Experimental Study on the Strength Characteristics of High-volume Fly-ash Concrete

A Project Report

Submitted by

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ABSTRACT

Waste disposal is one of the major problems being faced by the entire nation across the globe. Fly ash is an industrial by-product, generated from combustion of coal in the thermal power plants. Pozzolanic concretes are used extensively throughout the world where oil, gas, nuclear and power industries are among the major users. The applications of such concretes are increasing day by day due to their superior structural performance, environmental friendliness, and energy conserving implications. Fly ash is used as a mineral addition in concrete improves its strength and durability characteristics.

This research was carried out to investigate performance of structural grade concrete incorporating high volumes of low calcium fly ash. A Portland cement concrete, designed to have 7, 28 and 45 days compressive strength, splitting tensile strength, flexural strength and modulus of elasticity, was used in this investigation as a controlled concrete. Concrete mixes were also designed to have fly ash substitution based on total cement weight in the range of 10 – 70% by weight. Water to cementation ratio was maintained approximately constant and the desired workability was achieved by using a superplasticizer.

The main objective of this project is to study the strength characteristics of high volume fly ash concrete. Concrete specimens made with different percentage of fly-ash replacement levels (10 to 70%) for their compressive strength, split tensile strength, flexural strength and modulus of elasticity on 7, 28 and 45 days using M_{30} and M_{50} grade of concrete. Based on this experimental result, the mathematical model of strength properties for concrete will be developed. The experimental result reveals the optimum percentage of fly-ash content for the concrete to achieve the maximum strength.

Key words: High volume fly ash (HVFA), Compressive strength, Split tensile strength, flexural strength.

CHAPTER 1
INTRODUCTION

We are constantly facing with ever-large economical problems associated with the emission of CO_2 in to the atmosphere. The increasing scarcity of raw materials and an urgent need to protect the environment against pollution has accentuated the significance of developing new building materials based on industrial waste generated from coal fired thermal power station and is creating unmanageable disposal problems due to its potential to pollute the environment.

The utilization of by-products as the partial replacement of cement has important economical, environmental and technical benefits such as the reduced amount of waste materials, cleaner environment, reduced energy requirement, durable service performance during service life and cost-effective structures. It is well known that blending cement with fly-ash improves the rheological properties of hardened concrete. These improvements are generally attributed to both the physical and chemical effects.

The physical process is due to the particle fineness of the supplementary cementing materials that are much smaller than that of the cement, thereby providing densely packed particles between fine aggregates and cement grains, and hence, the reduction in porosity. The chemical process is due to the activation of the non-crystalline silica, the major constituent of fly-ash, by the calcium hydroxide produced from the hydrating cement to form secondary calcium silicate hydrate that also fills the pore spaces and further reduces the porosity.

This paper deals with the concrete containing supplementary cementing material: fly-ash. Because of the wide availability and low cost, coal fly-ashes are the most commonly used in the manufacture of cement-based materials to improve their microstructure. The compressive strength- developing behavior of concrete containing fly-ash widely differs from that of concrete without fly-ash depending on the method and the amount of fly-ash addition. The rate of strength increase of fly-ash concrete is slower but it is sustained for longer periods than the rate of strength increase of Portland cement concrete.

Advantages of High Volume Flyash (HVFA) Concrete:

Compared to the conventional concrete mixture HVFA system contains 1/3 rd less mixing water. Also the total volume of cement paste is nearly 16% less; consequently the drying shrinkage is much reduced. HVFA concrete system nearly 40% less heat of hydration at early age and there for, in massive structural member the potential for thermal shrinkage and cracking is also reduced.

Durability Properties of HVFA concrete:

High-volume fly ash concrete system was highly durable than conventional concrete. Low capillary absorption indicating high durability. HVFA concrete system had Low oxygen and water permeability and high resistance against chloride penetration.

Applications of HVFA Concrete

HVFA concrete system was suitable for structural concrete construction, concrete dams and other hydraulic structures and for concrete pavements. The main characteristics considered for particular applications of HVFA concrete are.

- Improved workability.
- Ease of placing.
- Decreased water demand.
- Reduced permeability.
- Increased strength

CHAPTER 2

LITERATURE REVIEW

Addition of low-alkali Class F fly ash in concrete generally increases durability of concrete subjected to alkali-silica reaction by reducing reactive alkali content of concrete mixes. Additionally, use of fly ash in concrete reduces its permeability which in turn diminishes alkali aggregate reaction that can occur due to water penetration in the structures.

1. A.K. MULLICK (2005)[1]

The engineering properties such as durability of concrete were improved with incorporation of fly ash. The modes of fly ash use, part replacement of ordinary Portland cement in ready- mix concrete for pavements and roads. The advantage of high volume fly ash concrete roads will be of cost reduction, reduced maintenance during service life. Heat of hydration of concrete is reduced by the addition of fly ash. Use of concrete, in which up to 70 percent cement has been replaced by fly ash, has been successfully adopted in USA for road construction.

2. SUVIMOL SUJJAVANICH, VORADEJ SIDA PRASERT (2005)[2]

This study investigated the effect of local high-volume fly ash incorporating a mid-range water reducer on compressive strength of concrete and on chloride penetration and steel corrosion under tropical conditions. HVFA provided significant reduction of chloride permeability and steel corrosion risk. The effectiveness of the corrosion reduction was independent of compressive strength. A mid range water reducer improved the 28-day strength by 50 to75%, HVFA concrete with a replacement of 50 to 65% was ranked at greater than 90% probability of no steel corrosion and decreasing chloride permeability.

