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Comparative study on mechanical properties of High Strength silica fume blended concrete using polyethylene glycol (PEG4000)

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Abstract : Concrete plays a major role in the construction applications of various concrete structures. It can be used for all high-rise buildings for the needs of durability and strength. We can mold concrete into any shape and size you require. In the manufacture of concrete, the cement used plays a crucial role in achieving its strength and durability properties. Nowadays High strength concrete (HSC) is widely used all over the world and to produce it is necessary to reduce the water/binder ratio and increase the binder content**.** This investigation mainly focuses on the strength properties of silica fume (SF)-based HSC. In this study, SF was kept at 15% in the production of HSC and also this study involves along with concrete the admixture polyethylene glycol (PEG4000) is added. The affect of adding (PEG 4000) on compressive strength, split tensile test by different percentage of PEG i.e.(0.5%, 1%, 1.5%) were studied for M60, M70 and M80 grades. By observing the results that the optimum dosage age of PEG is 1% for both M60,M70 and M80 grades. The compressive strength value is compared to normal concrete due to the addition of 15% silica fume, the strength is more as our desired grades of concrete. Also, when PEG4000 was added, the mechanical properties increased at 1% of peg 4000 compared to normal concrete having 15% silica fume.

IndexTerms **– Silica Fume, PEG(4000),Compressive strength, Split Tensile.**

I. INTRODUCTION

The Indian Cement Company Ltd produced only one type of cement, Artificial Portland Cement, which was designed by the British Standards Committee. This company became a financial success by marketing its products in Mumbai, Karachi, Madras, and other cities. HSC has piqued the interest of structural and structural engineers in recent years. The growing commercial use of these relatively new construction materials can be explained in part by the life cycle cost-performance ratio they provide, as well as engineering properties like higher compressive and tensile strengths when compared to conventional normal strength concrete.

Concrete plays an important part in the construction of many constructions. It can be employed in all high-rise constructions that demand durability and strength. We can shape and size concrete to any desired shape and dimension. The cement used in the production of concrete plays an important role in achieving its strength and durability attributes. Limestone, clay, and other minerals are often burned to high temperatures in a kiln to produce a fine powder that is used as cement in concrete. When coupled with water, cement undergoes a chemical reaction that produces a paste that fuses the rocks together to form a strong and long-lasting product. I used standard Portland cement and self-curing concrete for this project, which means that water will hold the concrete in place. Polyethylene glycol PEG (4000) is the self-curing concrete chemical I've used. In the 1980s, the terms high strength concrete (HSC) and high performance concrete (HPC) were developed, resulting in increased durability with compressive strengths ranging from 7000 to 17000 psi. Portland cement is still the most often used binder in concrete, driving a hunt for new environmentally friendly solutions. Several initiatives are underway to supplement the use of Portland cement in concrete in order to solve global warming concerns. These include using supplemental cementing elements like silica fume and developing alternative binders to Portland cement.

Research is mainly focused on

1. To study the mechanical properties of SF based HSC with M60,M70 and M80 grades after 7,14 and 28days of curing.
2. To determine the mechanical properties by adding 0%, 0.5%, 1% and 1.5% of Polyethylene glycol (PEG 4000) and compare the strength for conventional concrete and self curing concrete.

II. LITERATURE REVIEW

Piyush Kumar (2022), study shows that the cement has been replaced by fly ash accordingly in the range of 0%, 10%, 20%, 30%, 40%, 50%, and 60% by weight of cement and 10% of silica fume in common for M30 grade of Concrete. Concrete mixtures produced, tested and compared in terms of compressive strength and split tensile strength with the conventional concrete for 7, and 28 days. It is found that, 30% of fly ash and 10% of silica fume can be replaced and good strength obtained is comparable to the conventional concrete mix.

Mohamed M. Abu El-Hassan, Gamal M. Kamh, Mohamed A. Fahmy, Alaa A. Bashandy (2020), The investigational performance of hardened high strength concrete cast with Nano-silica, silica fume, and fly ash is revealed in this study. Experiments were carried out by replacing cement by weight with Nano-silica, silica fume, or fly ash in ratios of 5%, 10%, and 15% and comparing the results to a control mix. According to the findings, the hardened qualities of concrete improved based on the type of supplemental cementious materials used. The results of the tests showed that adding the specified types improves concrete strength. The addition of Nano-silica has a significant impact on the characteristics of concrete. Increasing the dosage above 5.0% has a negative impact on strength..

