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The Mechanical Properties of Concrete Incorporating Silica Fume And Fly Ash as A Partial Replacement of Cement.

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Abstract-- **Concrete is the world's most consumable product next to water. Concrete is the most used construction material in the civil engineering. Silica fume and Fly ash are the concrete containing cementitious material which increases its structural integrity. Silica fume and Fly ash are the materials made of a cementitious matrix. It has been widely used in the construction industry for non-structural elements, like façade panels, piping and channels. In the present work, fresh properties and harden properties of Silica fume and Fly ash concrete are compared. To evaluate the fresh properties, slump cone and compaction factor tests are conducted. To evaluate the harden properties, compression and split tensile tests are conducted for 7 days and 28 days of curing. M20 grade concrete is designed using IS 10262:2009 provisions.**

Keywords-- **Compressive strength; Split tensile strength; Slump test; Compaction factor test.**

I. INTRODUCTION

Concrete is one of the most common material used in the construction industry. In the past few years, many research and modifications has been done to produce concrete which has the desired characteristics. There is always a search for concrete with higher strength and durability. Particularly mineral admixtures are indispensable in production of high strength concrete for practical application. The use of mineral admixtures 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. The best mineral admixtures in optimum proportions mixed with OPC improves many qualities of concrete such as lowers the heat of hydration, increases the water tightness, reduces alkali-aggregate reaction, improves workability and resistance to attack by sulphate soils, sea water.

1.1Pozzolanic action

Micro silica is much more reactive than any other natural pozzolana. The reactivity of a pozzolana can be quantified by measuring the amount of $Ca(OH)_2$ in the cement paste at different times.

In one case, 15% of micro silica reduced the $Ca(OH)_2$ of two samples of cement from 24% to 12% at 90 days and from 25% to 11% in 180 days. Most research workers agree that the C-S-H formed by the reaction between micro silica and $Ca(OH)_2$ appears dense and amorphous.
When water is added to OPC (ordinary Portland cement), hydration occur forming two products, as shown below:

$$OPC + H_2O \rightarrow \text{C-S-H (Calcium silicate hydrate)} + Ca(OH)_2$$

In the presence of micro-silica, the silicon dioxide from the micro-silica will react with the calcium hydroxide to produce more aggregate binding C-S-H as follows:-

$$Ca(OH)_2 + SiO_2 + H_2O \rightarrow \text{C-S-H}$$

1.2. Silica fume applications in concrete

Because of the pozzolanic and micro-filler effect of micro-silica, its use in concrete can improve many of its properties opening up a wide range of applications including:-

1.2.1 Corrosion Resistance

The reduced permeability of micro-silica provides protection against intrusion of chloride ions thereby increasing the time taken for the chloride ions to reach the steel bar and initiate corrosion. In addition, micro-silica concrete has much higher electrical resistivity compared to OPC concrete thus slowing down the corrosion rate. The combined effect generally increased structures life by 5 –10 times.

1.2.2 Sulphate Resistance

Micro-silica concrete has a low penetrability and high chemical resistance that provides a higher degree of protection against sulphates than low C_3A sulphate resisting cements or other cementitious binder systems.

1.2.3 Heat Reduction

By replacing cement with Micro-silica and observing the efficiency factor of Micro silica, lowers the temperature rise and temperature differential will take place for concrete with the same strength.

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It is also the most effective way of achieving low heat without sacrificing early age strength.

1.2.4 Silica Fume Waterproof Concrete

Because of its low permeability, micro-silica can be use as an integral water-proofer for below ground structures where some dampness is acceptable, eg.., Car parks.

1.2.5 High Strength Concrete

Micro-silica in conjunction with super-plasticizers is used to produce very high strength concrete (70 – 120 MPa). It is also much easier to pump micro-silica concrete up the high rise buildings during construction.

1.2.6 Abrasion Resistance

Micro-silica concrete has very high abrasion resistance. In floor and pavement construction it's use saves money and time and improves operational efficiencies for the facility operator. It also improves the hydraulic abrasion-erosion resistance of concrete thus making it suitable for use in dam spillways.

1.2.7 Abrasion Resistance

Micro-silica concrete is widely used in industrial structures exposed to an array of chemicals aggressive. In the alimentary industry the exposure comes from fat acids and other acids, detergents, etc. In the chemical industry there is exposure from mineral acids, phosphates, nitrates, petrochemicals, etc. Micro-silica concrete is therefore invaluable in the industrial and agricultural sectors.

1.3. Advantages And Disadvantages Of FLY ASH

The following are the advantages of Fly ash:

1. Reduction in amount of water.
2. Reduces permeability.
3. Better workability and pump ability.
4. Increase in strength and durability.
5. Improves cohesiveness.

