MECHANICAL PROPERTIES OF HIGH VOLUME FLYASH CONCRETE INCORPORATED WITH MICROPARTICLES

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Abstract*: Flyash is considered as waste material. Production of flyash from thermal plants is very high and dumping of flyash is a major issue with the industry. In other hand production of cement is costly and affects the environment. Cement manufacturing industries contribute greatly in CO_2 emission. The utilization of High volume flyash concrete (HVFAC) in construction is considered as sustainable option. HVFAC shows significant reduction in strength compared to normal concrete. It was observed that HVFAC develops strength at lower rate compared to normal concrete. Aim of the study is to evaluate the strength of concrete replacing cement by flyash in 30%, 40%, 50% variations. Effect of micro calcium carbonate and micro silica in HVFAC. The major cost of normal concrete comes from cement in it. By reducing the cement content by replacing it with flyash cost of the concrete can be reduced considerably.*

Keywords: **High volume Flyash concrete (HVFAC), Micro calcium carbonate, Micro silica, Superplasticizer, water cement ratio.**

1. INTRODUCTION

Population growth, urbanization, industrialization and rise in disposable income are key growth drivers of the industry. It is expected to be the world's 3rd largest construction market by 2025. Cement capacity addition of 80-100 MT per annum is expected over the next five years. The most astonishing thing about cement is how much air pollution it produces. Manufacturing the stone-like building material is responsible for 7% of global carbon dioxide emissions, more than what comes from all the trucks in the world. It highlights the difficulties of taking greenhouse gases out of buildings, roads and bridges. After wresting deep cuts from the energy industry, policymakers looking to extend the fight against global warming are increasingly focusing on construction materials and practices as a place to make further reductions. The disposal of fly ash is a major problem in India. Industries and power plants in the country produce 40 million tonnes of this fine powder every year. While some companies use fly ash as landfill material, disposal remains a vexatious process. Fly ash does not require to be ground and can be used instead of clay in the manufacture of cement. Fly ash ran also be used in concrete a mixture of cement, stones, sand and water. Fly ash can be replaced more than 50% in concrete.

2. OBJECTIVE

- The aim of the present study is to investigate the properties of modified concrete which is produced by using industrial wastes like Fly ash as partial replacement of cement by intrusion of micro calcium carbonate particles ($CaCO_3$) and micro silicon oxide particles (SiO_2).
- The present investigation is aimed to study the behaviour of modified concrete on physical properties such as compressive strength, flexural strength, split tensile strength on cube, prism and cylinder specimen respectively.

3. LITERATURE REVIEW

K VEDA SAMHITHA, V SRINIVASA REDDY, M V SESHAGIRI RAO AND S SHRIHARI (2019)

In the present study, high strength high volume fly ash concrete of M70 grade is developed and its durability properties such as water absorption capacity, porosity, and sorptivity are ascertained. It was found that high volume fly ash does not yield high strength so silica fume is added for early strength gain and for later strength gain lime required for complete pozzolonic action is added to achieve high performance concrete. In this study after testing for various combinations of quaternary blended concrete it was reported that 30% cement +70% flyash as total powder achieves high strength of nearly 70 MPa, when silica fume of 10% by weight of powder and 30% of lime by weight of powder are added to the total powder content. The high strength high volume concrete developed with these optimum quantities of quaternary blends will be evaluated for the performance. It was found that water absorption in high strength high volume fly ash concrete reduced by nearly 85% and porosity is reduced by 34%. Final high strength quaternary blended mix is made up of 30% cement, 70% fly ash, 10% silica fume and 30% lime with water cement ratio of 0.3.

K. KRISHNA TEJA AND B. KAMESWARA RAO (2018)

This paper emphasizes the strength and durability aspects of replacing High Volume Fly-Ash (HVFA) in concrete by comparing with Plain Concrete. Eight numbers of different mix proportions were designed with different water to cementitious ratios for two grades such as 30MPa and 40MPa. Throughout eight batches two are of Plain Concrete with superplasticiser and other of fly-ash concretes with percentages 50%, 60% and 70% including superplasticiser. Concrete specimens were tested after a curing period of 7 and 28 days to obtain the compressive strengths, chloride ion penetration through concrete specimens by Rapid chloride permeability test using standard practice C-1202. The laboratory test results shows that the compressive strength of 28 days period for HVFA concretes attained satisfactory as compared to Normal concrete, except as for 70% replacements. Rapid Chloride Permeability tests shows that HVFA concretes have more resistance to chloride ion penetration as compared to Plain Concrete.