Judita Gražulytė, Audrius Vaitkus et. al,. (2020) study reveals that Three, the same type, concrete mixtures with different amount of silica fume (0%, 7% and 10%), but the same water/cement ratio (0.4) were produced and tested in compression, tension, bending and cyclic loading. In addition to this, density was determined to identify the difference in concrete microstructure due to presence of silica fume.

G. Thrinath, et.al (2017) By adding 1% more PEG-400, compressive strength increases, and by adding more PEG-400 than that, compressive strength decreases. When PEG-400 is added, the split tensile strength value increases by 1%, and the strength decreases by more than 0.5% of PEG. By adding 0.5% of PEG-400, the flexural strength value is enhanced, and by adding more than 0.5% of PEG, it is diminished.

T. Anbhazhagan, et.al (2017) M_{25} grade concrete with 2% of PEG, gives compressive & split tensile strength as same as ordinary concrete. It was discovered that 2% of PEG for M25 grade was the ideal dose for maximal strength. It was discovered that the workability of self-curing concrete decreased as the proportion of polyethylene glycol increased.

III. EXPERIMENTAL METHODOLOGY

Overall, the experimental methodology employed in research on the mechanical properties of silica fume blended high strength concrete is intended to give trustworthy and precise data that can be used to improve the performance and durability of concrete in a variety of applications. A thorough selection of components, an optimum mix design, controlled sample preparation, standardized testing processes, and rigorous data analysis and interpretation are all part of the technique.

Silica Fume: Silica fume is a byproduct of the silicon and ferrosilicon industries, and is typically added to high strength concrete in small quantities (up to 10% by weight of cement). Silica fume particles are extremely small (usually less than 1 micron in diameter) and have a high surface area, which can improve the strength and durability . Specific gravity of Silica fume is 2.2.

Fig.1 silica fume

Table 1. Properties of Silica Fume

Characteristics of S.F.	Results
Physical State	Micronized powder
Density	0.76 gm/cc
Sp. Gravity	2.2
Moisture Content	0.058%

Polyethylene Glycol:

Polyethylene glycol (PEG) is a water-soluble, odourless, and tasteless polymer that is commonly used in a wide range of applications, including medicine, food, cosmetics, and industrial manufacturing. PEG4000 is added to self-curing concrete as a pore-forming agent, which helps to create a network of interconnected pores in the concrete. These pores allow for the release of moisture from the concrete, which is necessary for the chemical reactions that occur during the curing process. The use of PEG4000 in self-curing concrete has several benefits, including improved strength, durability, and reduced cracking.

Fig.2.Polyethylene Glycol

2.Properties of Polyethylene glycol

Characteristics of PEG 4000	Test results
Physical state	Waxy solid
Melting point	50-60℃
Specific gravity	1.124

Super plasticizer:

A super plasticizer is a type of chemical admixture used in concrete mixes to increase its workability without sacrificing its strength. Super plasticizers are also known as high-range water reducers (HRWRs) as a result of their capacity to lower water content needed in the mix while maintaining a consistent level of fluidity**.**

Fig .3 Super Plasticizer

MIX DESIGN :

Table 3: Mix Design for M60, M70 and M80 grades

MATERIALS USED	M60	M70	M80
Cement (Kg/m^3)	350	400	450
Silica fume (Kg/m^3)	52.5	60	67.5
Water (lt / m^3)	160	160	130
Super plasticizer (lt / m^3)	3.22	3.68	4.14
Coarse aggregate (Kg/m^3)	1133	1117	1118
Fine aggregate (Kg/m^3)	692	656	692

TESTS PERFORMED FOR MECHANICAL PROPERTIES:

COMPRESSION TEST:

Compression tests are widely used to assess the quality and performance of materials used in construction, manufacturing, and engineering. Compression test findings can be used to establish a material's fitness for a specific application, compare the performance of other materials, and assure compliance with industry norms and regulations..

Fig 4: COMPRESSION TEST MACHINE

SPLIT TENSILE TEST:

A split tensile test is a type of mechanical test used to evaluate the tensile strength of cylindrical concrete specimens. In this test, a cylindrical concrete specimen is placed horizontally between two steel platens in a testing machine, and a compressive load is applied vertically to the specimen until it fails.

Fig 5.Splittng Test

IV RESULTS AND DISCUSSION

The Compressive strength and Split tensile values were measured after 7 and 28 days of curing with and without PEG4000

COMPRESSIVE STRENGTH TEST:

Universal Testing Machine (UTM) used to determine the compressive strength of cubes. The cubes are tested after dried for sun light about half an hour. Table shows the results of compressive strength of specimens at different curing periods such as 7 and 28 days.

