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Strength and Durability Studies on Higher Grade Concrete with High Volume Fly ash

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Abstract:-Portland cement, as an ingredient in concrete, is one of the widely used construction materials, especially in developing countries. The CO2 emission during its production and the utilization of natural resources are important issues for the construction industry to participate in sustainable development. These limitations led to the search for alternative binders or cement substitutes. Fly ash is finely divided residue resulting from the combustion of powered coal and transported by the flue gases and collected by electrostatic precipitator. There are multiple benefits for the sustainable development of the construction industry by using fly ash to increase the strength characteristics of structural members. The objective of the present investigation is to study the mechanical strength behavior of High Volume Fly ash concrete pavement slab. The optimum maximum coarse aggregate size for the best compressive strength of 28 day concrete was therefore found to be 8mm for the water/cement ratio of 0.63. The analysis further shows that as heterogeneity increases the compressive strength of concrete reduces.

Keywords – Fly Ash, Silica Fume, Strength, Durability, High-Volume Fly Ash Concrete, Oxide Composition.

1. INTRODUCTION

Concrete is one of the most versatile and widely produced construction materials in the world [1]. Fresh concrete is flow able like a liquid and hence can be poured into various formworks to form different desired shapes and sizes on a construction site. The maintenance cost for concrete structures is much lower than that for steel or wooden structures. Also, concrete can withstand high temperatures much better than wood and steel. All these characteristics make concrete, the most preferred structural material by civil engineers. The ever-increasing population, living standards, and economic development lead to an increasing demand for infrastructure development and hence concrete materials [2]. Compressive strength of concrete at the age of 28 days is the main parameterused in the design of concrete structure and also in judging concrete quality. In the recent years, it has been reported that gradual deterioration, caused by the lack of durability, makes concrete structures fail earlier than their specified service lives in ever increasing numbers. With the focus on increasing the service life of concrete structures, nowadays durability is also given importance in the design of structures.

Fly ash is finely divided residue resulting from the combustion of powered coal and transported by the flue gases and collected by electrostatic precipitator. There are multiple benefits for the sustainable development of the construction industry by using fly ash to increase the strength characteristics of structural members. Fly ash reacts with calcium hydroxide, a byproduct of the hydration of Portland cement. Use of cement leads to large amount of CO2 emission[3] which leads to environmental problem. Fly ash which is obtained from thermal power plant when added to cement reduces the cost and the problem of disposal of fly ash is solved.

1.1 Fly ash

Fly Ash is a by-product of coal combustion at thermal power stations. The fly ash particles are typically spherical, ranging in diameter from < 1μm to 150 μm. The specific surface area ranges from ≤ 1200 m2/kg to 1300 m2/kg. The specific gravity ranges from 1.90 to 2.96.

1.2Classification of fly ash

Lime fly ash is divided into two categories, namely Class C fly ash and Class F fly ash. Class C fly ash contains 25% analytical CaO, generally a product of combustion of lignite and sub-bituminous coals. It is generally called as the high calcium fly ash or high lime fly ash consisting of SiO2, Al2O3 and Fe2O3 in the range of 50% only. This has self cementing properties, with high fineness and light colour .Class F Fly Ash contains less than 10% analytical CaO[4], generally a product of combustion of anthracite and bituminous coals.
It is generally called as the low calcium fly ash or low lime fly ash with the sum of SiO2, Al2O3and Fe2O3 in the range of 70%. A minimum of 50% fly ash is used with low water content and low water/cementitious ratio.

2. MATERIALS USED:

The materials used for high volume fly ash concrete are cement, fine aggregate, coarse aggregate, mineral admixture, chemical admixture and water. In this investigation, Ordinary Portland[5] cement (43 Grade) was used for casting all the specimens Fineness (wt of residue) and specific gravity were 7% and 3.12 respectively. Class F type of fly ash is obtained from Metur power plant with fineness modulus and specific gravity were 7.86 and 2.30 respectively.

Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm Sieve will be used for casting all the specimens. The fineness modulus and specific gravity were 2.89 and 2.68. The coarse aggregate with specific gravity 2.75 and size passing from 12.5 to 20mm was used. Super Plasticizer is used as the chemical admixture. Conplast SP430 is based on Sulphonated Napthalene Polymers and is supplied as a brown liquid instantly dispersible in water. Conplast SP430 has been specially formulated to give high water reductions up to 25% without loss of workability or to produce high quality concrete of reduced permeability.

