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Durability study on high volume fly ash concrete with and without fibre for pavements

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Abstract: 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 durability of High Volume Fly ash concrete pavement. In this study the durability properties are studied with various replacements of cement with 50%, 60%, and 70% of Fly ash.

Keywords: *High Volume Fly Ash, Durability, Pavements, Fiber*

I. Introduction:

Cement concrete is the most widely used construction material in any infrastructure development projects. The production of Portland cement, an essential constituent of concrete, release large amount of CO_2into the atmosphere. These gases are the major contributor to the green house effect and the global warming of the planet, which is a major global environmental global issue currently the planet is encountering. The development and use of mineral admixture for cement replacement is growing in construction industry mainly due to the consideration of cost saving, energy saving, environmental production and conservation of resources. Mineral admixtures generally used are raw fly ash, rice husk ash, metakaolin, silica fume etc. Addition of such materials improves the concrete property.

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.

A. Need for the study:

Use of cement leads to large amount of CO_2 emission which leads to environmental problem. Fly ash which is the obtained from thermal power plant when added to cement reduces the cost and the problem of disposal of fly ash is solved.

II. Experimental investigation Preparation and casting of test specimens:

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 were cast from the same batch of concrete. The specimens were compacted using table vibratos. The test specimens were cured for 28 day, and 90 day in curing tanks.

- Concrete cubes of size 150mm x 150mm x 150mm were cast to test the permeability test of concrete.
- Concrete cylinder of size 100mm diameter and 50mm height were cast to test the impact test of concrete.
- Concrete cube of size100x100x100mm were cast to test the remaining test of concrete.

Experimental work and procedure:

Experimental investigations carried out on the test specimens to study the durability of HVFA 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.

The specimens such as cubes, cylinders to study following experiments such as cubes, cylinders to study following experiments:

- Saturated water absorption
- Porosity
- Acid resistance
- Impact test
- Alkalinity measurement of concrete
- Permeability

Tests on fresh properties of concrete:

1. 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. The procedure for slump test is as follows:

The mould is placed on a smooth, horizontal, rigid and non-absorbent surface. The mould is then filled in four layers, each approximately ¼ of the height of the mould. Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross section. After the top layer has been rodded, the concrete is struck off level with a trowel and a tamping rod.

The mould is removed from the concrete immediately by raising it slowly and carefully in the vertical direction. This allows the concrete to subside. The subsidence is referred to as the slump of the concrete. The difference in level is measured this difference in height is taken as the slump of the concrete.

Fig: 1 Slump Test Apparatus

2. Compaction Factor Test:

Prepare a neat concrete mix for the given grade. Place the sample of concrete in the upper hopper upto 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, 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. Then again weight this weight known as weight of fully compacted concrete.

Fig: 2 Compaction Factor test

Tests on hardened concrete:

Testing of hardened concrete plays an important role in controlling and conforming the quality of cement concrete work. Systematic testing of raw materials, fresh concrete and hardened concrete are inseparable part of any quality control program for concrete, which helps to achieve higher efficiency of the material used and greater assurance of the performance of concrete with regard to durability. The test methods should be simple, direct and convenient to apply. One of the purposes of testing hardened concrete is to confirm that the concrete used at site has developed the required strength. As the hardening of the concrete takes time, one will not come to know, the actual strength of concrete for some time. This is an inherent disadvantage in conventional test. Tests are made by casting cubes, cylinders.

1. Saturated water absorption:

Saturated water absorption (SWA) tests were carried out on 100 mm cube specimen at the age of 28 and 90 days curing as per ASTM C 642. The specimens were weighed before drying. The drying was carried out in a hot air oven at a temperature of 105 C. The drying process was agreed closely. The dried specimens were cooled at room temperature and immersed in water. The specimens were taken out at regular interval of time, surface dried using a clean cloth and weighed. This process was continued till the weights became constant.

The difference between the measured water saturated mass and oven dried mass expressed as % of oven dry mass gives the SWA. The water absorption was calculated as

% of water absorbed = (Ws-Wd) x 100/Wd

Where,

Ws = weight of specimen at fully saturated condition

Wd = weight of oven dry specimen

2. Porosity:

The saturated water absorption of concrete is a measure of the pore volume or porosity in hardened concrete which is occupied by water in saturated condition. It denotes the quantity of water which can be removed on drying a saturated specimen. The porosity obtained from absorption tests is designated as effective porosity. It is determined using the following formula

Effective porosity = (Volume of voids/bulk volume of specimen)*100

The volume of voids is obtained from the volume of water absorbed by an oven dried specimen or the volume of water lost on oven drying a water saturated specimen at 105ºC to constant mass. The bulk volume of the specimen in air and its mass under submerged condition in water

i.e., Effective porosity, n = ((Ws-Wd) / (Ws-Wsub)) × 100

Where,

Ws = weight of specimen at fully saturated condition

Wd = weight of oven dried specimen, and

Wsub = submerged weight of specimen in water

3. Alkalinity measurement on concrete:

The broken pieces of tested specimen were again broken into small pieces using hammer and ball mill and then powdered. Each of the powdered samples (say 20gm) was put into100ml distilled water. The aqueous solution was allowed to stand for72 hours and more and agitated often, to enable more of free lime of hydrated cement paste to get dissolved in water .The pH of the aqueous solution were measured by pH meter. The pH test results for 28 and 90 days were tabulated.