ER. BHUPINDER SINGH AND ER. AJAYJASROTIA2 (2017)
Design of M40 concrete mix replacement of cement by fly ash is to be made 28%, 50%, 70%. Compressive strength of 3, 7 and 28 days is to be calculated and Flexural strength of 28 and 56 days is calculated by casting beam. Cost comparison of 28%, 50% and 70% fly ash concrete are to be made. The compressive and flexural strength of M40 concrete at 50% fly ash replacement by the mass of cement are acceptable, and therefore can be used in construction practice.
If we compare M25 concrete with the compressive and flexural strength of M40 concrete at 70% fly ash replacement by the mass of cement the result are acceptable and at a cost lower than M25 concrete.

KALISETTI RENUKA DEVI AND J. SUDHAMANI (2017)
This article presents the results of an experimental investigation dealing with high volume fly ash (HVFA) concrete incorporating high volumes of Class F fly ash. Portland cement was replaced with high percentages (40%, and 50%) of Class F fly ash. M 30 is used as control mix (M1) with 0% fly ash. M2 and M3 contain Fly ash of 40 and 50%. Tests were performed for fresh concrete properties: slump, Compressive, splitting tensile, and flexural strengths were determined up to 7 and 28 days of testing. The workability of concrete measured from slump cone test. The slump value for control mix was obtained as 65mm. For M2 and M3 which contain Fly Ash in 40 and 50 % wt. of Cement, the slump values obtained were 85 and 100 mm respectively. This shows that the addition of Fly Ash increases the workability of concrete without addition of water. This will have a positive impact on the strength of concrete. Test results indicated that the use of high volumes of Class F fly ash as a partial replacement of cement in concrete decreased its 28-day compressive, splitting tensile and flexural strengths of the HVFA concrete. However, the rate of strength development from 7 days to 28 days is very interesting and likely to continue beyond 28 days. Based on the test results, it was concluded that Class F fly ash can be suitably used up to 50% level of cement replacement in concrete for use in precast elements and reinforced cement concrete construction.

TAPESHWAR KALRA AND RAVI KUMAR (2016)
During this work cement has been replaced by fly ash consequently within the range of 0% (without fly ash), 25%, 40%, 50% and 60% by weight of cement for M-25 Mix Concrete mixtures were moulded, tested and compared in terms of compressive, split and flexural strength. Compressive strength of 3, 7 and 28 days is to be calculated by casting cubes for M40 mix at 28%, 50% and 70% fly ash replacement by cement. Flexural strength of 28 and 56 days is to be calculated by casting beam shaped samples of M40 mix at 28%, 50% and 70% fly ash replacement by cement. Comparison of the compressive and the flexural strength Obtained at different percentages of fly ash is to be made. Cost comparison of 28%, 50% and 70% fly ash concrete are to be made.

SRILA DEY (2016)
An attempt is made to study the effect of compressive strength of high-volume fly ash concrete with varying proportion of silica fume and fly ash. Cement is replaced by fly ash and silica fume 50 to 80% and 0 to 15% by weight respectively. The compressive strength development of silica fume modified high-volume fly ash mixes immersed in water up to 7 to 45 days is reported. As the water content is low in high volume fly ash concrete, the bleeding is very low and often negligible. Setting time is little longer than that of conventional concrete. This is because of low cement content, low rate of reaction and high content of super plasticizer. The investigation revealed that by maintaining a constant dosage of high-performance super plasticizer along with fly ash and silica fume, it is possible to maintain optimum slump value i.e., workability, thereby satisfying most of the modern structural applications. Also, the isolated effect of silica fume on the high-volume fly ash concrete with a water cement ratio of 0.40 has been studied. The results indicate that there is a remarkable increase in the compressive strength of concrete on replacement of cement by silica fume and fly ash and also obtained 10% replacement of silica fume by cement on high volume fly ash concrete gives higher compressive strength in the present investigation.

MR. A. GUNASEELAN AND MR. K. M. RAMALINGAM (2016)
This article presents the results of an experimental investigation dealing with concrete incorporating high volumes of Class F fly ash. Portland cement was replaced with three percentages (40%, 45%, and 50%) of Class F fly ash. Tests were performed for fresh concrete properties: slump, air content, unit weight, and temperature. Compressive, splitting tensile and flexural strengths were determined up to 28 days of testing. Test results indicated that the use of high volumes of Class F fly ash as a partial replacement of cement in concrete decreased its 28-day compressive, splitting tensile strength and flexural strengths of the concrete. Based on the test results, it was concluded that Class F fly ash can be suitably used up to 50% level of cement replacement in concrete for use in precast elements and reinforced cement concrete construction.