The following are the disadvantages of Fly ash:

1. It may cause negative effect.
2. Concrete sets slowly with Fly ash.

II. Objectives Of The Study

The following are the main objective of the study

1. Main objectives of this experimental investigation is to find out the effect of addition of the Silica fume and Fly ash as partial replacement of cement at varying percentages.
2. To evaluate the compressive strength of M20 grade of concrete with varying equal percentages of Silica fume and Fly ash (0%,5%,10%,15%,20%and 25% by weight of concrete) at 7 and 28 days of curing.
3. To evaluate the split tensile strength of M20 grade of concrete with varying equal percentages of Silica fume and Fly ash (0%,5%,10%,15%,20%and 25% by weight of concrete) at 7 and 28 days of curing.
4. To evaluate the optimum dosage of Silica fume and Fly ash for M20 grade of concrete.

III. Materials And Methodology

1. Cement

In this present work Zuwari cement of 43grade ordinary Portland Cement (OPC) was used for casting cubes and cylinder for all concrete mixes. The cement was of uniform color i.e. Grey with a light greenish shade and was free from any hard lumps. The various tests conducted on cement are specific gravity, initial and final setting time and compressive strength. Testing on cement was done as per IS codes. The results obtained are presented in the table 1.

Table 1
Physical properties of cement

Particulars	Experimental Results	As per standard IS 8112:2013
Specific gravity	3.15	---
Setting time (minutes)		
Initial setting time	45 minutes	30 minutes (Minimum)
Final setting time	560 minutes	600 minutes (Maximum
Compressive strength		
3 days	22.79MPa	16MPa (minimum)
7 days	34.52MPa	22MPa (minimum)
28 days	46.28MPa	43MPa (minimum)

2. Fine Aggregate

The sand used for this project was locally procured and conformed to grading zone II as per IS: 383-1970. The physical properties of the river sand are as shown in the table 2.

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Table 2
Physical properties of FA

Particulars	Experimental Results
specific gravity	2.5
Fineness modulus	3.06
water absorption	1.0%
free moisture content	0%

3. Coarse Aggregate

Locally available coarse aggregate having the maximum size of 20mm were used in the present work. The physical properties of the coarse aggregate are as shown in the table 3.

Table 3
Physical properties of CA

Particulars	Experimental Results
specific gravity	2.66
water absorption	0.5%
free moisture content	0%

4. Water

Potable tap water was used for the preparation and curing of the specimens.

5. Silica Fume

It is the Mineral admixture available in mineral industries. In present work silica fume from "Manglore Minerals Pvt Ltd…" was used. It is having specific gravity of '2.3'.

6. Fly ASH

This mineral admixture produced during the burning of coal, charcoal etc. Fly ash used in the present work is obtained from "Manglore Minerals Pvt Ltd…". It is having specific gravity of '2.5'.

IV. MIX-DESIGN

The proportioning of the ingredients of concrete is an important phase of concrete technology as it ensures quality and economy. In pursuit of the goal of obtaining concrete with desired performance characteristics the selection of component materials is the first step, the next step is a process called mix design by which one arrives at the right combination of the ingredients. The mix design procedure adopted in the present work to obtain M20 grade concrete is in accordance with IS: 10262-2009.

The specific gravities, mix proportion, mix designation of the materials used are as tabulated in the below table 4,5 and 6 respectively.

Table 4
Specific gravities of materials used

Ingredients	Specific gravity
Cement	3.15
Fine aggregate	2.50
Coarse aggregate	2.66

Table 5
Mix proportion

W/C ratio	Water (kg/m^3)	Cement (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)
0.55	212.56	386.47	796.70	903.9

Table: 6
Mix designations

Mix	Description
M0	Control concrete of grade M20
M1	5% of Silica fume and 5% of Fly ash
M2	10% of Silica fume and 10% of Fly ash
M3	15% of Silica fume and 15% of Fly ash
M4	20% of Silica fume and 20% of Fly ash
M5	25% of Silica fume and 25% of Fly ash

V. CASTING OF SPECIMEN AND TESTING PROCEDURE

Cement, sand and aggregates were taken in the mix proportion 1:2.04:2.62 which correspond to M20 grade concrete. The concrete was produced by mixing all the ingredients homogeneously. To this dry mix, required quantity of water was added (w/c ratio=0.55) and the entire mix was again homogeneously mixed and respective proportion of Silica fume and fly ash are added (Fig 2) and mixed thoroughly. This wet concrete was poured into the moulds which was compacted both through hand compaction in three layers as well as through vibrator. After the compaction, the specimens were given smooth finish and taken out of the table vibrator. After 24 hours, the specimens were de molded and transferred to curing tanks where they were allowed to cure for required number of days.