4. Impact test:

Impact test was conducted on the square slabs after 28 days of curing by using a drop weight and the test setup shown fig 1 was adopted. It consisted of a rigid welded steel frame square in plan and supported by short columns .The specimen was laid flat resting on four 20 mm diameter bars to provide line support along the four edges .A hammer having a mass of 3.5 kg shown in fig 2 was used for applying repeated impact on the specimens from a pre –determined height .The height of the drop was kept 1.18 m for 30 mm thick slab respectively.

To prevent the specimen from lifting up during impact due to rebound under impact, the edges of the panels were clamped down to the supporting frame by C-clamps as shown in fig 2.The plunger which loads the panels has a spherical tip enabling a point contact to be made. A steel rope and pulley arrangement with a pipe guide, which enables a central impact in the vertical direction ,was used to manually rise the hammer to the required height and repeatedly drop it on the specimen surface .Grease was applied on the rollers to reduce friction and to ensure a smooth fall.

Fig 3 Test Set Up For Impact Strength

5 Acid resistance:

The acid resistance were carried out on 100 mm size cube specimen at the age of 28 and 90 days curing. The cube specimen were weighted and immersed in water diluted with one percent by weight of sulphuric acid for 45 days continuously. Then the specimens are taken out from the acid water and the surfaces of the cubes were cleaned. Then the weight and the compressive strength of the specimens were found out the average percentage of loss of weight and compressive strengths are calculate.

6. Permeability test:

The test was conducted as per IS: 3085(part 7)-1963. The equipment comprises of three cells each square cross section mounted on stands. These cells are connected with connecting pipe through valve. A pressure regulated is mounted on a pressure chamber with two pressure gauges on 0-20kg/cm^2 gauges and the other 0-15kg/cm^2. First one show the input pressure and second show the test pressure. The pressure is regulated by turning the handle of pressure regulated in the clock wise direction to the desired pressure. A pressure chamber fitted with a Schrader valve water inlet for pouring water and valve provided as a water source.

Results and discussion:

General:

This chapter deals with result and discussion as the various fresh and hardened properties of HVFA concrete.

Workability studies:

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

1. Slump Test:
Slump value for various mixes are shown in table 1

Discussion:
The slump values of mix M0, M2& M3 for HVFA has less workability and the mix M1 has high workability.

2. Compaction Factor Test:
Compaction Factor value for various mixes are shown in table 2.

Table 2 Compaction Factor

Mix proportions	Compaction factor
M0	0.762
M1	0.712
M2	0.796
M3	0.812

Discussion:
The slump values of mix M0, M2 & M3 for HVFA has less workability and the mix M1 has high workability.

3. Durability test results:

1. Alkalinity Test:
The results of the alkalinity tests of various HVFA concrete mixes at the age of 28, 90 days are given in Table 6.3 .The influence of different ratios fly ash of concrete specimens is shown in Fig 3.
The alkalinity for HVFA concrete with replacement of cement with Fly ash of 50%, at the age of 28 days was found as shown in Table 3. The alkalinity is increase when the replacement of fly ash is increased.

Table 3 Alkalinity Measurement Results

Replacement of cement with fly ash (percentage)	pH
0%	11.49
50%	11.68

Discussion:
HVFA concrete attained higher alkalinity of mix M1 when compared with control mix concrete (M0) at the age of 28 days. It was found that control mix (M0) lags behind the mix (M1) by 2%.

2. Impact test:
The total energy absorbed by the specimen when struck by a hard impactor depends on the energy absorbed both in contact zone and by the impactor.
The energy absorption can be obtained by using the following formula:
E = N x (w x h) joules ……….. (1)
Where
E = energy in joules
w = weight in Newton's
h = drop height in meter
N = number of blows

In the above equation, the weight of ball as 34.34 N and the height of fall 1.18 m. A comparison of average of initial energy-absorption capacities of different cylinder specimens at first crack and at ultimate impact failure stages are presented in table below.

Table 4 Impact test Results

Mix	Number of blows		E(joules)	
	First crack	Final crack	Initial	Final
M_0	3	7	123.9	289.1
M_1	2	5	82	206.5

Discussion:
HVFA concrete attained lesser impact strength of mix M1 when compared with control mix concrete (M0) at the age days.

II. Conclusion:

- In this investigation, the durability of HVFA concrete, and control concrete were studied and compared. The weight replacements of cement used 50% is arrived.
- HVFA concrete attained lesser impact strength when compared with OPC concrete.
- HVFA concrete attained higher alkalinity measurement when compared with OPC concrete.

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