F.N. OKOYE AND N.B. SINGH (2016)
In the present investigation Portland cement has been replaced up to 60% by Fly ash. Five concrete mixes were designed to determine the effect of fly ash on workability, compressive, tensile and flexural strengths of concrete. Portland cement was replaced with fly ash by 20%, 30%, 40% and 60% respectively, while 100% Portland cement was used as control. The mechanical properties were

determined at 3, 14, 28, 56 and 90 days of hydration. Heat evolution profile has revealed that with the increase of fly ash, the rate of heat evolution is decreased. X-ray diffraction and SEM studies have shown the formation of different hydration products. The concrete containing different proportions of fly ash showed higher workability than the control. Higher the replacement of cement by FA, the higher was the workability. HVFA cement reduced cement consumption in concrete and minimized the amount of energy required in cement production. The compressive strength of concrete with fly ash decreased as the proportion of fly ash increased without any regular sequence. However, the compressive strengths obtained were of the order that could be used for normal construction work. The flexural strength decreased as the proportion of fly ash increased. In general, it can be inferred that high volume fly ash concrete can be used in normal construction work.

K. BAZZAR, M.R. BOUATIAOUI AND A. HAFIDI ALAOUI (2013)

This article presents the results of an experimental study containing large volumes of fly ash Moroccan class F. Cement has been replaced by two percentages (25% and 50%) of Class F fly ash [500μm]. This incorporation affects the properties of fresh concrete and mechanical properties and durability of concrete. The magnitude of this effect depends on the nature and proportion of fly ash used. The replacement of cement by this fly ash reduces the compressive strength, the tensile strength, the flexural strength and modulus of elasticity of the concrete at early age which has been improved in this study, and their continuous improvement and significant strength properties beyond 28 days. The reactivity of fly ash [500 μm] is increased by grinding them up to an average size of particles between [63-100] μm. The cement was replaced by 25% and 50% ground FA, so to produce a high-performance concrete.

4. MATERIALS USED

4.1 Cement

Ordinary Portland cement of grade 53 was used.

4.2 Flyash

In this research Class F Flyash was used.

Table 1: Physical Characteristics of class F flyash

Sl. No.	Characteristics	Unit	Results
1	Silicon Dioxide (SiO_2), Aluminium Oxide (Al_2O_3), Iron Oxide (Fe_2O_3)	% by mass	91.84
2	Silicon Dioxide (SiO_2)	% by mass	82.98
3	Magnesium Oxide (MgO)	% by mass	2.54
4	Total Sulphur as Sulphur Trioxide (SO_3)	% by mass	0.31
5	Available Alkalis as Sodium Oxide (Na_2O)	ppm	0.5
6	Total Chlorides	% by mass	0.03
7	Loss on Ignition		0.35
8	Specific Gravity		2.2
9	Bulk Density	Kg/m^3	1.21

4.3 Fine Aggregate

Fine aggregates used in this project belong to Zone-II.

Table 2: Physical characteristics M-Sand

Sl. No.	Particular of test	Results
1	Fineness Modulus	4.31
2	Specific Gravity	2.60
3	Zone	II

4.4 Coarse Aggregate

In this research 20 mm aggregates and 12.5 mm aggregates used in 60% and 40% respectively.

Table 3: Physical characteristics of Coarse Aggregates (12.50 mm)

Sl. No.	Test specification	Observations
1	Specific Gravity	2.65 mm
2	Absorption value (% by wt.)	0.50
3	Elongation Index	6.50 %
4	Flakiness Index	5.10 %
5	Crushing Value	22 %
6	Impact Value	22 %

Table 4: Physical characteristics of Coarse Aggregates (20 mm)

Sl. No.	Test specification	Observations
1	Specific Gravity	2.65
2	Absorption value (% by wt.)	0.30
3	Elongation Index	9.1 %

4	Flakiness Index	3.1 %
5	Crushing Value	23 %
6	Impact Value	22 %

4.5 Water

Potable water free from impurities was used.

