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EFFECTS OF FIBER AND SILICA FUME CHARACTERISTICS ON MECHANICAL PROPERTIES OF HIGH-STRENGTH CONCRETE

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Abstract - *Cement industry is one of the major sources of emitting greenhouse gases, such as CO_2, which contributes about 65% of global warming besides deforestation and burning of fossil fuels. In order to address the environmental effects associated with cement industry, there is a need to develop an alternative binding material for concrete manufacturing. Extensive research has been conducted to identify a better replacement for cement using waste materials and industrial by-products. Recent studies on silica fume supports that it can be used as partial replacement of cement. In this current study, silica fume(SF) is used as a partial replacement of cement and polypropylene fiber (PP)is added in order to investigate the mechanical properties of concrete. Silica fume were partially replaced from 5% to 25% and 0.1% of polypropylene fiber were added to test for its compressive and tensile strength. The result of 7^{th} and 28^{th} days of concrete were compared with those of conventional concrete, reveals that silica fume in combination with polypropylene fiber yields high strength both in compression and in tension. The addition of polypropylene fiber increases the strength of concrete by reducing its unit weight whereas the silica fume act as a better replacing material with its own characteristics. It is observed that the optimum percentage for replacement of Silica fume is 10% and addition of 0.1% Polypropylene fiber increases the compressive and tensile strength up to 27.18N/mm^2 and 4.4N/mm^2 respectively.*

Key Words: Fiber Reinforced Concrete, Polypropylene Fiber, Silica Fume, Concrete.

1. INTRODUCTION

Cement is very commonly used construction material; concrete has better resistance to compression. Conventional concrete has limited ductility, low impact and abrasion resistance and little resistance to cracking. A good concrete must possess high strength and low permeability. Admixtures are also added in concrete to improve their strength properties of the concrete material such as silica fume, which are usually very fine, the average size being about 0.15 µm. This makes it approximately 100 times smaller than the average cement particle. Because of its extreme fineness and very high amorphous silicon dioxide content, silica fume is a very effective pozzolanic material. When added to concrete in right proportion can improve the strength of concrete extremely. In order to improve the mechanical properties of concrete, it is good to mix cement with fiber which has good tensile strength. Addition of fibers to concrete makes it as a homogeneous and isotropic material.Considering the economic criteria and several advantages, polypropylene fiber is used for this study. The addition of polypropylene fibers decreases the unit weight of concrete and increases its strength. Silica fume used in 5%, 10%, 15%, 20% and 25% and polypropylene fiber used in 0.1% constant in the mix of M25. The addition of Fiber in concrete improves the tensile strength, flexural strength, toughness, impact strength and also failure mode of concrete.

2. MATERIALS & METHODS

2.1 Materials:

Commonly available Portland Pozzolona Cement of 53 grade was selected for the investigation. Cement used is made by lime & clay and it is powdery, dry, and free from lumps. Cement used is hydraulic & sets very easily. Concrete is prepared by using locally available sand and aggregates. Aggregates used are ordinary crushed stone with the size of 20mm.They posses all the essential qualities of a good stone showing very high crushing strength, less porosity & low absorption value. Water used in this investigation is bore water. Polypropylene fiber was collected from the nearby district in the form of long threads at reasonable cost. These threads are cut into small pieces of 2cm length while using in the concrete mix. Silica fume is replaced with cement and it is collected from industrial areas. Specific gravity and other material properties were tested for all the materials and the results are given below in Table 1.

Table -1: Material Properties

S.No	Properties	Cement	Fine Aggregate	Coarse Aggregate
1	Specific Gravity	3.15	2.388	2.89
2	Sieve Analysis	-	3.17	8.02
3	Water Absorption	-	1.0%	0.5%
4	Initial Setting Time	31mins	-	-

2.2 Concrete Mixes:

The mixes were designated with the grade of concrete and the type of fine aggregates used. IS Method of concrete mix was used to achieve a mix a strength of 25MPa. Mix design was done by using IS 10262-2009, IS 10262-1982 code books. Mix proportions arrived and silica fume along with polypropylene fiber was added to the concrete mix with a W/C ratio of 0.43. Mix specifications for varying percentage of silica fume & control specimen are given in Table 2.

Table -2: Mix Specifications

S.No	Mix ID	Silica Fume (%)	Polypropylene Fiber (%)
1.	SF0PP0	0	0
2.	SF5PP0.1	5	0.1
3.	SF10PP0.1	10	0.1
4.	SF15PP0.1	15	0.1
5.	SF20PP0.1	20	0.1
6.	SF25PP0.1	25	0.1

3. EXPERIMENTAL METHODOLOGY

3.1 Preparation of test Specimens:

Test specimens are prepared for various concrete specimens. It is prepared by mixing cement, fine aggregate, coarse aggregate, admixtures along with water. Hand mixing is preferred for this investigation. After thorough mixing, the concrete is placed into the moulds which were properly oiled. Compaction is done simultaneously while placing the concrete into the mould, it is done by using vibrator table and manually by hand. Cube specimens of 150 x 150 x 150 mm are moulded to test compressive strength and rebound hammer test. Cylinders of 150mm diameter and 300mm height are moulded to test split tensile strength. Specimens are demoulded after 24 hours of casting and were kept in a curing tank for curing. A durability test was carried out with cube specimens after 28 days curing.