Langley ET.Al. reported that maximum fly ash percentage might range between 55 and 60 percent of total cement content in order to produce structural grade concrete. Their test rsults revealed that strength properties, modulus of elasticity, drying shrinkage, creep and freeze-thaw durability of low-cement and high fly ash content concrete compared favorably to normal Portland cement concrete.

3. ARVIND KUMAR, JAGROOP SINGH (2005)[3]

Kaolinite clay is treated with fly ash in different proportions to investigate the relative strength gain in terms of unconfined compression. The inclusion of fly ash in kaolinite significantly increases the peak compressive strength and ductility. The increase unconfined compressive strength was found to be a function of fly ash content and curing period of fly ash treated sample. When mixed with soil, fly ash can develop cementation bonds due either to the pozzolanic effect or an inherent self hardening property.

4. V.SARASWATHY, S.MURALIDHARAN, S. SRINIVASAN (2004)[4]

Concrete specimens made with fly ashes at different percentage of fly ash replacement (10 to 40%) levels were evaluated for their compressive strength at 7, 14, 28 and 90 days of curing period Flexural strength of concrete and steel to concrete bond strength characteristics at 28 and 90 days of curing also carried out. The results obtained were compared with those obtained for ordinary Portland cement concrete. The curing time increased the compressive strength, flexural strength and bond strength irrespective of the system studied. Activated fly ashes showed improved mechanical properties when compared to inactivated fly ashes. Replacement levels of 10 to 20% activated fly ashes showed improved mechanical properties of blended cement concrete. Therefore activated fly ash blended cement may be utilized as a substitute for OPC in construction.

5. TARUN R. NAIK, BRUCE W. RAMME, AND RUDOLPH N. KRAUS (2004)[5]

To evaluate the long term performance of concrete pavements made with high volumes of class F and class C fly ash. Long term test were conducted for compressive strength, resistance to chloride-ion penetration and density. Concrete density was not greatly influenced by either the type or the amount of fly ash or the age with in the tested range. Class F flies ash exhibited high resistance to chloride ion penetration relative to mixtures containing class C fly ash. The rate of early age strength gain of class C fly ash concrete mixtures was higher compared to the class F fly ash concrete. The best long-term performance was recorded for both the 53% and 67% class F fly ash and 70% of class C fly ash concrete. Based on the investigation, it is desirable to use high-volumes of class C or class F fly ash in the manufacture of low-cost HPC concrete systems for improved performance.

6. S. K.SEKAR, P. DEVADAS MANOHARAN (2004)[6]

A quantitative assessment of different cement replacement levels with fly ash on the Compressive strength, split tensile strength and flexural strength properties of HPC of M_{20} and M_{40} and to arrive at the optimum level of replacement of cement with fly ash. The compressive strength of fly ash concrete was analyzed for 7,28,60,90 and 180 days curing. The spit tensile strength and flexural strength values of concrete were determined at 28 and 60 days of water curing. The above mentioned properties of concrete with and without fly ash are compared with for various dosages of superplasticizers. The compressive strength of concrete with superplastisizer increases up to the fly ash content of 20% for both M_{20} and M_{40} concrete mixtures. The split tensile strength of concrete increases up to a maximum of 40% and 44% in the presence of superplastisizer for M_{20} concrete at 20% replacement of cement with fly ash. The flexural strength of concrete increases up to a maximum of 14% and 23.6% in the presence of superplastisizer for M_{20} concrete at the 20% replacement with fly ash. The naphthalene based superplasticizer showing the higher compressive strength for M20 concrete mixtures than the higher grade. The melamine based superplastisizer Shows better performance in higher grade concrete than the lower grade.

7. DJWANTORO HARDJITO, STEENIE E. WALLAH (2004)[7]

In geopolymer concrete, a by-product material rich in silicon and aluminum such as low calcium fly ash, is chemically activated by a high-alkaline solution to form a paste that binds the loose coarse and fine aggregate. The application of geopolymer concrete and future research needs is also identified. Higher concentration of sodium hydroxide solution results in a higher compressive strength of geopolymer concrete. Higher the ratio of sodium silicate-to-sodium hydroxide liquid ratio by mass, higher is the compressive strength of geopolymer concrete. As the curing temperature in the range of 30 to 90 ^{0}C increases, the compressive strength of geopolymer concrete also increases.

8. S.K. SINGH, M.P. SINGH, VENUS NATHALIA (2004)[8]

The concrete mix comprising of OPC-CA-FA with\without fly ash and superplastisizer was designed. The cement was replaced with varying amount of fly ash in the mix and the Superplastisizer dose was determined to increase the slump value from 25-30mm 150-200mm with same water-binder ratio. Fly ash incorporation in the mix ingredient enhances performance of concrete by improving workability, compressive strength, flow ability, finishability, and compact ability in fresh state of concrete. At 28 days, 18-20% part replacement of cement by fly ash resulted higher in Compressive strength than that of controlled concrete for same mix.7 days compressive strength of fly ash mix is lower than that of normal mix whereas 28 days compressive strength it gains the strength well above than that of normal mix.

9. PARDEEP K. GUPTA, VIKAS CHAUDHARY (2004)[9]

FLY ash can be properly utilized as an engineering material for production of high strength cement as a construction material in books and blocks for soil stabilization and for pavement construction for highways. If the fly ash is properly managed and utilized, not only the cost incurred in disposing of the fly ash can be saved but the organizations can also earn profit from it. Since the demand for thermal energy is increasing continuously, the generation of fly ash is also increases and safe disposal is limited. Many technologies are available for fly ash use in cement manufacturing, brick manufacturing and other bulk applications.