Table :4 Compressive strength with out PEG4000

Compressive Strength (MPa)		
Grade of Concrete used	**7 days**	**28days**
M60	47.75	71.26
M70	53.94	79.32
M80	59.89	88.89

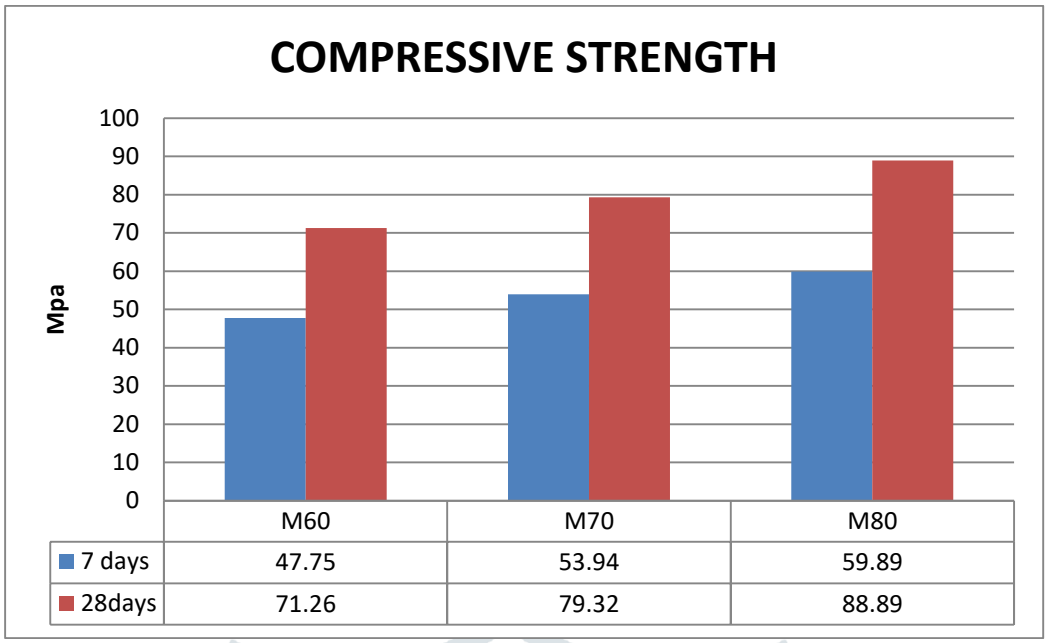

Fig 6.Compressive strength without PEG4000

As we know, when the grade of concrete increases, the compressive strength also increases. Here M60 has 71.26 MPa compressive strength but M70 and M80 has 79.32 MPa and 88.89 MPa respectively. It is observed that increase of compressive strength is resulting when increasing the grade of concrete.

SPLIT TENSILE STRENGTH TEST:

The cylindrical concrete specimens are taken to test. The weights of specimens are to be noted. The metal strips are placed above and below the specimen while placing for testing at the testing machine. The loading is gradually applied. Table shows the results of split tensile strength of cylindrical specimens for different curing periods of 7 and 28days**.**

Table:5 Split Tensile Strength without PEG4000

Split Tensile Strength(MPa)		
Grade of Concrete used	**7 days**	**28days**
M60	2.07	3.59
M70	2.07	4.21
M80	3.28	4.37