3.2 Testing of Specimens:

3.2.1 Compressive Strength Test

The compression test shows the compressive strength of hardened concrete. The compression test shows the best possible strength concrete can reach in perfect conditions. The compression test measures concrete strength in the hardened state. Testing should always be done carefully. Wrong test results can be costly.

The testing is done in a laboratory off-site. The only work done on-site is to make a concrete cylinder for the compression test. The strength is measured in MPa and is commonly specified as a characteristic strength of concrete measured at 28 days after mixing. The compressive strength is a measure of the concrete's ability to resist loads which tend to crush it. The following table shows the test values:

Table -3: Compressive Strength

S.NO	MIX ID	AVERAGE	
		7DAYS	28DAYS
1	SF0PP 0	21.96	34.31
2	SF5PP 0.1	23.40	36.56
3	SF10PP 0.1	17.4	27.18
4	SF15PP 0.1	18.2	28.43
5	SF20PP 0.1	22.9	35.78
6	SF25PP 0.1	24.85	38.82

3.2.2 Tensile Strength Test

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on the concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. The following table shows the test values for the cylinder specimens:

Table -4: Split Tensile Strength

S.NO	MIX ID	AVERAGE	
		7DAYS	28DAYS
1	SF0PP 0	2.4	3.75
2	SF5PP 0.1	3.46	5.4
3	SF10PP 0.1	2.82	4.4
4	SF15PP 0.1	2.97	4.63
5	SF20PP 0.1	3.04	4.75
6	SF25PP 0.1	3.39	5.28

3.2.3 Rebound Hammer Test

Rebound hammer test is done to find out the compressive strength of concrete by using rebound hammer as per IS: 13311 (Part 2) – 1992. The underlying principle of the rebound hammer test is the rebound of an elastic mass depends on the hardness of the surface against which its mass strikes. When the plunger of the rebound hammer is pressed against the surface of the concrete, the spring-controlled mass rebounds and the extent of such a

rebound depends on the surface hardness of the concrete. The surface hardness and therefore the rebound are taken to be related to the compressive strength of the concrete. The rebound value is read from a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer.

Figure – 1: Rebound Hammer Test

The average value is 14. Hence, from rebound hammer chart the compressive strength test value is given below:

Table - 5: Rebound Hammer Test Results:

S.No	Specimen	Rebound Hammer Readings		Compressive Strength	
		7 Days	28 Days	7 Days	28 Days
1	SF0PP0	15	16	23.1	23.7
2	SF5PP0.1	17	17	24.3	24.3
3	SF10PP0.1	19	20	25.8	26.2
4	SF15PP0.1	19	21	25.8	27.5
5	SF20PP0.1	20	21	26.2	27.5
6	SF25PP0.1	21	22	27.5	28.2

3.2.4 Ultrasonic Pulse Velocity Test:

Ultrasonic test on concrete is a recognized non-destructive test to assess the homogeneity and integrity of the concrete. With this ultrasonic test on concrete, the following can be assessed. Qualitative assessment of the strength of concrete, its gradation in different locations of structural members and plotting the same. Any discontinuity in cross section like cracks covers concrete delamination etc. The depth of surface cracks. Aiming to understand how some parameters influence the UPV, this work studied different concrete types, with different characteristics, manufactured with Portland cement and various types of aggregates.

Table - 6: Ultrasonic Pulse Velocity Test Results:

S.No	Specimen	Ultrasonic Pulse Velocity Readings		Compressive Strength	
		7 Days	28 Days	7 Days	28 Days
1	SF0PP0	3439	3456	23.2	23.6
2	SF5PP0.1	3486	3492	24.1	24.1
3	SF10PP0.1	3521	3587	25.7	26.1
4	SF15PP0.1	3527	3642	25.7	27.5
5	SF20PP0.1	3598	3654	26.3	27.5
6	SF25PP0.1	3659	3754	27.8	28.5

4. RESULT & DISCUSSIONS:

4.1 Compressive Strength Test:

From the test results obtained, the compressive strength for 7days and 28 days for the prepared specimen and control specimen is compared and shown in the chart below.