10. GEORGE CARETTE, ALAIN BILODEAU, V. M. MALHOTRA (2003)[10]

In high volume fly ash concrete, the water cement content are kept low at about 115 and 155 kg\m^3 of concrete respectively and the proportion of fly ash in the total cementatious material as ranges from 55 to 60%.The properties of fresh concrete investigated included workability, bleeding and setting time. The properties of hardened concrete investigated included compressive, flexural, and splitting tensile strengths, creep and drying shrinkage. High volume fly ash concrete with good overall performance regarding workability, setting time, temperature rise and mechanical properties. significant variations were observed in the rheological properties of the various concrete mixtures Compressive strength in the range of 40 to 50 MPa were achieved for all concretes at the age of 91 days. The increase of the water curing period from 7 to 91 days reduced the amount of Shrinkage in all cases.

11. R. NAIK, BRUCE W. RAMME (1990)[11]

Test was carried out on nominal structural grade concrete utilizing fly ash. The test were performed to report the effect of high- lime(class C) fly ash on water demand, workability, time of set, and compressive strength of concrete. As the amount of fly ash increases, the water demand decreases. For the same workability the water to-cemetitious ratio decreases significantly as the fly as content increases from no replacement to 60% replacement. The initial and final set time is not significantly different when the fly ash replacement for cement is increased up to 55% of concrete. The fly ash can be used for structural grade concrete up to at least 40% replacement of cement, with improved workability and improved strength.

12. MARTA KOSIOR- KAZBERUK, MALGOZATA LELUSZ (2006)[12]

Mathematical models were elaborated to predict the development of compressive strength of concrete with fly ash replacement percentages up to 30% Strength of concrete with different type of cement have been analyzed to the effect of addition content, the time of curing and the type of cement on the compressive strength changes. The test result shows that finally all mixes, containing fly ash, were able to develop a higher flexural strength than the control mixes. The result shows that the fly ash has a beneficial effect on compressive strength of all cement tested. The rate of strength increase of fly ash concrete is slower and sustains for longer periods, the concrete containing fly ash are capable of developing higher strength than Portland cement concrete. Statistical methods can be used to investigate the selected range of binders combinations influence on chosen performance characteristics of concrete. Elaborated statistical models can serve as a tool for estimating the compressive strength development of concrete according to fly ash content and time of curing as well as the optimum binder content.

13. A. CAMOES (2006)[13]

Large scale cement replacement in concrete by by- product such as will be extremely beneficial from the overall ecological and environmental point of view An experimental research work was carried out focused on the evaluation of the possibility of producing low

Portland cement content concrete with enhanced or even high performances, including local by- products such as fly ash and common low cost aggregate. The total binder used was composed by 40% of Portland cement and 60% of fly ash by mass of the total cementitious material. The compressive strength tests indicate that concrete with about 35 MPa strength at 28 days can be produced using 160 kg\m^3 of cement and 400 kg\m^3 of binder content which is sufficient for the majority of the structural concrete constructions application. Increasing the binder content to 500kg\m3 or 600kg/m3, and maintaining the 60% of cement replaced by fly ash, the 28 days compressive strength increases respectively to about 45 MPa or 55 MPa. All the determined durability parameters show that these concretes seem to be highly durable ones which permit to classify them as high-performance concrete.

14. L. K. CROUCH, RYAN HEWITT, BEN BYARD (2006)[14]

It is the brief review of the theory and construction practice with concrete mixtures containing more than 50% fly ash by mass of cementitious material. Mechanisms are discussed by which the incorporation of high volume fly ash in concrete reduces the water demand, improves workability, and minimizes cracking due to thermal and drying shrinkage. The concrete construction industry has realized that coal fly ash is relatively inexpensive and widely available by-product that can be used for partial cement replacement to achieve excellent workability in fresh concrete mixtures. High amounts of fly ash on the order of 25% - 30% are recommended when there is a concern for thermal cracking, alkali-silica expansion, or sulfate attack. Properly cured high- volume fly ash concrete products are very homogenous in microstructure, crack-free and highly durable. The high volume concrete offers a holistic solution to the problem of meeting the increasing demand for concrete in the future in a sustainable manner and at a reduced or no additional cost. The technology of high -volume fly ash concrete is especially significant for countries like China and India, where, given the limited amount of financial and natural resources.

CHAPTER 3

PROBLEM DEFINITION:

We are constantly faced with ever-larger ecological problems associated with the emissions of CO_2 into the atmosphere. It is well known that for every ton of Portland cement produced, approximately one ton of CO_2 is released, which means that the Portland cement industry contributes for about 7% of the total CO_2 emissions. Also, other adverse environmental impact of Portland cement production refers to the high energy consumption. After aluminum and steel, the manufacturing of Portland cement is the most energy-intensive process that consumes about 4 GJ of energy per ton [1]. So as to reduce the emission of CO2 concerning the production of cement, we must reduce the use, and therefore the demand of Portland cement.

However, the emission of CO2 and the energy consumption are only some of the many problems we are facing nowadays. The inadequate durability of reinforced portland cement concrete structures and the increase of the volume of construction in the last few decades has resulted in a rampage of our natural resources. The availability of resources is finite and therefore we must alert the industry to the sustainability of construction.

OBJECTIVE

The main objective of this project is to study the strength characteristics of high volume fly ash concrete. Concrete specimens made with different percentage of fly-ash replacement levels (10 to 70%) for their compressive strength, split tensile strength, flexural strength and permeability on 7, 28 and 45 days using M_{30} and M_{50} grade of concrete. Based on this experimental result, the mathematical model of strength properties for concrete will be developed. The experimental result reveals the optimum percentage of fly-ash content for the concrete to achieve the maximum strength.