4.6 Micro Calcium Carbonate

Table 5: Properties of micro calcium carbonate

Micro Calcium carbonate	Appearance Bulk density (gm/ml) pH	Snow white 0.44 9.5

4.7 Micro Silica

Table 6: Properties of micro silica

Micro Silica	Appearance Surface area Average particle size (µm) Water absorption (by weight %) Bulk density (gm/cc) pH	Snow white 123 11.18 224 0.18 6.8

4.8 Superplasticizer

Auramix 400 is a unique combination of the latest generation superplasticizers, based on a polycarboxylic ether polymer with long lateral chains. Auramix 400 combines the properties of water reduction and workability retention. It allows the production of high-performance concrete and/or concrete with high workability.

Dosage: The optimum dosage of Auramix 400 to meet specific requirements should always be determined by trials using the materials and conditions that will be experienced in use. The normal dosage range is between 0.2 to 1.5 ltrs/100 kg of cementitious material.

Properties

Appearance: Light yellow coloured liquid
pH: Minimum 6.0
Volumetric mass @ 200 C: 1.09 kg/litre
Chloride content: Nil.
Alkali content: Typically, less than 1.5 g Na_2O equivalent/ litre of admixture.

5. MIX DESIGN

Table 7: Proportioning of different mixes

Mix design was done for M40 concrete as per IS: 10262.

MIX 1: 100% cement
MIX 2: 70% cement + 30% flyash
MIX 3: 60% cement + 40% flyash
MIX 4: 50% cement + 50% flyash

MIX	Flyash (kg/m^3)	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	micro particles (kg/m^3)
MIX 1	000	400	796	1099	-
MIX 2	280	120	788	1064	-
MIX 3	240	160	772	1043	-
MIX 4	200	200	766	1036	-
MIX 5	200	200	766	1036	32

MIX 5: 50% cement + 50% flyash + 4% micro silica + 4%micro calcium carbonate

Water/cement ratio: 0.4
Superplasticizer : 0.4% of cementitious material.

6. TESTS ON CONCRETE AND RESULTS

- Compression strength was done on concrete cubes of 150 mm.
- Split Tensile Test performed on cylinders of 300 mm length and 150 mm diameter.
- Flexural Strength of concrete was done on prism of dimension 10 mm X 10 mm X 500 mm.

6.1 Compressive Strength Test

Table 8: 7, 14, 28 days compressive strength on cubes

COMPRESSIVE STRENGTH (N/mm²)			
MIX	**7 DAYS**	**14 DAYS**	**28 DAYS**
MIX 1	29.33	37.03	45.92
MIX 2	26.96	35.40	37.03
MIX 3	24.59	26.81	27.25
MIX 4	14.22	18.07	21.03
MIX 5	16.59	18.51	28.29

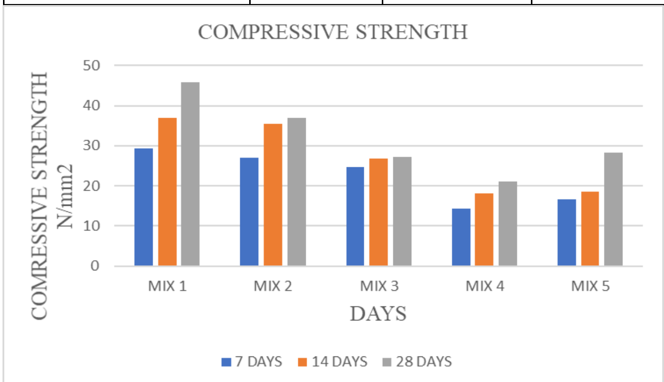

Chart 1: Compressive strength of different concrete mix

6.2 Split Tensile Strength Test

Table 9: 7, 14 and 28 days split tensile on cylinders

SPLIT TENSILE STRNGTH (N/mm²)			
MIX	**7 DAYS**	**14 DAYS**	**28 DAYS**
MIX 1	3.491	3.916	4.340
MIX 2	2.028	2.594	3.444
MIX 3	1.415	1.792	2.642
MIX 4	0.849	1.604	2.359
MIX 5	1.132	1.840	2.783