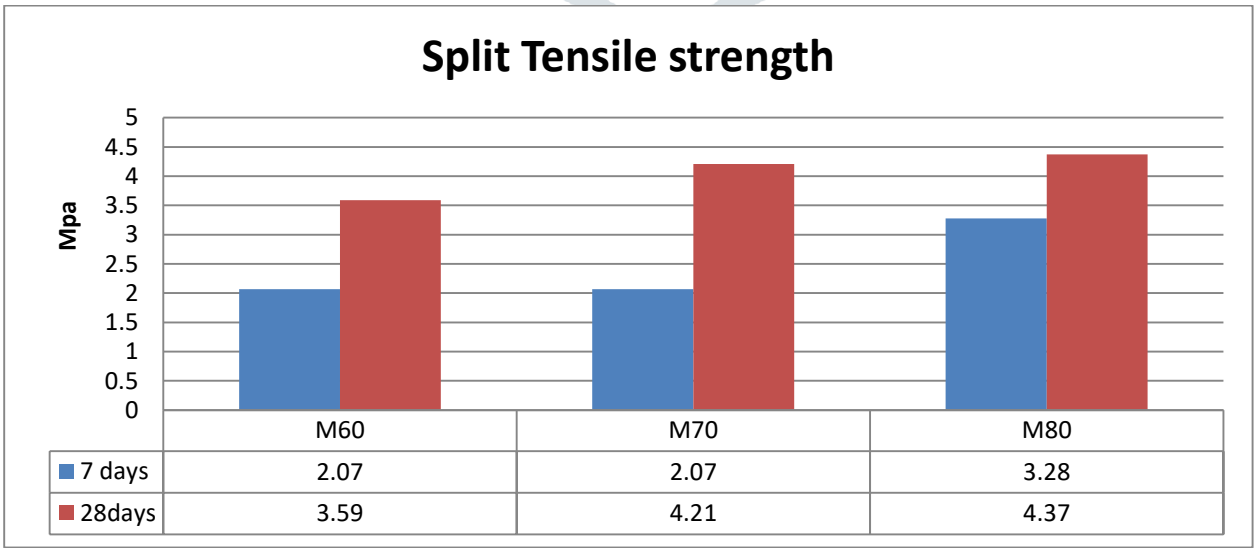

Fig:7 Split Tensile Strength without PEG4000

Here M60 has got 3.59 MPa for 90 days of curing but in the case of M70 and M80 the split values are increased when compared to M60 grade's split values. We can observe that the higher grade of concrete and more curing period are resulting high split tensile strength.

Comparison on Mechanical properties of High strength concrete with and without PEG4000:

The findings of compressive strength, split tensile strength, and elastic modulus for concrete of grades M60,M70 and M80 are tabulated for the appropriate % dose of polyethylene glycol (PEG 4000), and are explained below.

Compressive strength Parameters:

M60 Grade

Table: 6 Evaluating the compressive strength of concrete with Silica fume and Polyethylene Glycol (PEG-4000).

Type of concrete	Grade of mix	Range of Polyethylene glycol (%)	Compressive strength (MPa)	
			7 days	28 days
Conventional Concrete	M60	0	47.75	71.26
Polyethylene Glycol	M60	0.5	57.02	75.13
		1	62.15	78.25
		1.5	45.2	70.25

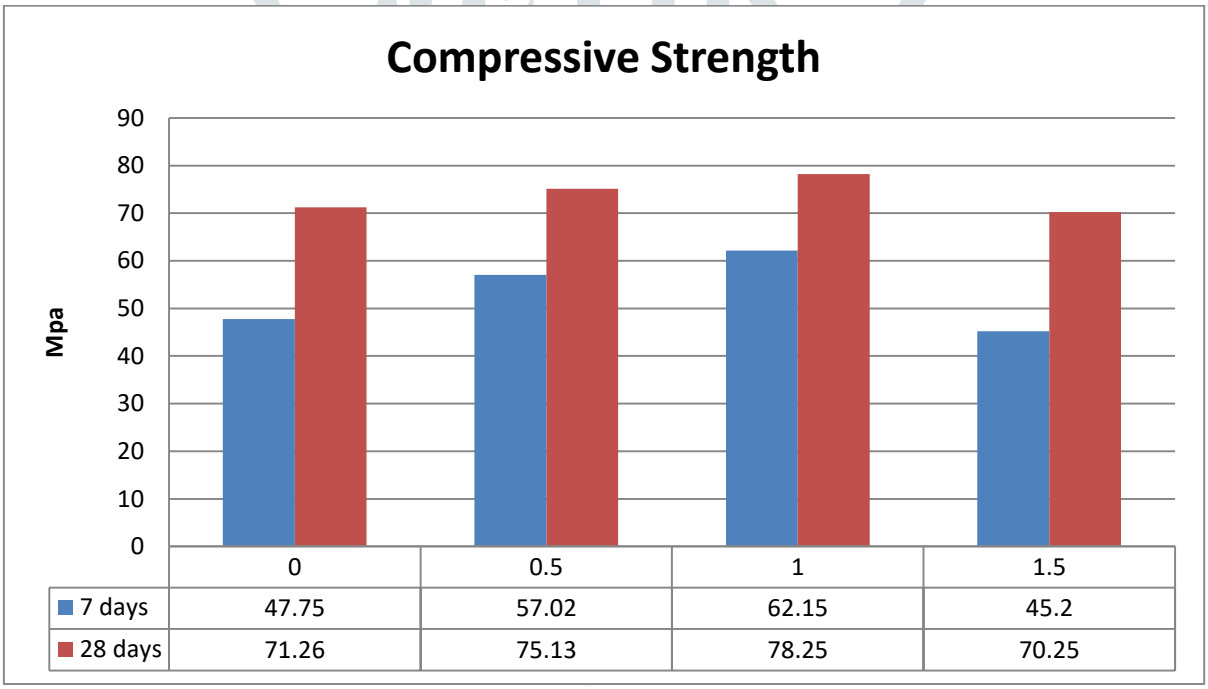

Fig:8 Comparison on Compressive strength of High strength (M60) concrete with and without PEG4000:

When we compare with conventional concrete having silica fume with peg 4000 the strength value is increases with increasing peg4000 upto1%. The highest value of compressive strength at 7 days and 28 days was 62.15mpa,78.25mpa at 1% of peg4000 . The use of peg4000 has given good strength results in concrete up to 1%. Compressive strength value decreases due to use of more than 1% peg4000. Using 1.5% peg4000 in concrete has reduced the strength value significantly as compared to conventional concrete having silica fume. The least strength values were observed at addition of 1.5% Peg4000.

M70 Grade

Table 7 Evaluating the compressive strength of concrete with Silica fume and Polyethylene Glycol (PEG-4000).

Type of concrete	Grade of mix	Range of Polyethylene glycol (%)	Compressive strength (MPa)	
			7 days	28 days
Conventional Concrete	M70	0	53.94	79.32
Polyethylene Glycol	M70	0.5	62.95	82.45
		1	67.65	84.46
		1.5	58.5	76.24

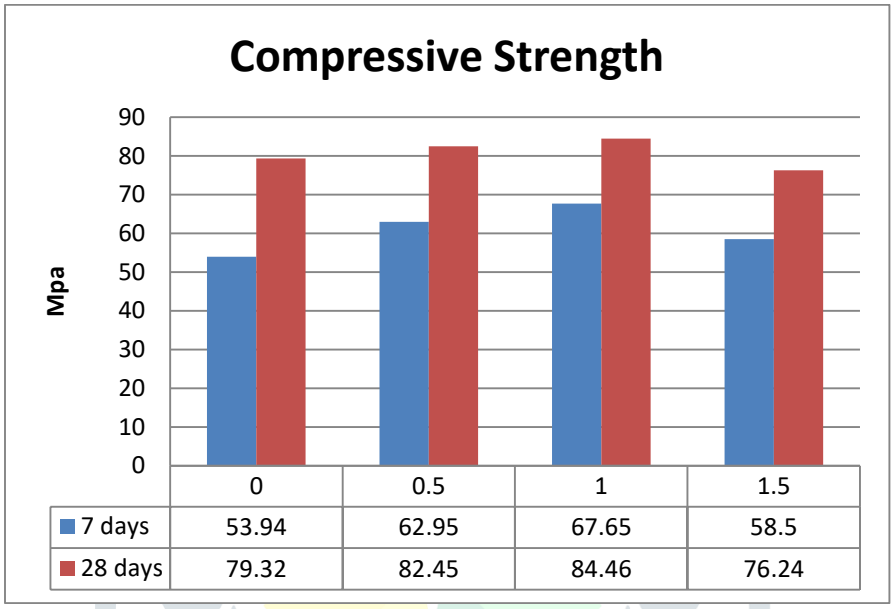

Fig 9:Comparison on Compressive strength of High strength (M70) concrete with and without PEG4000

When we compare with conventional concrete having silica fume with peg 4000 the strength value is increases with increasing peg4000 upto1%. The highest value of compressive strength at 7 days and 28 days was 67.65mpa and 84.46mpa at 1% of peg4000 . The use of peg4000 has given good strength results in concrete up to 1%. Compressive strength value decreases due to use of more than 1% peg4000. Using 1.5% peg4000 in concrete has reduced the strength value significantly as compared to conventional concrete having silica fume. The least strength values were observed at addition of 1.5% Peg4000.

M80 Grade

Table 8.Concrete's compressive strength in comparison to Silica fume and Polyethylene Glycol (PEG-4000)

Type of concrete	Grade of mix	Range of Polyethylene glycol (%)	Compressive strength (MPa)	
			7 days	28 days
Conventional Concrete	M80	0	59.89	88.89
Polyethylene Glycol (PEG-4000)	M80	0.5	65.91	93.54
		1	68.8	95.15
		1.5	60.12	89.7