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Fig2 : Addition of silica fume and fly ash

For evaluating the compressive strength, specimens of dimensions 150× 150×150mm were prepared. They are tested on 3000kN capacity compression testing machine as per IS 516 – 1959. The compressive strength is calculated by using the equation,

$$f_{ck} = P/A$$

Where,

f_{ck} = compressive strength of the specimen(in MPa).
P = Maximum load applied to the specimen (in N).
A = Cross sectional area of the specimen (in mm^2).

For evaluating the split tensile strength, cylindrical specimens of diameter 150mm and length 300mm were prepared. Split tensile strength test was carried out on 3000kN capacity compression testing machine as per IS 5816 – 1999. The split tensile strength is calculated using the equation,

$$f_{sp} = 2P/(\pi DL)$$

Where,

F_{sp} = split tensile strength of concrete (in MPa).
P = Load at failure (in N).
L = Length of cylindrical specimen (in mm).
D = Diameter of cylindrical specimen (in mm).

VI. Experimental Results

Fresh properties of concrete: - The test conducted on fresh properties of control concrete and concrete made with partial replacement of Silica fume and fly ash. The tests conducted for workability of concrete were slump test and compaction factor test; results are represented in Table 7 and 8also with figure 3 and 4 respectively.

Table 7
Slump test results

Sl.no	Mix	Slump(mm)
1	M0	91
2	M1	91
3	M2	94
4	M3	95
5	M4	98
6	M5	98

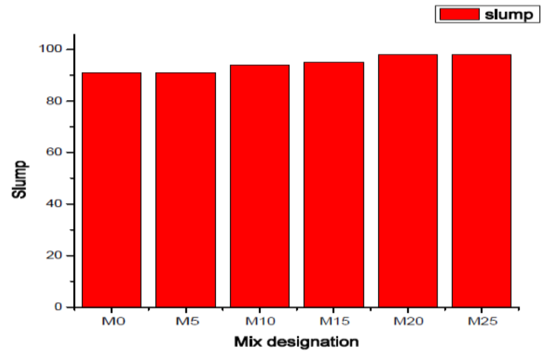

Fig 3: Variation of slump for different mixes

Table 8
Compaction factor test values

Sl.no	Mix	Compaction factor
1	M0	0.81
2	M1	0.80
3	M2	0.82
4	M3	0.84
5	M4	0.86
6	M5	0.86

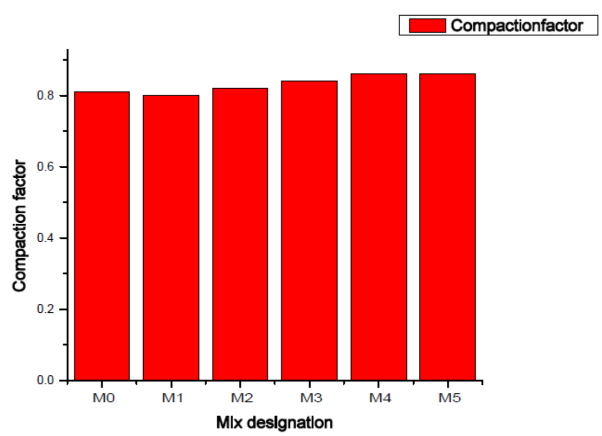

Fig4: Variation of compaction factor for different mixes

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Hardened properties of concrete:

Compressive strength test results: For each concrete mix, the compressive strength is determined on three 150X150X150mm cubes at 7 and 28 Days of curing. Following Table 9 and Fig 5shows the compressive strength test results of control concrete and concrete made with different percentages of Silica fume and Fly ash.

Table 9:
Overall Results of Compressive Strength

Mix	Compressive strength (N/mm²)	
	7 Days	28 Days
M0	15.98	27.17
M1	16.71	24.56
M2	19.76	27.61
M3	22.23	31.60
M4	22.09	23.25
M5	19.62	22.09

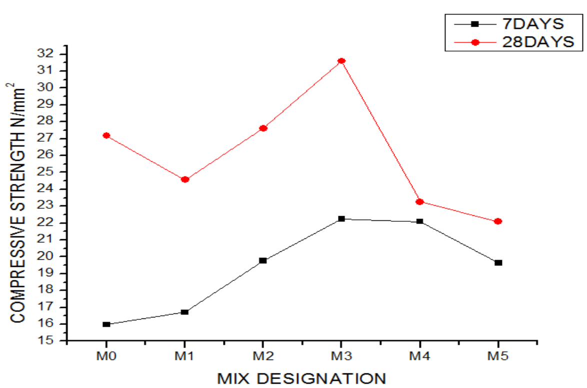

Fig 5: compressive strength of different mixes

Split tensile test results: The test has been conducted after 7 and 28 days of curing. Split tensile test conducted on 150mm diameter and 300mm length cylinder as per IS: 5186-1999. Following Table 10 and Fig 6shows the split tensile test results of control concrete and concrete made with different percentages of Silica Fume and Fly ash.

