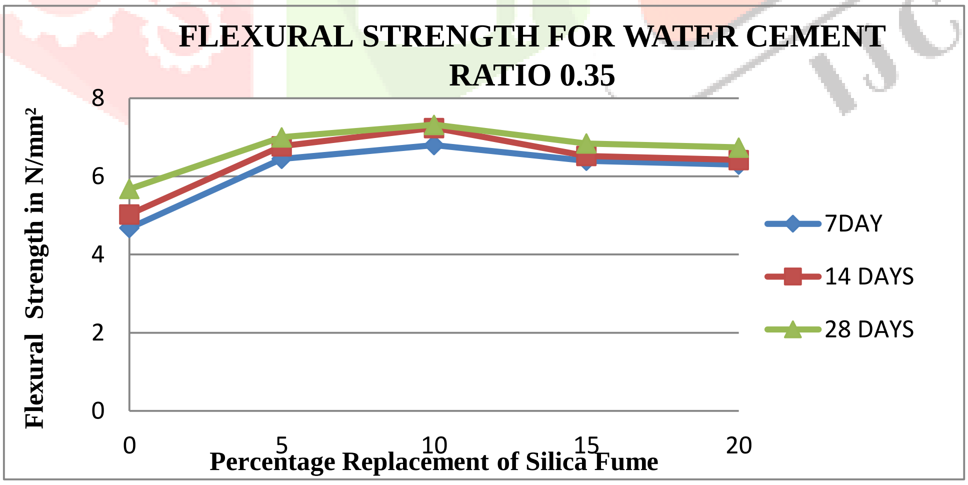
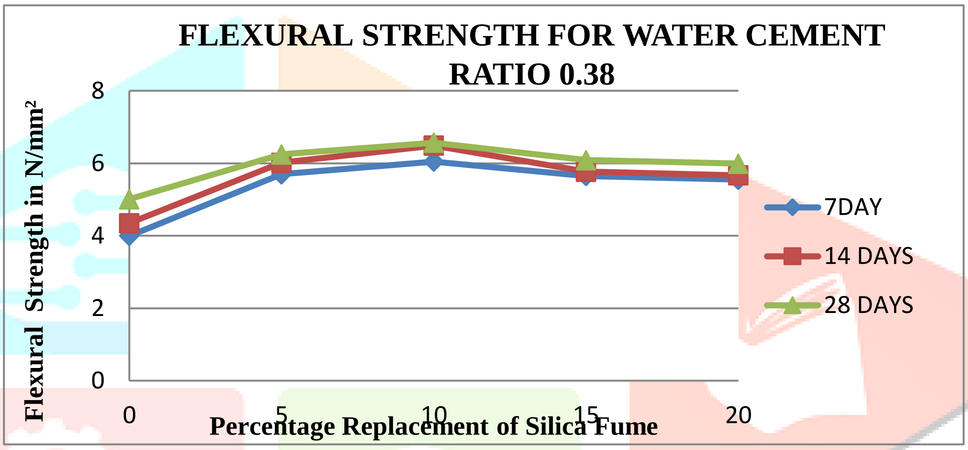


Table 5.6: Flexural Strength Test for Water Cement Ratio 0.38 at 7,14 and 28 days.

Mix	% Replacement	Average Flexural Strength in N/mm² 7 days	Average Flexural Strength in N/mm² 14 days	Average Flexural Strength in N/mm² 28 days
M0	0	4.00	4.35	5.01
M1	5	5.70	6.02	6.25
M2	10	6.05	6.49	6.57
M3	15	5.65	5.77	6.09
M4	20	5.55	5.67	5.99



With 10% replacement the proportion of silica fumes to water cement. 0.35 at 7, 14 and 28 days, the strongest flexural capacity was determinedto be 45.29%, 43.93% and 30 %.

The 28-day flexural strength is really boosted by the addition of 5% silica fume, and the flexural strength increases to its maximum level when the silica fume volume reaches 10%. Otherwise, silica fume at 15% and 20% addition rates reduces the 28-day strength water cement must be used for all purposes ratios.

In comparison with conventional concrete, the flexural bond strength of silica fume concrete at twenty eight days grew steadily. M30 grading for concrete, the maximum value was 10% the water cement ratio needs to be replaced 0.35.