3. MIX DESIGN:

The mix composition is chosen to satisfy all performance criteria for the concrete in both the fresh and hardened states. Proportioning of concrete mixes can be regarded as a procedure set to proportion the most economical concrete mix for specified durability and grade for required site conditions. The basic principle of the concrete mix design is to select the proportion of all the-ingredients the basis of the irresolute volume and taking total absolute volume of concrete 1m3.Inthe present Guidelines, the absolute volume of air has been considered as nil as against 2 per cent for 20 mm and 1percent for 40mm maximum size of aggregate each provided in IRC: 44-2008. The method given in these Guide lines is to be regarded as guidelines only, to arrive at an acceptable product which satisfies the requirements of replacement quire with development of strength with age and ensures the requirements of durability[6].

4. LITERATURE REVIEW

Though high strength concrete is constrained to use aggregate of 19mm or lower, its influence in high volume fly ash concrete was almost unexplored. Researchers are either on the aggregate properties in high strength concrete or in high volume fly ash concrete. But a specific result indicating the influence of the maximum size of aggregate in higher grade concrete using high volume fly ash is not yet present. To fill the gaps in these aspects, an attempt is made in this investigation.

Objectives of the investigation

1. To study the effect of different sizes of aggregates in concrete.
2. To study the effect of different replacements of cement with fly ash in concrete.
3. To study the effect of different sizes of aggregates in concrete using different replacements of cement with fly ash.

The present work is carried out to study the effect of different maximum sizes of aggregates 10 mm, 12.5 mm and 20 mm in M 50 grade of concrete by replacement of cement with 0%, 10%, 20%, 30%, 40%

and 50% fly ash by conducting compressive strength, splitting tensile strength and flexural strength. Averages of 3 specimens for M50 grade concrete were cast for each mix. A total of 54 cubes, 54 cylinders and 54 prisms were cast for 18 mixes.

Rehsi, S.S [6] studied on a number of Indian fly ashes in 1973. It was found that, the water requirement of concrete was increased with inclusion of fly ash. Ghosh, R. S., and Timusk, J [7] in their studies in 1981, showed that, in general, for the same maximum size of aggregate and for all strength levels, the shrinkage of concrete containing fly ash is lower than that for concrete not containing fly ash.Ganesh Babu, K and Dinakar, P [9] studied on concretes with 550-770 kg/m3 total cementitious materials and fly ash percentages varying from 30%-40%, to achieve concretes over a wider strength range, with water-cement ratio in the range of 0.33 to 0.40, the studies resulted in self compacting concretes in the strength range of 63-93 MPa. Jain, A. K Ramesh Joshi, Narasimha Rao, M., Ganesh, K.R and Haroon, A.S.M [10] carried out research work at Birla Ready Mix Concrete Plant, Hyderabad for a pavement by incorporating fly ash more than 35% replacing cement.Rafat Sodium [8] studied on various concrete mixes and found that the abrasion resistance was found to increase with age for HVFA concrete mixes and found to be maximum at 60 minutes of abrasion. Lakshmanan N [6] carried out experimental investigations on structural elements with HVFA concrete and found that HVFA concrete and OPC concrete mix have similar behaviour under flexural and axial loading.

5. METHOD OF EXPERIMENT:

Mould for casting specimens for strength study are of cast iron. Oil was applied on the inner surface of the moulds of cube and cylinder. Concrete was mixed in a concrete mixer. The cube, cylinder and prism were cast from the same batch of concrete. The specimens were compacted using table vibratos. The test specimens were cured for 7 day, and 28 day in curing tanks. Concrete cubes of size 150mm x 150mm x 150mm were cast to test the compressive strength of concrete. Concrete cylinder of size 150mm diameter and 300mm height were cast to test the tensile strength of concrete. Concrete prism of size 100x100x500mm was cast to test the flexural strength of concrete. Experimental investigations carried out on the test specimens to study the mechanical properties of HVFA [11]concrete. All the test specimens such as cube and cylinder were cast using steel moulds. The specimens were removed from the mould after 24 hours and cured in water.

5.1 Research Program:

Slump Test

This test is performed to check the workability of freshly made concrete. It is a term which describes the state of fresh concrete. It refers to the ease with which the concrete flows. It is used to indicate the degree of wetness. A higher slump implied better consistency and workability. Slump test is the most commonly used method of measuring workability of concrete. The apparatus for conducting the slump test essential consists of a metallic mould in the form of a cone having the internal dimensions as under.

Compaction factor

Prepare a neat concrete mix for the given grade. Place the sample of concrete in the upper hopper up to the brim. Open the trap door so that the concrete felt into the lower hopper. Then open the trap door and allow the concrete fall into the lower hopper cylinder. Open the trap door of the upper hopper and allow to fall the concrete into the cylinder[12], the excess is removed from the top level of the cylinder. Then the cylinder was weighted after it all the concrete was removed and again fill by 5cm layers.

Compressive Strength

Compression test is the most common test conducted on hardened concrete, partly because it is easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The compression test is carried out on specimens cubical or cylindrical in shape. The cube specimen is of the size 150 x 150 x 150mm. Due to compression load, the cube or cylinder undergoes lateral expansion owing to poisons ratio effect.