Table 10
Overall Results of Split tensile Strength

Mix	Split tensile strength (N/mm²)	
	7 Days	28 Days
M0	1.988	2.219
M1	1.981	2.210
M2	2.158	3.090
M3	1.757	2.580
M4	1.711	2.390
M5	1.618	2.310

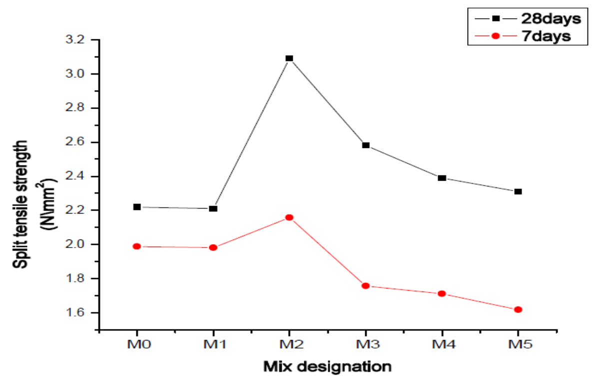

Fig 6: split tensile strength of different mixes

VII. Observations And Discussions

In the present work an attempt has been made to use silica fume and fly ash as the partial replacement for cement. The effect of silica fume and fly ash on cement concrete in fresh and harden state is investigated and the following observations were made from the experiment conducted.

To study the fresh properties of concrete, slump and compaction factor tests were conducted for control concrete and concrete made with fly ash and silica fume with equal percentages.

1. From the results of the workability it is clearly observed that addition of silica fume and fly ash increases the workability
2. From slump test, it is observed that the slump value increases as the percentage of the silica fume and fly ash increases in concrete, the resulting mix will be more cohesive.
3. From compction factor test, it is observed that the value of compaction factor increases as the percentage of silica fume and fly ash in the concrete increases. The particals of silica fume and fly ash are very small, resulting in the cohesive mix.
4. At 7 day curing periode the compressive strength of the mix M3 is higher than the all other mixes. The compressive strength of M1, M2, M3, M4 and M5is showing higher strength compared to control concrete by 4.57%, 23.65%, 39.11%, 38.23%, and 22.78% respectively M3 mix showed maximum increased strength of 39.11% when comapared to referance mix.

5. At 28days of curing M3 mix showes the maximum compressive strength. When compared to referance mix,the strength increased for M2 and M3 mixes but for M1, M4, and M5 mixes the strength were decreased. Increased in strength for M2 and M3 are 1.619% and 16.31% respectively also decrease in strength for M1, M4 and M5 are 9.6%, 14.42% and 18.69% respectively.
6. At 7 days of curing M2 mix showed maximum split tensile strength when compaared to the other mixes. The value of strength increased for M2 mixes by 39.25% , but for M3, M4 and M5 it again increased by 16.26%, 7.7% and 4.91% respectively.
7. The over all result showed that, the compressive and split tensile strengthgot increased as the percentage of Silica fume and Fly ashis increased from 0% to 15% (15% silica fume and 15% fly ash) also further addition of Silica fume and fly ash more than 15%, showed the decreases og compressive and split tensile strength.
8. The test on fresh conrete showed the increase of workability with the addition of both of the miniral admixtures.
9. Use of mineral admixtures showed early strength in the concrete.

VIII. Conclusions

1. Use of silica fume and fly ash with same percentage by partial replacement of cement,increases the workability of concrete.
2. At 28 days of curing by using 15% of Silica fume and 15% of fly ash as parial replacement of cement increase in the compressive strength of 39.11% is achived
3. At 28 days of curing by using 10% of silica fume and 10% of fly ash as a partial replacement of cement increase in split tensile strengthof 29.25% is achived when compared to the referance mix.
4. Workability of concrete can be increased by the addition of silica fume and fly ash at higher percentages.
5. Compressive strength of the higher value can be obtained at 15% of silica fume and 15% of fly ash replacement with cement as a pozzolona.
6. Split tensle strength of higher value can obtained at 10% of silica fume anf 10% of fly ash replacement with cement as a pozzolona.
7. Hence from the carried out experimental work, it can be concluded that the optimum dosage og both silica fume and fly ash can be ristricted between 10% to 15% by partial replacement of cement.
8. Higher early strength can be obtained by using silica fume and fly ash.

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