5.2 Split Tensile Strength

Tensile strength test as per IS 5816:1999 were conducted regarding M30 grade concrete made having and not having silica fume with a number of water cement ratios of 0.32, 0.35 and 0.38 were determined 7 days, 14 days and 28 days. The results that occurred of investigation concrete M30 provided in table. The gain in splitting tensile the strength has been noticed in silica fume in a contrast to normal mix at 7days, 14 days as well as the 28th day with 5% replacement level.

Table 5.7: Split Tensile Strength for Water Cement Ratio 0.32 at 7, 14 and 28 days.

Mix	% Replacement	Average Split Tensile Strength in N/mm² 7 days	Average Split Tensile Strength in N/mm² 14 days	Average Split Tensile Strength in N/mm² 28 days
M0	0	3.15	3.23	3.63
M1	5	3.55	4.02	4.37
M2	10	3.84	4.30	4.86
M3	15	3.66	3.96	4.20
M4	20	3.51	3.78	3.86

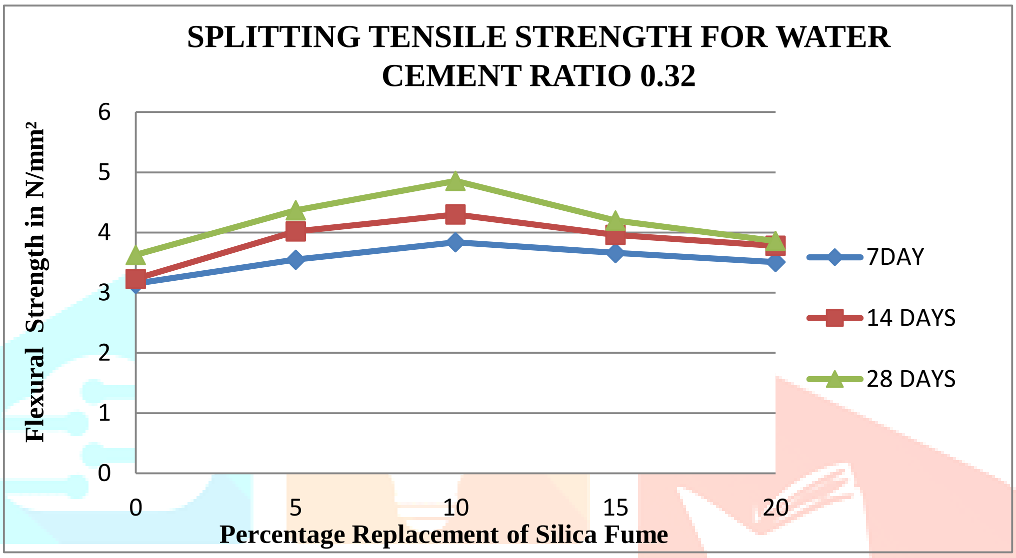


Table 5.7: Split Tensile Strength for Water Cement Ratio 0.35 at 7,14 and 28 days.

Mix	% Replacement	Average Split Tensile Strength in N/mm² 7 days	Average Split Tensile Strength in N/mm² 14 days	Average Split Tensile Strength in N/mm² 28 days
M0	0	3.23	3.55	3.98
M1	5	3.63	4.10	4.42
M2	10	3.92	4.38	4.94
M3	15	3.74	4.04	4.28
M4	20	3.59	4.10	4.18

