iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 Issue: IV Month of publication: April 2016

DOI:

Volume 4 Issue IV, April 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Experimental Study on Fibre Reinforced High Volume Fly Ash Concrete for RCC Construction

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Abstract: Road projects in future have to be environmental friendly and cost effective apart from being safe so that society at large is benefited by the huge investments made in the infrastructure projects. To achieve this, component materials of the pavement system have to be optimized with reference to behavior, performance, cost effectiveness, and sustainability to be considered. Experimental programmers had to be conducted to obtain the fatigue-lives of concrete at various stress levels. Recent environmental policies and regulations concerning the disposal of by products have increased the need to use of fly ash in concrete. In the present scenario, High-volume fly ash (HVFA) concrete has emerged as construction material. This present investigation focused on the performance of economical and viable concrete pavements made with hybrid fiber and high volume fly ash. The experimental investigation was carried out to evaluate the strength properties of concrete in which cement was partially replaced with Class F fly ash. High Volume Fly ash was replaced with different percentages of 55%, 60% and 65%of Class F fly ash by weight of cement. Hybridization of two different types fibers were used at different volume fractions. Tests were performed on the compressive strength and flexural strength at 7 and 28 days. Test results indicated there is a appreciable improvement in the strength properties of hybrid fiber reinforced HVFA concrete. It was also suggested that a large quantity of fly ash with discrete fiber reinforcement will enhance the strength characteristics and can be effectively used for the long term performance of concrete pavements.

I. INTRODUCTION

A. General

Concrete is the most used construction material in the world. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. Portland cement concrete slabs are a common form of highway pavements. As a result of their widespread use, the economic impact of their maintenance and life span is therefore tremendous. The production of Portland cement is currently exceeding 2.6 billion tons per year worldwide and growing at 5 percent annually. Portland cement is a major contributor to greenhouse gas emissions that are implicated in global warming, climate change and other significant environmental problems. One of the most common and most effective options to reduce carbon-di-oxide emissions is to replace the cement either by fully or partially by supplementary cemetitious materials (SEM) such as fly ash, silica fume, granulated blast furnace slag, metakaolin, rice husk etc. However, recent environmental policies and regulations concerning the disposal of by products have increased the need to use of fly ash in concrete. In the present scenario, High-volume fly ash (HVFA) concrete has emerged as construction material. This type of concrete normally contains more than 50% of fly ash by mass of total cementitious materials [1]. Many researchers have used high volumes of Class C and Class F fly ashes in concrete.

B. High Volume Fly Ash (HVFA)

According to some researchers, more than 30% fly ash by mass (equivalent as 50% by volume) of the cementitious material may be considered enough to classify the mixtures as High-Volume Fly Ash (HVFA) concrete. It is possible to produce sustainable, high performance concrete mixtures with 50% or more cement replacement by fly ash. It is generally observed that a higher substitution of Portland cement by fly ash reduces the water requirement for obtaining a given workability, mainly due to three mechanisms:

Fly ash gets absorbed on the surface of oppositely charged cement particles and prevents them from flocculation, releasing large amounts of water, thereby reducing the water-demand for a given workability.

The spherical shape and the smooth surface of fly ash particles help to reduce the interparticle friction and thus facilitate mobility. Due to its lower density and higher volume per unit mass, fly ash is a more efficient void-filler than Portland cement. HVFA system has proven to be an economical construction material. Several applications of HVFA concrete in structures, and pavements have

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ISSN: 2321-9653
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been reported all over the world.

C. Need for Study

The utilization of fly ash can be partly used on economic grounds as pozzolana for partial replacement of cement and partly because of its beneficial effects such as lower water demand for similar workability, reduced bleeding, and lower evolution of heat. Fly ash is used particularly in mass concrete applications and large volume placement to control expansion due to heat of hydration and also helps in reducing cracking at early ages.

D. Objectives of Study

To design a concrete mixture containing low calcium fly ash in fibrous material.

To determine the fresh and hardened properties of concrete.

The economical and alternative concrete pavement has been made through this research work to utilize the different types of fibers and HVFA which will lead to the strength enhancement for concrete pavements.

II. LITERATURE REVIEW

A. Literature

Aravindkumar et al.,(2013) investigated with various mix proportions for high volume fly ash concrete were determined at cement replacement levels of 50%, 55%, 60% and 65% with low calcium fly ash. Flexural and compressive strengths of different mixes were measured at ages of 7, 28 and 90 days. The test results indicated that the High volume fly ash concrete mixes exhibited higher rate of strength gain and age factors than corresponding reference concrete mixes. Also, they concluded that the consideration of bond between pavement quality and lean of high volume fly ash concrete will be beneficial in design of rigid pavements.