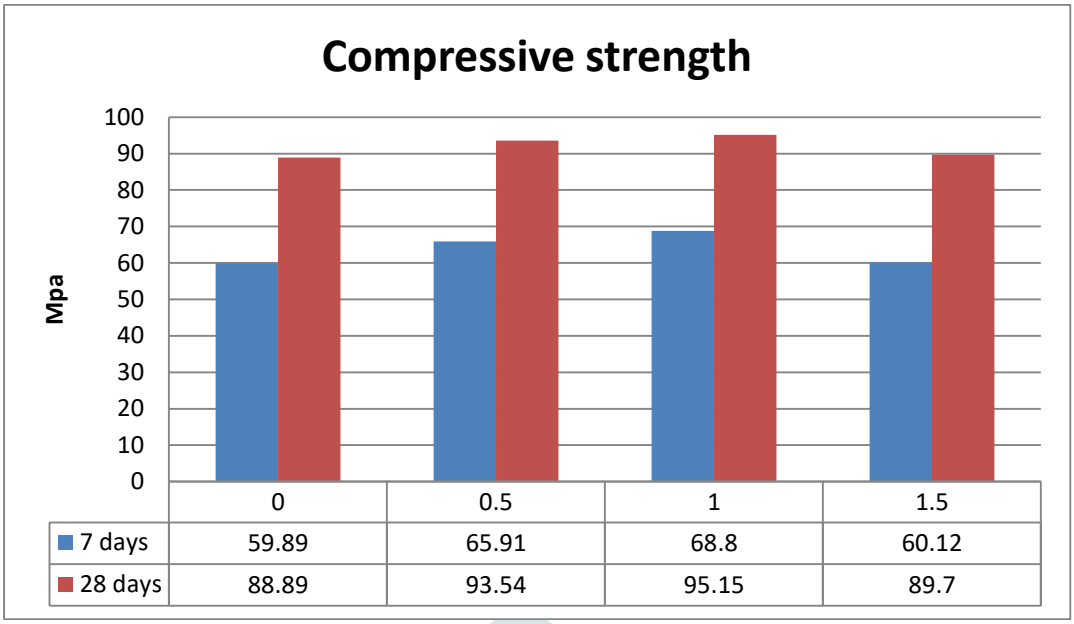

Fig 10:Comparison on Compressive strength of High strength (M80) concrete with and without PEG4000

When we compare with conventional concrete having silica fume with peg 4000 the strength value is increases with increasing peg4000 upto1%. The highest value of compressive strength at 7 days and 28 days was 68.8mpa and 95.15mpa at 1% of peg4000 . The use of peg4000 has given good strength results in concrete up to 1%. Compressive strength value decreases due to use of more than 1% peg4000. Using 1.5% peg4000 in concrete has reduced the strength value significantly as compared to conventional concrete having silica fume. The least strength values were observed at addition of 1.5% Peg4000.

Split tensile strength Parameters:

M60 Grade

Table 9.comparison of the concrete's split tensile test with Silica fume and Polyethylene glycol (PEG- 4000).

Type of concrete	Grade of mix	Range of Polyethylene glycol (%)	Split tensile strength (MPa)	
			7 days	28 days
Conventional Concrete	M60	0	2.07	3.59
Polyethylene Glycol	M60	0.5	2.26	3.87
		1	2.42	4.06
		1.5	2.12	3.62