CHAPTER 4

EXPERIMENTAL PROGRAM

A Portland cement concrete was proportioned to produce the 28-daystrength of 6000 psi (41 MPa). In addition, concrete mixes were also proportioned to incorporate fly ash at various percentages of cement replacements ranging between 10 - 70%. Experiments were designed to evaluate performance of fly ash concretes with respect to compressive strength, splitting tensile strength flexural strength, and secant modulus of elasticity.

MATERIALS USED

Portland cement (OPC), 53 grade obtained from a single source was used in this work. Locally available river sand, with a specific gravity of 2.61 and fineness modulus of 2.62 were used as fine aggregate. The crushed aggregates with a maximum size of 20 mm having a specific gravity of 2.80 and fineness modulus of 6.59 were used as course aggregate. Fly-ash having specific gravity of 2.15 obtained from thermal power plant was used for the replacement of cement. The super plasticizer conplast was used; the optimum content was estimated to be between 0.5% to 1.0% by mass of the binder. The value of 1.0 was adopted in this work. Table 1 shows the oxide content of cement and fly-ash used.

Table 4.1 Oxide composition of cement and fly-ash

Chemical composition	Cement %	Fly ash %
SiO_2	19.74	60.87
Al_2O_3	4.13	20.40
Fe_2O_3	3.27	7.82
CaO	62.99	2.72
MgO	1.90	1.40
SO_3	3.02	0.22
Cl^-	0.04	0.00
Free Lime	1.43	0.00

CONCRETE:

In general, concrete is a mixture of four to six components i.e. coarse aggregate, fine aggregate, fine aggregate, water, Portland cement, supplementary cementing materials (SCMs), and chemical admixtures. The last two components are sometimes optional. A chemical reaction called hydration occurs between water and Portland cement. When SCMs are used, then a second chemical reaction called pozzolanic reaction happens between some of the hydration products and the SCMs. These two reactions bind the aggregate particles to produce a very hard and strong binding material that is concrete.

is the most used material in civil engineering construction. More than a tone of concrete is produced every year for each person in the planet, which makes the total quantity approximately six billion tonnes per year. If perfectly understood concrete is strong, inexpensive, versatile and easy to make.

FLY ASH:

Fly ash is a by-product from coal-fired electricity generating power plants. The coal used in these power plants is mainly composed of combustible elements such as carbon, hydrogen, oxygen and non-combustible impurities (10 to 40%) usually present in the form of clay, shale, quartz, feldspar and limestone. As the coal travels through the high-temperature zone in the furnace, the combustible elements of the coal are burnt off, where as the mineral impurities of the coal fuse and chemically recombine to produce various crystalline phase of the molten ash. The molten ash is entrained in the flue gas and cools rapidly, when leaving the combustion zone (from 1500°C to 2000°C in fiew seconds) into spherical, glassy particles. The fly ash is then collected in electrostatic precipitators or bag houses and the fineness of the fly ash can be controlled by how and where the particles are collected.

COARSE AGGREGATE:

Coarse aggregates are particles of gravel or crushed stone retained on the 10mm sieve. The most commonly used maximum aggregate size is 20mm.

FINE AGGREGATE:

Fine aggregates are particles of natural or synthetic sand passing the 4.75mm sieve.

PORTLAND CEMENT:

A cementing material obtained by pulverizing clinker, consisting essentially of hydraulic calcium silicate that hardens by reacting with water.

SUPERPLASTICIZER:

A high range water reducing admixture with brand name FOSROC CONPLAST SP337 was used to increase the workability. This superplasticizer was of dark brown colour in an aqueous solution with sulphonated naphthalene formaldehyde as its base. The minimum and maximum dosage range is 0.3 to 0.70 litrs/50kg cement respectively. Mix thoroughly into water to be used for making concrete. The properties of superplasticiser are given in table 2

Table (4.2) Properties of superplasticiser (CONPLAST SP337)

Sulphonated Naphthalene Formaldehyde Condensate
Specific Gravity : 1.22 – 1.25
Chloride Content – Nil
Recommended Dosage – 0.6 to 1.4 litre per 100 kg of cement
Approximate Additional Air Content: 1 % at normal dosage
Solid Content : 40 %
Compatibility – All types of cement except high alumina cement
Operating Temperature = 10°C to 40°C

- Data taken from the product brochure of the supplier

HIGH-VOLUME FLY ASH CONCRETE

Fly ash, a principal by-product of the coal-fired power plants, is well accepted as a pozzolanic material that may be used either as a component of blended Portland cements or as a mineral admixture in concrete. In commercial practice, the dosage of fly ash is limited to 15%-20% by mass of the total cementitious material. Usually, this amount has a beneficial effect on the workability and cost economy of concrete but it may not be enough to sufficiently improve the durability to sulfate attack, alkali-silica expansion, and thermal cracking. For this purpose, larger amounts of fly ash, on the order of 25%-35% are being used. From theoretical considerations and practical experience the authors have determined that, with 50% or more cement replacement by fly ash, it is possible to produce sustainable, high-performance concrete mixtures that show high workability, high ultimate strength, and high durability.

MIXTURE PROPORTION

The concrete mixtures were designed initially on the basis of ACI Committee 211 and IS 456:2000. The control concrete mix proportions for M_{30} and M_{50} having the slump of 75-100mm with air content of 2.0% are shown in table. The various mix proportions were obtained by replacing 10, 20, 30,40,50,60 and 70 % of the mass of the cement by fly ash. Also, the composition of water reduced mix was established by reducing the water content of all the mixes by 20% with slump being maintained the same by the use of superplasticizers. Details of mix proportions for M30 and M50 concrete as shown in table 3 and 4.

Table (4.3) Mix proportion details of M30 concrete.