Shivakumara et al.,(2013) studied the effect of variation of fiber content from 0% to 1.8% in high volume fly ash concrete. From the test results, it was concluded that the strength characteristics of fiber reinforced high volume fly ash concrete (FRHVFAC) showed higher values at 1.4% addition of steel fibers.

Mukherjee et al., (2013) conducted an experimental investigation to compare the compressive strength of zero slump and high slump concrete with high volume fly ash. By weight, 40% to 70% replacements of OPC have been incorporated with class F fly ash. The results showed that the apparent porosity and water absorption were higher for zero slump concrete than high slump concrete. Zero slump concrete showed better compressive strengths than super plasticized concrete with 40 to 60% fly ash addition for all the age of days.

Muntadher Ali Challoob et al., (2013) investigated to evaluate the mechanical properties of concrete with steel fiber and steel fiber fly ash in which Portland pozzolana cement was partially replaced with fly ash by weight. The experimental investigation carried out on steel fibers concrete up to a total fiber volume fraction of 0.5%, 1% and 1.5% and fly ash in which Portland pozzolana cement (PPC) was partially replaced with 30% fly ash. The mechanical properties, compressive strength and splitting tensile strength were studied for concrete prepared. Compressive strength and splitting tensile strength were determined at 7, 28 and, 56 days. The laboratory results showed that addition of steel fibers reinforced fly ash into PPC concrete decreases the strength properties. While the results showed that steel fibers addition into PPC concrete improve the strength properties.

III. STUDY ON MATERIAL PROPERTIES

A. General

This chapter deals with the details of various material properties studied with reference to Indian standards and concrete mix design. The following are the properties of the materials

Ordinary Portland cement (53 grade) Fine aggregate
Coarse aggregate Fibers
Fly ash Water
Super plasticizer

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Table 3.1 Properties of fine aggregate

Test	Result	As per IS 383-1970
Fineness modulus	3.01	2.9-3.2
Specific gravity	2.64	2.6-2.7

B. Coarse Aggregate

Coarse aggregate are the crushed stone used for making concrete. The commercial stone is quarried, crushed, and graded. Granite is a coarse-grained, igneous rock having an even texture and consisting largely of quartz and feldspar with often small amounts of mica and other minerals. There are many varieties. Granite is the most important building stone. Granite is extremely durable, and since it does not absorb moisture, as limestone and sandstone do, it does not weather or crack as these stones do. The colors are usually reddish, greenish, or gray. Rainbow granite may have black or dark green background with pink, yellowish, and reddish mottling; or to may have a pink or lavender background with dark mottling. The maximum size of coarse aggregate adopted was 12.5 mm. Water absorption of aggregate is 0.25%. The properties of coarse aggregate are given in Table 3.2

Table 3.2 Properties of coarse aggregate

Test	Result	As per IS 383-1970
Fineness modulus	2	6.5 – 7.5
Specific gravity	2.7	>2.6

C. Fibres

Bundled hooked end steel fiber (BHSF) and polypropylene fibers (PPF) depicted in Fig 1.5(a) and Fig 1.5(b) was used as a hybrid fiber (HF) in this investigation. The properties of bundled hooked end steel and polypropylene fibers are shown in Table 3.3

Table 3.3 Properties of discrete fibers

Property	BHSF	PPF
Length(mm)	60	30
Diameter (mm)	0.75	0.92
Aspect ratio (l/d)	80	33
Tensile strength (MPa)	1225	550
Elastic modulus (MPa)	210000	3500

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D. Fly Ash

Class F fly ash is available in the largest quantities. Class F is generally low in lime, usually under 15 percent, and contains a greater combination of silica, alumina and iron (greater than 70 percent) than Class C fly ash

Table 3.4 (a) Properties of fly ash (Class-F)

Property	ASTM C618 Requirements, %
SiO_2 plus Al_2O_3 plus Fe_2O_3, min	70
SO_3, max	5
Moisture content, max	3
Loss on Ignition, max	6

Fly ash is obtained from ennore thermal power plant in Chennai and contains large amounts of silica. Since the physical and chemical properties are given in Table 3.4 (a) (b) (c)

Table 3.4 (b) Physical properties of fly ash

Parameters	Fly ash Class- F
Specific gravity	2.41
Specific surface area (m^2/kg)	320

Table 3.4 (c) Chemical properties of fly ash

Properties	Fly ash Class-F
SiO_2	59.5
Al_2O_3	34.7
Fe_2O_3	5.87
CaO	<1
MgO	<1
SO_3	0.1
Na_2O	0.6

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E. Water

This is the least expensive but most important ingredient of concrete. The water, which is used for making concrete, should be clean and free from harmful impurities such as oil, alkali, acid, etc., in general, the water, which is fit for drinking should be used for making concrete.