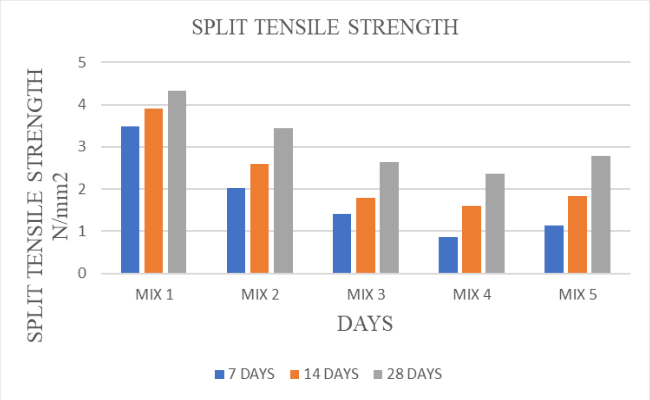

Chart 2: Split Tensile Strength of different concrete mix

6.3 Flexural Strength Test

Table 10: 7, 14 and 28 days flexural strength on prisms

FLEXURAL STRNGTH N/mm2			
MIX	**7 DAYS**	**14 DAYS**	**28 DAYS**
MIX 1	5.40	5.60	5.73
MIX 2	4.40	5.33	5.40
MIX 3	3.06	4.00	5.26
MIX 4	2.66	3.20	4.40
MIX 5	2.86	3.66	5.20

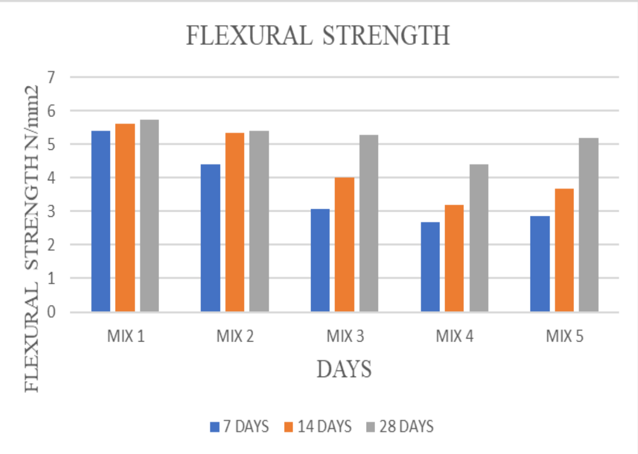

Chart 3: Flexural Strength of different concrete mix

7. CONCLUSIONS

- As percentage of flyash in concrete increases, compressive strength, split tensile strength and flexural strength of the concrete decreases.
- Early strength of High volume flyash concrete is less as compared to normal concrete. The difference reduces at later ages.
- Incorporated micro particles give filler effect in the concrete. Hence, strength increases after addition of micro particles.

7.1 Compressive Strength

- For Compressive strength of concrete at 7 days there is decrease in strength for M2, M3, M4 and M5 respectively are 9.34%, 18.7%, 59.6% and 50.28% compared to M1.
- For Compressive strength of concrete at 14 days there is decrease in strength for M2, M3, M4 and M5 respectively are 4.3%, 27.58%, 51.19% and 49.99% compared to M1.
- For Compressive strength of concrete at 28 days decrease in strength for M2, M3, M4 and M5 respectively are 19.34%, 40.63%, 54.18% and 38.37% compared to M1.

7.2 Split Tensile Strength

- For Split tensile strength of concrete at 7 days there is decrease in strength for M2, M3, M4 and M5 respectively are 18.51%, 43.20%, 50.61% and 46.91% compared to M1.
- For Split tensile strength of concrete at 14 days there is decrease in strength for M2, M3, M4 and M5 respectively are 4.76%, 28.57%, 42.85% and 34.52% compared to M1.
- For Split tensile strength of concrete at 28 days there is decrease in strength for M2, M3, M4 and M5 respectively are 5.75%, 8.08%, 23.19% and 9.24% compared to M1.

7.3 Flexural Strength

- For Flexural strength of concrete at 7 days there is decrease in strength for M2, M3, M4 and M5 respectively are 41.86%, 59.44%, 75.66% and 67.55% compared to M1.
- For Flexural strength of concrete at 14 days there is decrease in strength for M2, M3, M4 and M5 respectively are 33.63%, 54.14%, 58.97% and 52.93% compared to M1.
- For Flexural strength of concrete at 28 days there is decreases in strength for M2, M3, M4 and M5 respectively are 20.64%, 39.12%, 45.64% and 35.86% compared to M1.

8. SCOPE FOR FURTHER STUDY

- In this study we have replaced only 50 % flyash. Further investigation can be carried out by replacement of greater percentage of flyash.
- In the present study the micro particles are used, for further studies nanoparticles may be used.
- This experimental program tests were conducted for 28 days. It can be further studied for different curing days such as 56 days and 90 days.

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