Mix Design CRM %	A 0	AFA1 10	AFA2 20	AFA3 30	AFA4 40	AFA5 50	AFA6 60	AFA7 70
w/c ratio	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Cement(kg/m3	465	418.5	372	325.5	279	232.5	186	139.5
Fly ash(kg/m^3)	0	46.5	93	139.5	186	232.5	279	325.5
Sand(kg/m^3)	604	604	604	604	604	604	604	604
C.A (kg/m^3)	1250	1250	1250	1250	1250	1250	1250	1250
Water (kg/m^3)	190	190	190	190	190	190	190	190

Table (4.4) Mix proportion details of M50 concrete.

Mix Design CRM %	B 0	BFA1 10	BFA2 20	BFA3 30	BFA4 40	BFA5 50	BFA6 60	BFA7 70
w/c ratio	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Cement(kg/m^3	489	440.1	391.2	342.3	293.4	244.5	195.6	146.7
Fly ash(kg/m^3)	0	48.9	97.8	146.7	195.6	244.5	293.4	342.3
Sand(kg/m^3)	683.1	683.1	683.1	683.1	683.1	683.1	683.1	683.1
C.A (kg/m^3)	1108	1108	1108	1108	1108	1108	1108	1108
Water (kg/m^3)	145	145	145	145	145	145	145	145

Note:

CRM - Cement Replacement material (fly ash)

A - M30 control concrete

FA10 - 10% fly ash

FA 20 - 20% flyash

FA30 - 30% flyash

FA 40 -40% flyash

FA50 - 50% fly ash

FA60 - 60%flyash

FA70 - 70%flyash

Note:

CRM - Cement Replacement material (fly ash)

B - M50 control concrete

FB10 - 10% fly ash

FB20 - 20% flyash

FB30 - 30% flyash

FB 40 -40% flyash

FB50 - 50% fly ash

FB60 - 60%flyash

FB70 - 70%flyash

PREPARATION AND CASTING OF TEST SPECIMEN

Fourteen batches were made from concrete mixtures to cast total 42 cubes (150mmx150mmx150mm), 42 cylinders (150mm dia. And 300mm height), 42 prisms (100mmx100mmx500mm). These specimens were tested for compressive strength, split tensile strength, flexural strength and modulus of elasticity respectively at 7,28 and 45 days in accordance with IS: 516- 1959 and IS: 5816 – 1970. Prepared specimens are shown in fig. (1)

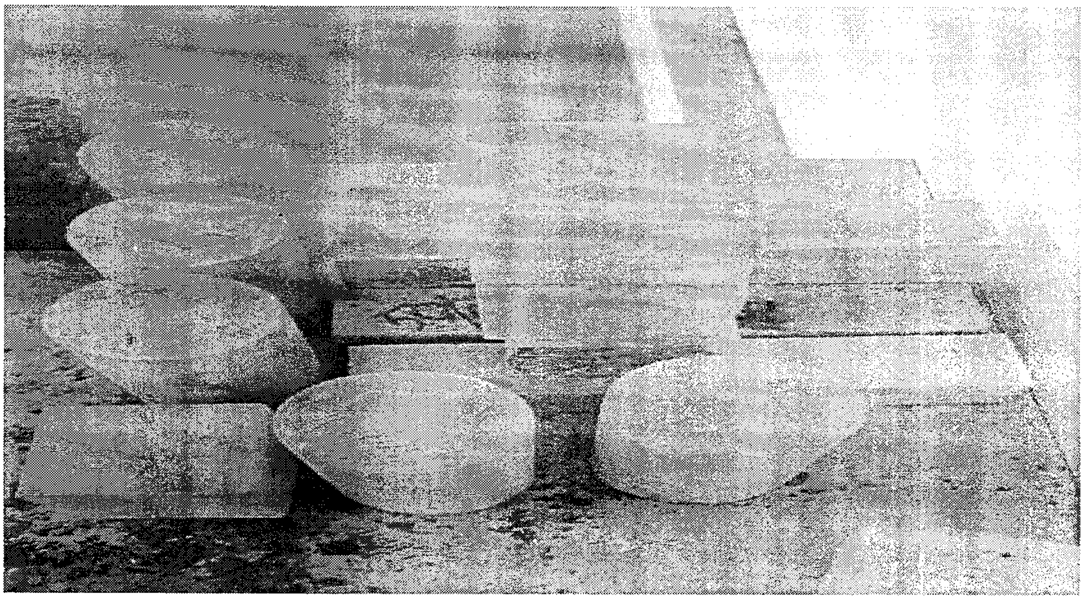


Fig. (1) Prepared specimens

MIXING PROCEDURE:

The coarse and fine aggregate were initially poured in to the concrete mixer. After that, mixer was stopped. Then Portland cement, fly ash and half of water were poured into the mixer. While the mixer was operated, remaining water in the case of without superplasticizer otherwise remaining water and superplasticizer were subsequently added into the mixer. The mixing time was 4 to 4.5 minutes from the time when all the mix ingredients had been charged into the mixer.