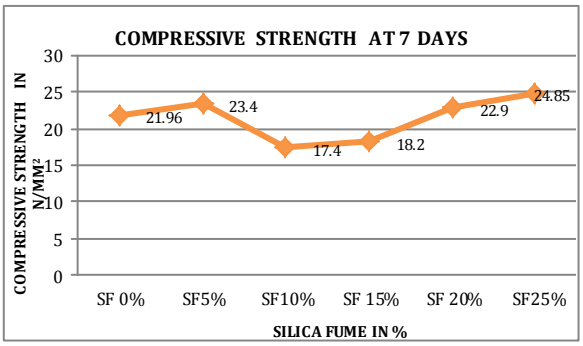

Chart – 1: Compressive Strength 7 Days

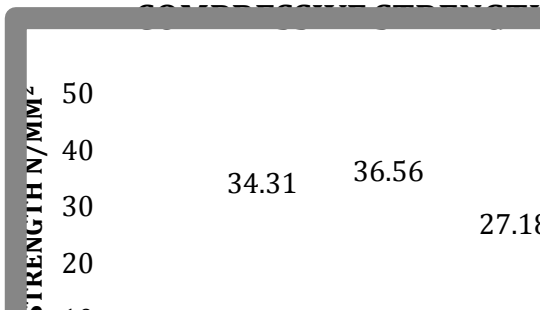

Chart - 2: Compressive Strength 28 Days

4.2 Split Tensile Strength Test:

From the test results obtained, the split tensile strength for 7days and 28 days for the prepared specimen and control specimen is compared and shown in the chart below.

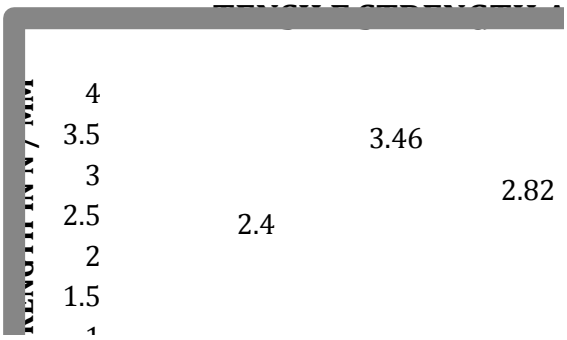

Chart - 3: Split Tensile Strength 7 Days

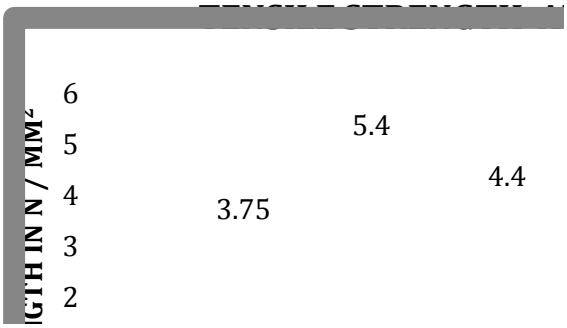

Chart - 4: Split Tensile Strength 28 Days

An investigation was made on the mechanical properties and strength characteristics by conducting the tests on Silica fume concrete with the addition of Polypropylene fiber and the results revealed that replacement of silica fume with 15% and the addition of polypropylene fiber with 0.1% gives better results in compressive and tensile strength.

4.3 Rebound Hammer Test:

Finally, from the above test results, it is observed that the compressive strength value determined by this method is almost equal to the direct compressive strength while testing the cube. Also, the quality of concrete is good and it is properly compacted and cured.

4.3 Ultrasonic Pulse Velocity Test:

Finally, from the above test results, it is observed that the compressive strength value determined by this method is almost equal to the direct compressive strength while testing the cube and Rebound Hammer Test. Since path travel time is less it is observed that the quality of concrete is good, it is homogenous, low crack visibility and has very good dynamic elastic modulus.

5. CONCLUSIONS

This study is intended to find the effective ways to use silica fume as replacement of cement and addition of polypropylene fiber in concrete. Analysis of the strength characteristics of concrete with SF and PP gave the following results:

1. Replacement for the cement and the compressive strength are increased as the percentage of silica fume and polypropylene fiber is increased.
2. The optimum percentage of replacement of cement by silica fume and the addition of polypropylene fiber is 10%, i.e: SF10PP 0.1. The percentage of increase in the compressive strength for optimum SF10PP0.1 is 27.18 N/mm^2 at the age of 28 days by replacing of cement with silica fume 25% and polypropylene fiber 0.1%.
3. Rebound hammer test results and UPV test results are nearby equal to the compressive strength test result while testing under CTM.
4. Concrete with silica fume and polypropylene fiber can be effectively used in round floor slab and precast product/units.
5. Finally, it is concluded that 10% of Silica fume concrete can be incorporated as a cement replacement in concrete without any long term determinantal effects and with acceptable mechanical and strength development properties.

6. LIMITATIONS & FUTURE WORKS

In this study, the effect of fiber and silica fume characteristics with replacement of SF ranging from 5% to 25% and addition of PP with a constant of 0.1% was carried out. Here are few limitations, which shows that there is a constant PP0.1% but fiber can be added in concrete within the range of 0.1-3% and instead of Silica fume other natural or mineral admixtures can be added. Future works is to be performed by conducting Flexural strength test, Scanning Electron Microscopic (SEM) analysis, Rapid Chloride Penetration Test and other durability tests.

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