F. Super Plasticizer

To improve the workability of fly ash concrete in the mixes, a commercially available water reducing admixture, Glenium-B233, polycarboxylic ether was used.

G. Concrete Mix Design

The mix proportion for M35 grade of concrete was designed as stipulated in IS:10262:1982. The coarse aggregate of size 12.5mm was used as a maximum size of aggregate and fine aggregate of size 4.75mm was used as a minimum size of aggregate. The physical properties of cement, fine aggregate and coarse aggregate are found out and the results were used for the mix design of concrete. The quantity of materials as per mix design is presented in Table 3.5

Table 3.5 Concrete mix proportion

Material	Quantity (kg/m^3)	Proportion
Cement	416	1
Fine Aggregate	796	1.9
Coarse aggregate	1090	2.6
Water	208	0.50

IV. EXPERIMENTAL PROGRAM

A. General

This chapter deals with the experimental program on both fresh and hardened properties of concrete. Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space between the aggregate particles and glues them together.

B. Slump Test

Slump test was carried out as per IS: 1199- 1959 (Methods of Sampling and Analysis of Concrete) to measure the consistency of concrete. The slump cone mould in the shape of a truncated cone with the internal dimensions 200mm diameter at the base, 100mm diameter at the top and height of 300 mm. The apparatus is shown in Fig 4.1

Fig 4.1 Slump cone apparatus

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ISSN: 2321-9653
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1) Test Procedure: The internal surface of the mould shall be thoroughly cleaned and freed from superfluous moisture and any set concrete before commencing the test. The mould shall be placed on a smooth, horizontal, rigid and non-absorbent surface, such as a carefully leveled metal plate, the mould being firmly held in place while it is being filled. The mould shall be filled in four layers, each approximately one-quarter of the height of the mould. Each layer shall be tamped with twenty-five strokes of the rounded end of the tamping rod. The mould shall be removed from the concrete immediately by raising it slowly and carefully in a vertical direction. This allows the concrete to subside and the slump shall be measured immediately by determining the difference between the height of the mould and that of the highest point of the specimen being tested.

C. Static Flexural Test

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength. It is the ability of a beam or slab to resist failure in bending. The test set up for flexural test is in Fig 4.2 The bearing surfaces of the supporting and loading rollers shall be wiped out and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. The specimen shall then be placed in the machine in such a manner that the load should be applied to the uppermost surface as cast in the mould, along two lanes spaced 20·0 or 13·3 cm apart.

Fig 4.2 Static flexural testing machine

The axis of the specimen shall be carefully aligned with the axis of the loading device. No packing shall be used between the bearing surfaces of the specimen and the rollers, The load shall be applied without shock and increasing continuously at a rate such that the extreme fiber stress increases at approximately 7 kg/sq.cm/mm. that is, at a rate of loading of 400 kg/min for the 15·0 cm specimen- and at a rate of 180 kg/min for the 10·0 cm specimens, The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure shall be noted. A flexure test produces tensile stress in the convex side of the specimen and compression stress in the concave side. This creates an area of shear stress along the midline. There are two test types; 3-point flex and 4-point flex. And we are testing on three point bending. The flexural strength of the specimen shall be expressed as the modulus of rupture *f*b, which, if „*a*‟ equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, shall be calculated to the nearest 0.5 kg/sq cm as follows:

$$f_b = PL/BD^2$$

when „*a*‟ is greater than 20.0 cm for 15.0 cm specimen, or greater than 13.3 cm for a 10.0 cm specimen, or

$$f_b = 3Pa/BD^2$$

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When „a" is less than 20.0 cm but greater than 17.0 cm for 15.0 cm specimen, or less than 13.3 cm but greater than 11.0 cm for a 10.0 cm specimen

Where

B = measured width in cm of the specimen,

D = measured depth in cm of the specimen at the point of failure, L= length in cm of the span on which the specimen was supported, P = maximum load in kg applied to the specimen.