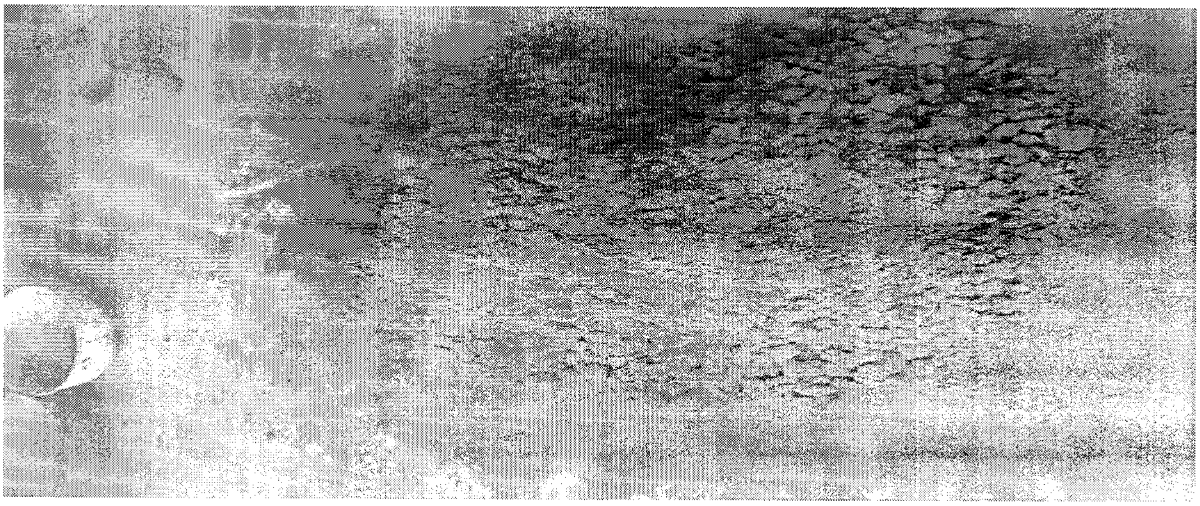


Fig. (2) Mixing of Concrete

COMPACTION AND CURING OF TEST SPECIMENS

Cubes and prisms were cast in two layers and cylinders were cast into three layers. For all specimens the compaction was achieved using a vibration table. For all the specimens steel moulds were used. After casting, all moulds were left in the casting laboratory for 24 hours. Afterwards, they were demoulded and transferred into curing tank at room temperature till the time of testing. Compaction and curing as shown in fig. (2).

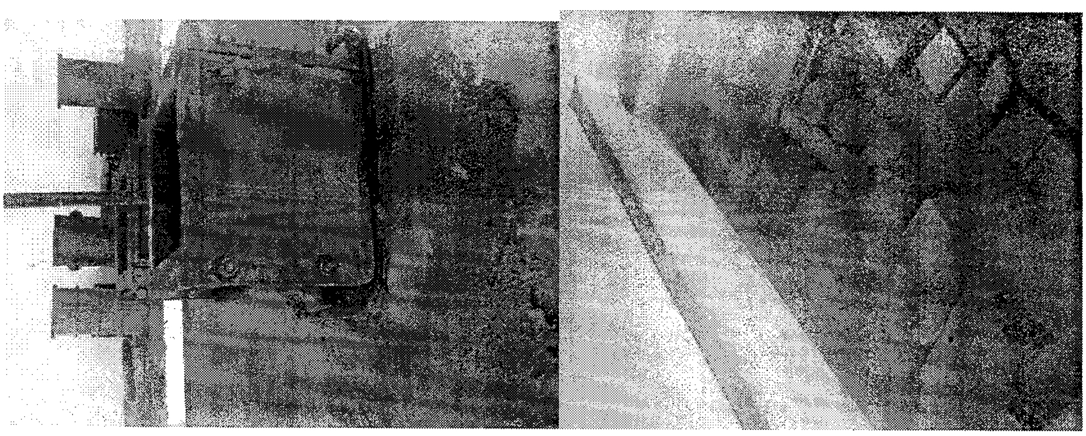


Fig. (3) Compaction and curing.

CHAPTR 5

TESTING OF SPECIMENS

TESTING METHODS:

COMPRESSIVE STRENGTH TEST

150mmx150mmx150mm concrete cubes were cast using M30 grade (1:1.4:2.8) and M50 grade (1:1.35:2.3) with W/C ratios 0.43 and 0.30 respectively. Specimens with ordinary Portland cement (OPC) and OPC replaced by fly ash at 10%, 20%, 30%, 40%, 50%, 60% and 70% levels were cast. During casting, the cubes were mechanically vibrated by using a table vibrator. After 24 hours, the specimens were removed from the mould and subjected to water curing for 7, 28 and 45 days. After curing, the specimens were tested for compressive strength using a calibrated compression testing machine of 2000 KN capacity. The compressive strength testing arrangement was shown in fig. (3).