Splitting Tensile Strength

The split tension test is a method of determining the tensile strength of concrete. The experiment consists of casting and testing of cylinder, 150mm diameter and 300mm height. Specimens were cured for 7, 28 days under water prior to testing. Compression testing[13] machine having 2000kN is used for loading.

Flexural strength

A beam specimen was to test the flexural strength of the concrete[14]. The standard specimen size is 100x100x500 mm. The test specimen should be casted and cured for 7,28days and tested for maximum load.

6. RESULTS AND DISCUSSIONS

Slump test

The slump values [15] increase as the maximum coarse aggregate size increases, and decreases with smaller coarse aggregate size at constant water/cement ratio.

Mix Proportions (%)	Slump(mm)
M0	27
M1	26
M2	28
M3	29

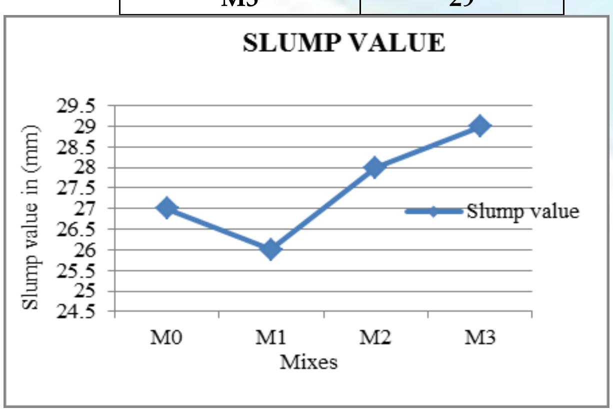

Fig 1. Slump Value

Larger aggregate sizes will consequently require less water in other to maintain high strength .The change in the slump values also reflect in the compressive strength of the hardened concrete. Concrete made with smaller coarse aggregate size have higher strength than concrete made with bigger size of coarse aggregate due to the weak bonds in the later resulting from greater heterogeneity, internal bleeding and the development of micro cracks.

Compaction factor test

Mix Proportions (%)	Compaction Factor
M0	0.762
M1	0.712
M2	0.796
M3	0.812

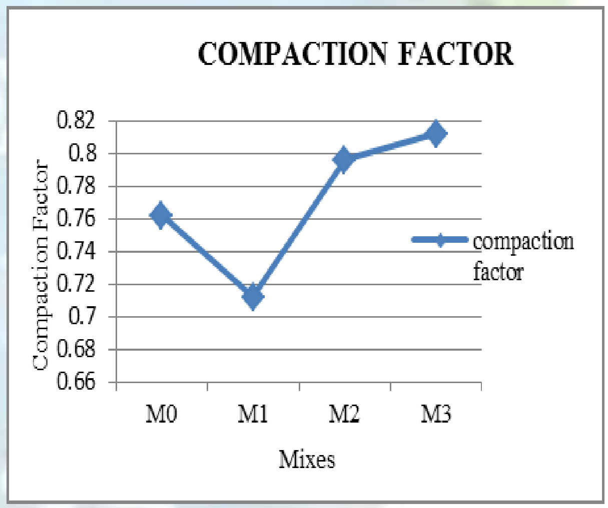

Fig 2 Compaction Factor Value

Split tensile strength

Mix	7 days	28 days
M0	3.79	4.25
M1	3.08	3.43
M2	3.24	3.24
M3	2.51	3.32

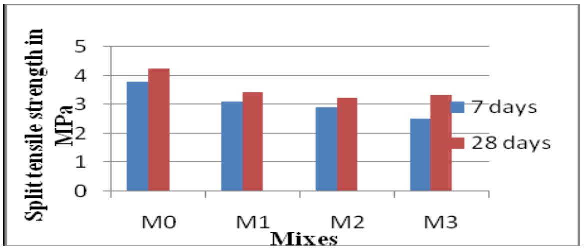

Fig 3. Variation of Split Tensile Strength with Various Mixes

7. CONCLUSION

The compressive strength of concrete made with10mm maximum aggregate size is higher than that of 14mm and 20mm sizes. However, the slump values of concrete made with 20mm sizes of gneisses is higher than that of 10mm and 14mm sizes gneisses at the same water/cement ratio. The relationship between the compressive strength and the maximum coarse aggregate size follows a polynomial with R2= 1, indicating that the model is reliable for predicting the compressive strength of concrete for a given size of coarse aggregate. Consequently the optimum maximum coarse aggregate size for the best compressive strength of 28 day concrete was found to be 8mm for water/cement ratio of 0.63. The optimum ratio of the maximum size of fine aggregate to the maximum size of coarse aggregate for the highest compressive strength is 0.18 for the water/cement ratio selected. This shows that the greater the heterogeneity the lower the compressive strength of concrete.

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