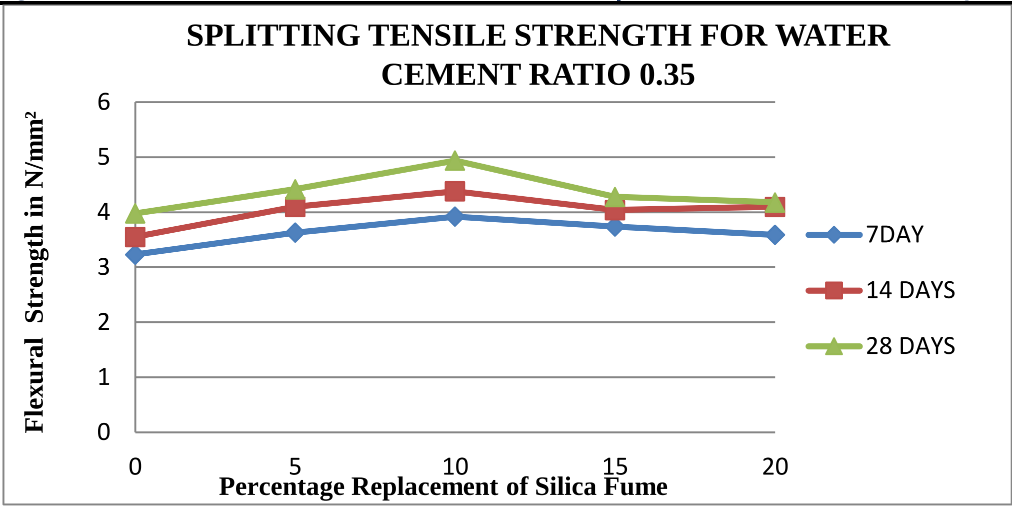
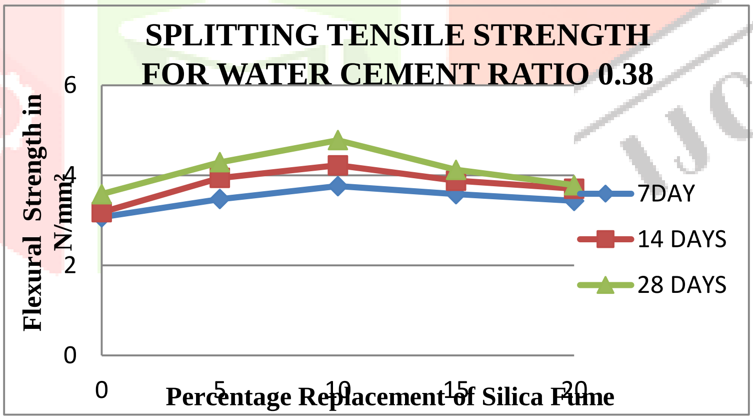


Table 5.7: Split Tensile Strength for Water Cement Ratio 0.38 at 7,14 and 28 days.

Mix	% Replacement	Average Split Tensile Strength in N/mm² 7 days	Average Split Tensile Strength in N/mm² 14 days	Average Split Tensile Strength in N/mm² 28 days
M0	0	3.07	3.18	3.58
M1	5	3.47	3.94	4.29
M2	10	3.76	4.22	4.78
M3	15	3.58	3.88	4.12
M4	20	3.43	3.70	3.78



For cement to water ratio of 0.35, the growth in strength from figure (7.19) is 21.36%, 23.38%, and 24.12% at seventh, fourteenth and twenty-eight days. At a 10% substitution of silica fume, the greatest improvement in tensile stiffness strength is shown.

The water-cement-ratio of the mix has been discovered being a consequence of the ideal silica fume replacement percentages for tensile strength. The best 28-day the split tensile strength was discovered to be between 5 and 10% silica fume replacement level, whereas the strength in split tensile varied from 15 to 25% for water cement ratios between 0.32 and 0.38.

6 CONCLUSIONS AND SCOPE OF FUTURE WORK

6.1 Conclusions

Consequently, the present experimental investigations the outcomes are as follows.

1. When the percentage is a silica fume increases the workability is also increasesbecause the particle size of fumes from silica finer than cement.
2. As the percentage of silica fume increases water absorption is also increases.
3. When the proportion of silica fumes rises from 0% to 20%, the usual consistencyincreases.
4. The results obtained for 0.35 water cement ratio has better values as compared to 0.32 and 0.38 water cement ratios.
5. At days 7, 14, and 28 with water-cement ratio of 0.35 with 10% replacement of silica fume, the compressive strength improves by 48.98%, 33.16% and 23.49% as compared to typical compression strength of planar concrete.
6. When 10% replacement of silica fume is added to cement with a water-to-cement ratio of 0.35, the flexural strength increases by 45.29%, 43.93%, and 30% compared to the typical flexural strengths for flat concrete at 7 days, 14 days, and 28 days.
7. Tensile strength increases by 21.36%, 23.38%, and 24.12% during days 7, 14, and28 respectively, with a water-cement ratio of 0.35 and 10% replacement of silica fume as compared to the typical tensile values for ordinary concrete.
8. It is observed that behind 10% usage of silica fume for all water cement ratios the strength of concrete starts to decrease. Therefore the optimum replacing silica fume with is 10% for compressive, split tensile and flexural strength tests.
9. Industrial by-products, such as silico fume are effectively utilized in place concrete for better results and also to cut the price of construction.

6.2 Future Scope of Studies

1. When compared to market prices and the advantages we obtain, adding silica fume to concrete improves its qualities while also being very cost-effective.
2. Different grades of concrete can be employed by using silica fume in place ofcement for varying water cement ratio

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