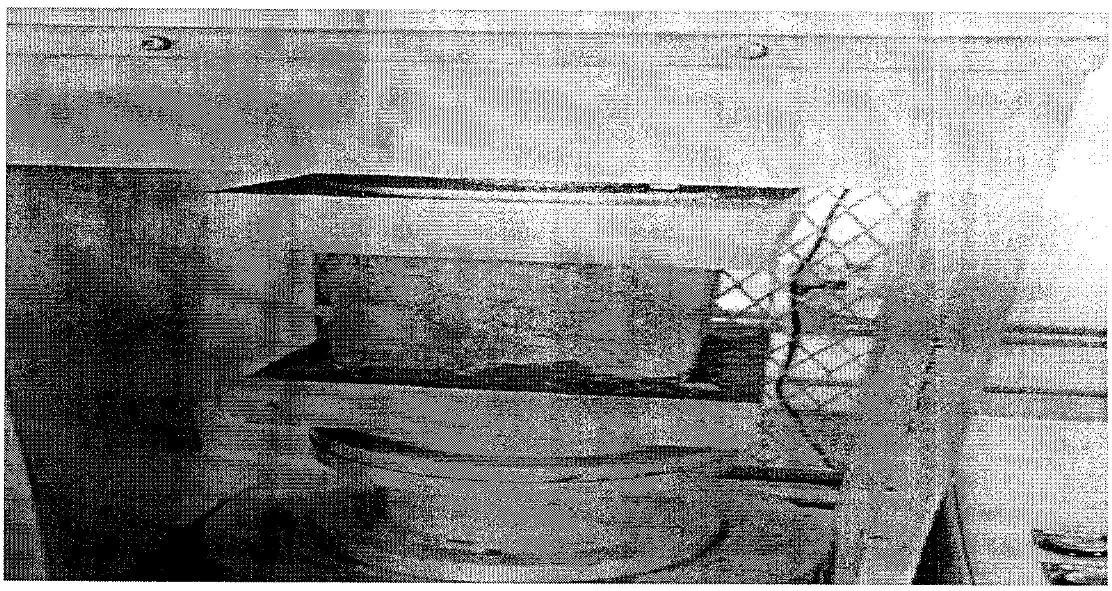


Fig (4) Compressive strength testing arrangement

SPLIT TENSILE STRENGTH

Split tensile strength of concrete is usually found by testing plain concrete cylinders. Cylinders of size 150mm x 300 mm were casting using M30 and M50 grade concrete with w/c ratio of 0.43 and 0.30 respectively. Specimen with OPC and OPC replaced by fly ash at 10%, 20%, 30%, 40%, 50%, 60% and 70% replacement levels were cast. During molding, the beams were mechanically vibrated using a table vibrator. After 24 hours, the specimens were removed from the mould and subjected to water curing for 7, 14 and 28 days. After curing, the specimens were tested for compressive strength using a calibrated compression testing machine of 2000kN capacity.

The specimen is placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould. The axis of the specimen is carefully aligned with the axis of the loading device. The load is applied without shock and increasing continuously at the rate such that the extreme fiber stress increases approximately 0.7kg/sq cm/min that is, at a rate of loading of 400kg/min for the 150mm specimen.

Fig (5) Split tensile strength testing arrangement

FLEXURAL STRENGTH

Flexural strength of concrete is usually found by testing plain concrete beams. Beams of size 500mmx100mmx100mm were cast using M30 grade (1:1.4:2.8) and M50 grade (1:1.35:2.3) mix with W/C ratios of 0.43 and 0.30 respectively. Specimen with OPC and OPC replaced by fly ash at 10%, 20%, 30%, 40%, 50%, 60% and 70% replacement levels were cast. During molding, the beams were mechanically vibrated using a table vibrator. After 24 hours, the specimens were removed from the mould and subjected to water curing for 7, 14 and 28 days. After curing, the specimens were subjected to flexure test by two points loading using flexural testing machine of 100KN capacities.

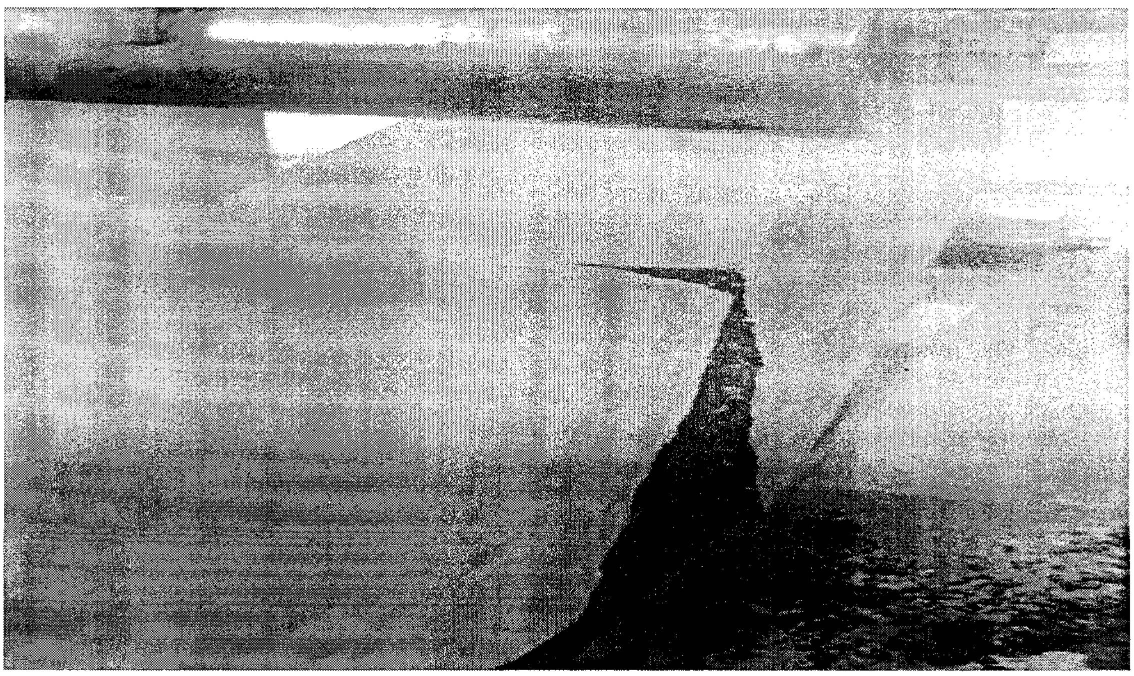


Fig.(6) Flexural strength testing arrangement

MODULUS OF ELASTICITY

In this investigation, the modulus of elasticity, this is also called secant modulus, is taken as the slope of the chord from the origin to some arbitrary point on the Stress-strain curve. The secant modulus calculated in this study is for 33% of the maximum stress. Modulus of elasticity of concrete mixtures was determined at the ages of 28 and 45 days.