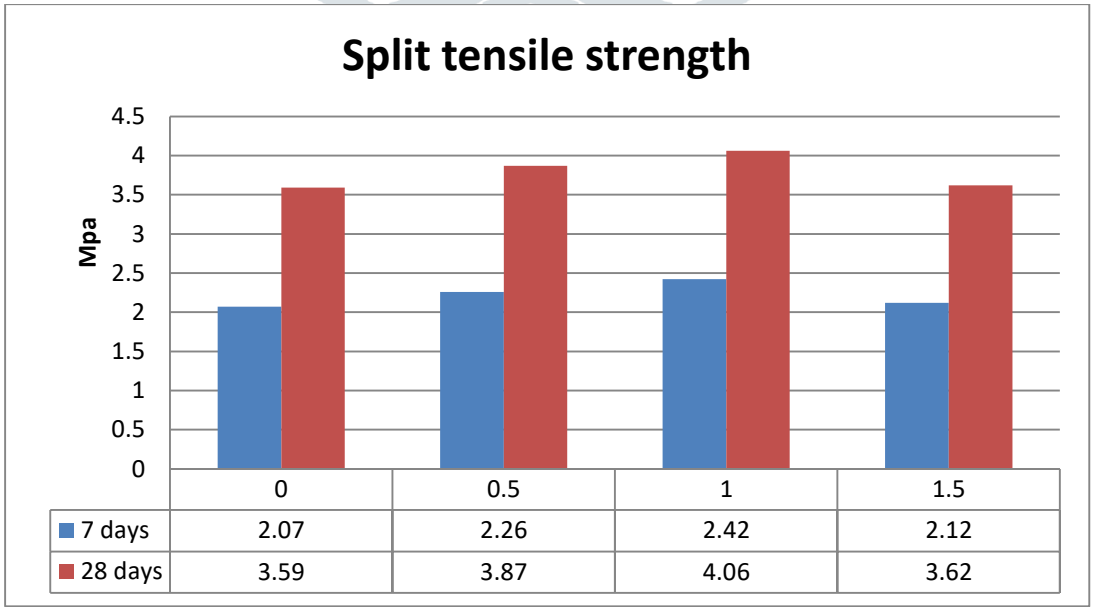

Fig 11:Comparison on Split tensile strength of High strength (M80) concrete with and without PEG4000

The splitting tensile strength for the mixtures is presented in Figure. The splitting tensile strength were tested after 7days and 28days in accordance with IS standard. Figure shows that the splitting tensile strength increased as the Peg4000 content increased

for mixes upto 1%. The strength of split started to increase when 0.5% of Peg4000 was added to the concrete compared to conventional concrete having silica fume. Maximum strength is achieved by adding 1% peg4000 in concrete and the strength values are 2.42Mpa, 4.06Mpa for 7 days, 28days of curing. Addition of more than 1% of peg4000 in concrete resulted in decreased strength values of split. The values of 1.5% addition of peg4000 in concrete are 2.12Mpa,3.62Mpa for 7days,28days of curing.

M70 Grade

Table 10.comparison of the concrete's split tensile test with Silica fume and Polyethylene glycol (PEG- 4000).

Type of concrete	Grade of mix	Range of Polyethylene glycol (%)	Split tensile (MPa)	
			7 days	28 days
Conventional Concrete	M70	0	2.07	4.21
Polyethylene glycol (PEG-4000)	M70	0.5	2.21	4.37
		1	2.39	4.64
		1.5	2.11	4.21

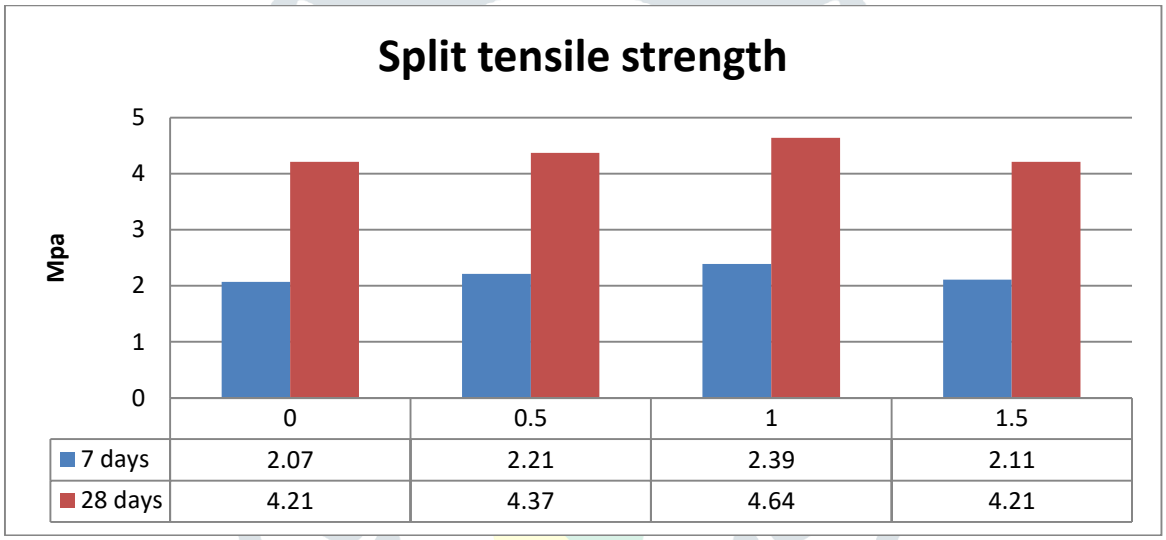

Fig 12:Comparison on Split tensile strength of High strength (M80) concrete with and without PEG4000

The strength of split started to increase when 0.5% of Peg4000 was added to the concrete compared to conventional concrete having silica fume. Maximum strength is achieved by adding 1% peg4000 in concrete and the strength values are 2.39Mpa, 4.64Mpa for 7 days, 28days of curing. Addition of more than 1% of peg4000 in concrete resulted in decreased strength values of split. The values of 1.5% addition of peg4000 in concrete are 2.11Mpa,4.21Mpa for 7days,28days of curing.