If „a" is less than 17.0 cm for a 15.0 cm specimen, or less than 11.0 cm for a 10.0 cm specimen, the results of the test shall be discarded.

V. RESULTS AND DISCUSSIONS

A. Slump Test

The workability calculated for this type of investigation is for four mix design including control mix. The other mixes are replaced by fly ash in cement for different ratios and the slump attained should be zero slump or true slump, the same test was used by Mukherjee et al.,(6)

Fig 5.1 Result on zero slump

Table 5.1 Result of slump test

CEMENT	FLY ASH (%)	W/C	SP(%)	SLUMP mm
416	0	0.50	0	20-25
187	55	0.45	O.6	zero
166	60	0.45	0.65	zero
146	65	0.45	0.7	zero

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ISSN: 2321-9653
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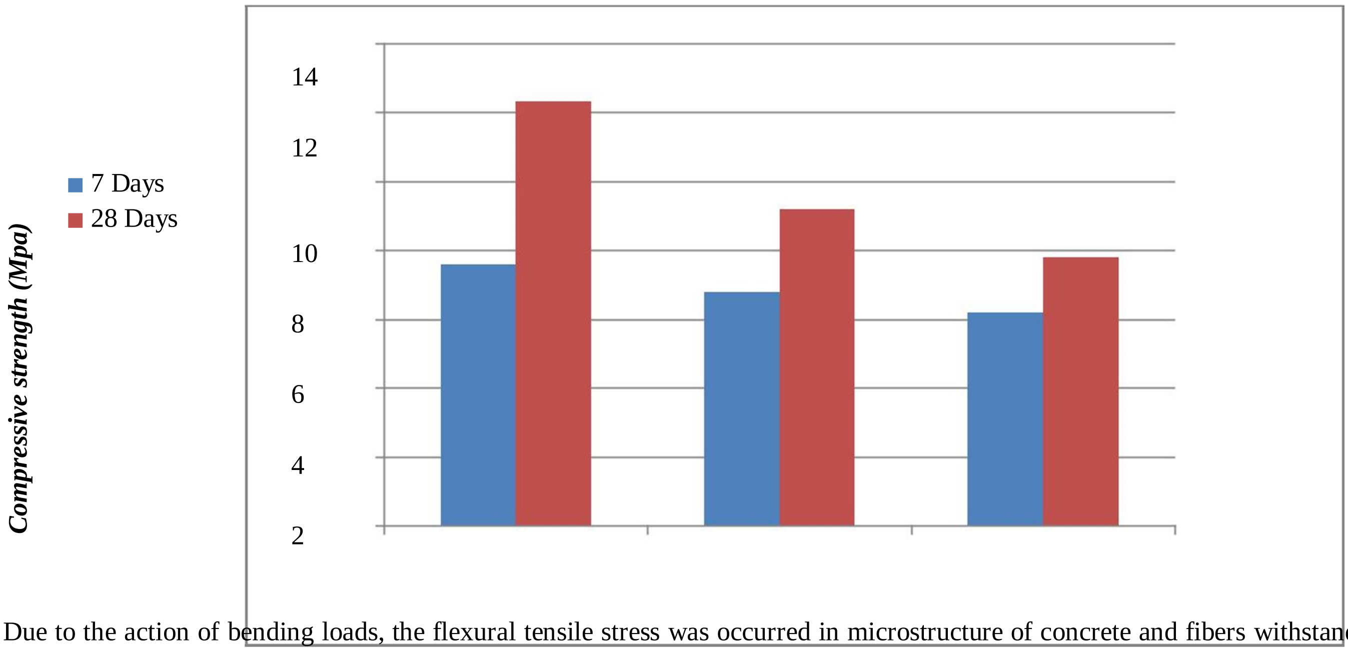
The result of slump test showed in Fig 5.1 that the apparent porosity and water absorption were higher for zero slump concrete. It showed good compressive strength in fly ash for various ratios respectively.

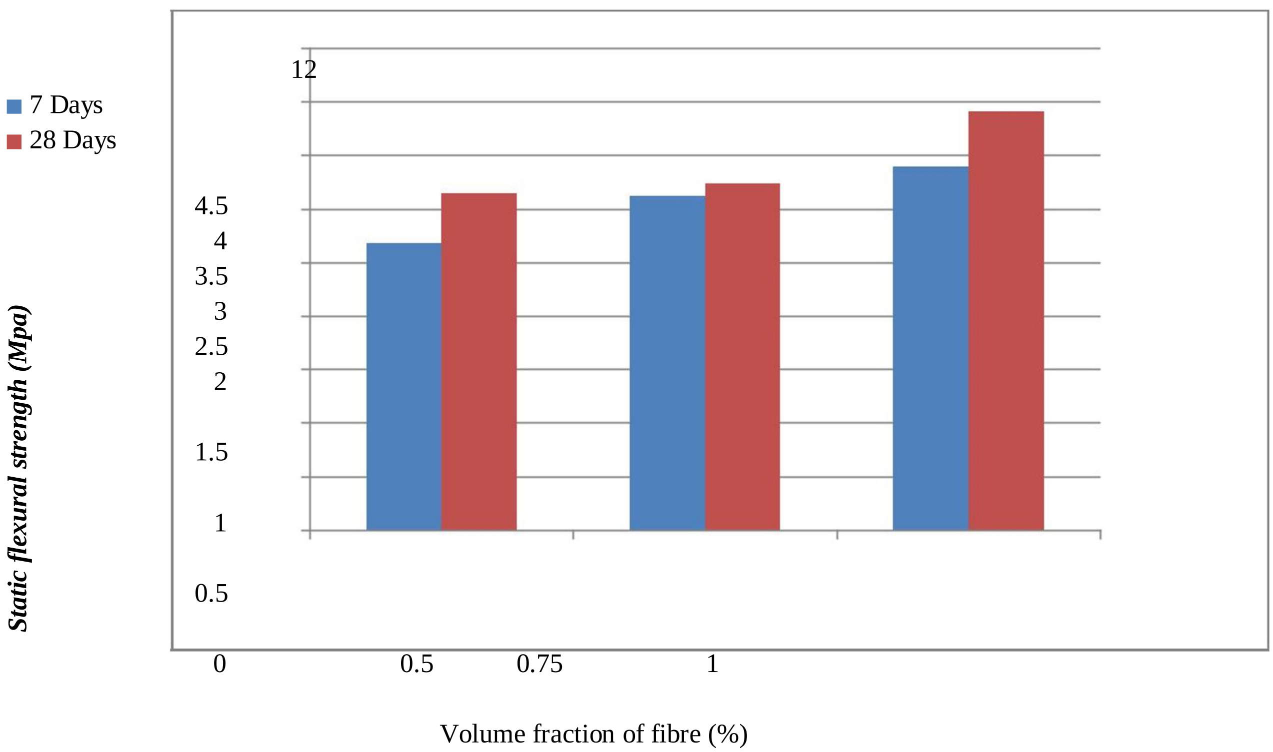
B. Compressive Strength Test

From the test results in Table 5.2, it can be observed that the compressive strength of high-volume fly ash concrete mixtures replaced with cement at different percentages was showed lower than that of the control concrete at 7 and 28 days.



Due to the action of bending loads, the flexural tensile stress was occurred in microstructure of concrete and fibers withstand these tensile stresses, thus it enhanced the bending strength of concrete. It was perceived from the Fig. 5.3, the maximum strength of 5.17 MPa was observed for hybrid fibre reinforced HVFA concrete.

Fig 5.3 Static flexural strength of 65% Fly ash



VI. CONCLUSION

Based on the experimental investigation always be acknowledged that there is the limitations of the test results. This research study investigated the effect of two different types of fibers with 55%, 60% and 65% of high volume fly ash replaced to the weight of cement. Based on the study, the following conclusions can be drawn

The proper selection of various ingredients such as water to binder ratio and fine to coarse aggregate ratio had significant effect on the micro-structural alterations in concrete, which results in improvements in the mechanical properties.

When compared to the control concrete, a reduction in the compressive strength was observed with the increase in the higher percentages of fly ash content.

With increase of volume of fiber content, the maximum compressive strength of concrete was 35.8 MPa.

The maximum flexural strength has been found to occur with 55% fly ash content at 28 ages of days.

Due to the action of bending loads, the flexural tensile stress was occurred in microstructure of concrete and fibers withstand these tensile stresses, thus it enhanced the bending strength of concrete.

It was also suggested that a large quantity of fly ash with discrete fiber reinforcements will enhance the strength characteristics and can be effectively used for the long term performance of concrete pavements.

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