M80 Grade

Table 11: Concrete's split tensile strength in comparison to silica fume and polyethylene glycol (PEG-4000).

Type of concrete	Grade of mix	Range of Polyethylene glycol (%)	Split tensile (MPa)	
			7 days	28 days
Conventional Concrete	M80	0	3.28	4.37
Polyethylene glycol (PEG-4000)	M80	0.5	4.47	4.86
		1	4.62	5
		1.5	4.11	4.41

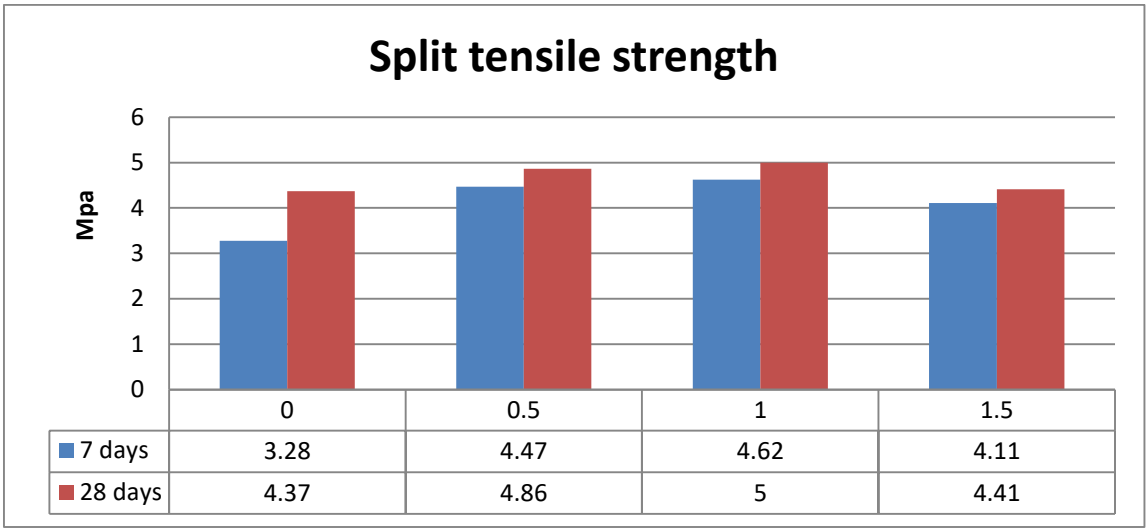

Fig 13:Comparison on Split tensile strength of High strength (M80) concrete with and without PEG4000

The strength of split started to increase when 0.5% of Peg4000 was added to the concrete compared to conventional concrete having silica fume. Maximum strength is achieved by adding 1% peg4000 in concrete and the strength values are 4.62Mpa, 5Mpa for 7 days, 28days of curing. Addition of more than 1% of peg4000 in concrete resulted in decreased strength values of split. The values of 1.5% addition of peg4000 in concrete are 4.11Mpa,4.41Mpa for 7days,28days of curing.

V.CONCLUSIONS

- The 15% replacement of silica fume improved the mechanical properties of concrete significantly.
- It is observed that as curing period increases, the compressive strength and splitting tensile strength values were increased.
- It is concluded that the optimum proportion of silica fume significantly contributed to the strength of high strength concrete
- We have clearly observed that M60, M70 and M80 grade mixes are resulting high compressive strength for 56days curing period i.e., 71.26MPa, 79.32MPa and 88.89 MPa respectively
- Split tensile values are increasing with increasing of curing periods when grades of concrete are increasing.
- Split tensile strength for M60 is 3.59 MPa for 28days but incase of M70 and M80 are 4.21MPa and 4.37 MPa respectively.
- For all M60, M70 and M80 grades, 1% is the recommended polyethylene glycol (PEG 4000) dose percentage.
- At 1% of (PEG4000) the compressive strength values were reached highest when compared it with conventional concrete having 15% silica fume for all grades.
- At 1.5% of (PEG4000) the compressive strength values are reduced but that value is more than conventional concrete.
- At 1% of (PEG4000) the Split tensile strength values were reached highest when compared it with conventional concrete having 15% silica fume for all grades.
- At 1.5% of (PEG4000) the Split tensile strength values are reduced but that value is more than conventional concrete.
- By using polyethylene glycol (PEG4000) the specimens were not cured in water hence, the water usage is reduced and the cost of PEG4000 is effective.

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