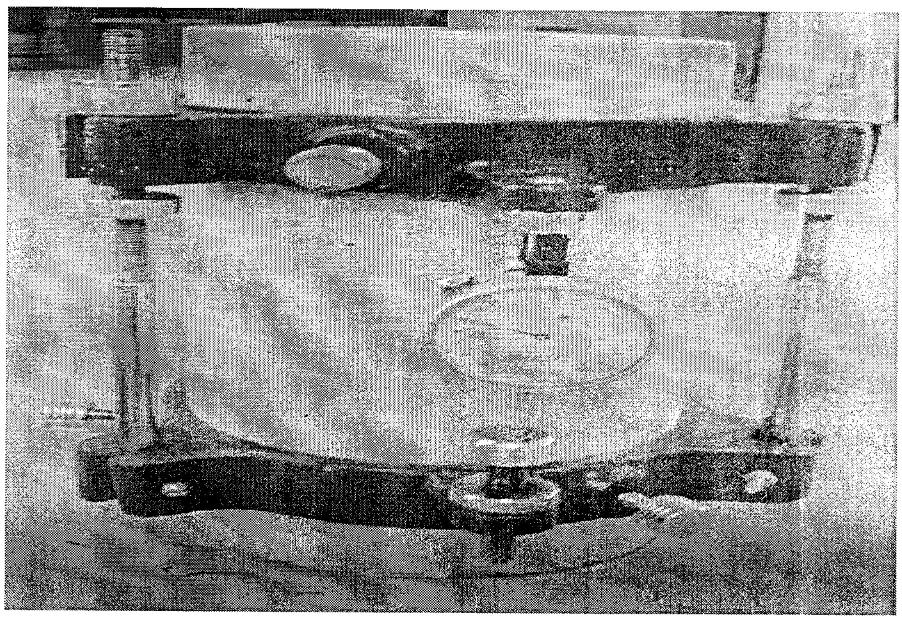


Fig. (7) Stress Strain testing arrangement

CHAPTER 6
RESULTS AND DISCUSSION

COMPRESSIVE STRENGTH

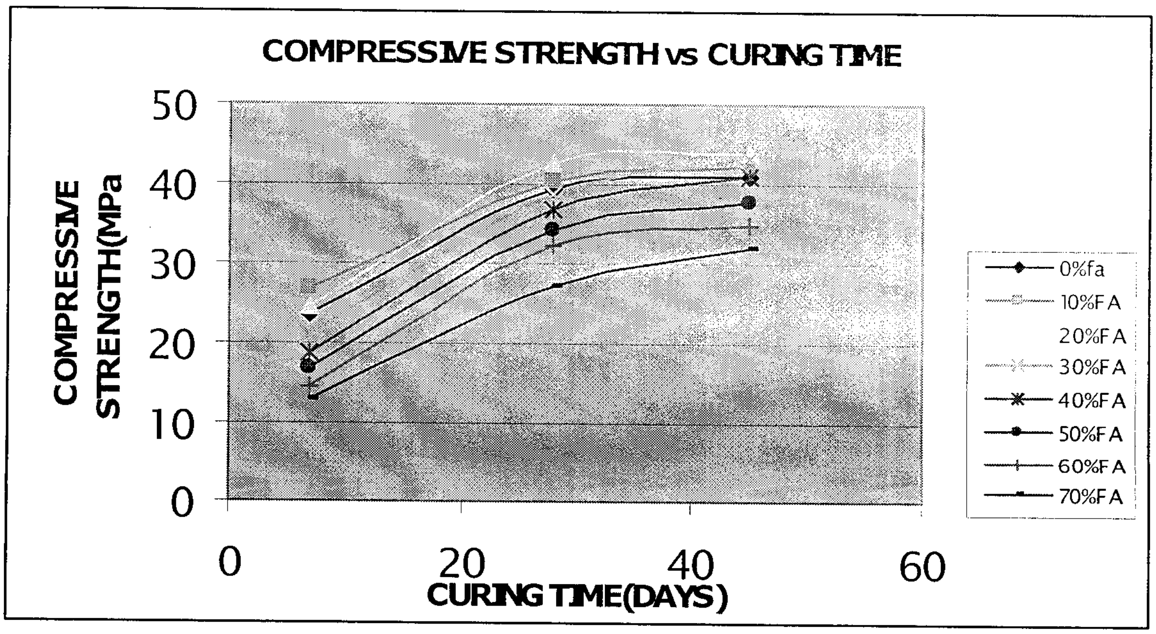
The average compressive strength Vs. curing time for ordinary Portland cement concrete and fly ash blended concrete of 10%, 20%, 30%, 40%,50%, 60% and 70% replacement levels are shown in fig. From these figures it can be noted that, the compressive strength of concrete generally increases with curing time. This observation is made irrespective of the amount of fly ash replacement. In the case of OPC, a two-fold increase in compressive strength is observed at the end of 28 days. At 7 days and 28 days compressive strength values are observed as 23.4 MPa and 39.2 MPa. On the other hand, in fly ash blended concrete, there is an increase in the compressive strength of about 1.5 times was observed. A decrease in compressive strength was observed as the percentage of fly ash replacement level increases at early ages irrespective of the type of fly ash used.

For example, in the case of FAC, at 7 days of curing, the compressive strength at 10 and 40% replacement level were found to be 26.75 MPa and 18.74 MPa, respectively.. But the results after 28 and 45 days curing shows improved performance with increased cement replacement levels. After 45 days curing, up to 30% cement replacement by fly ash shows better results than conventional concrete. At higher percentage of replacement (above 30%), a decrease in compressive strength values were observed irrespective of the period of curing and type of fly ash used.

This observation was made due to the fact that as the mineral admixtured phase exceeds the threshold value, a decrease in strength was observed. At 40% level, decreases in compressive strength values were observed due to the fact that for fly ash no additional lime available to proceed secondary hydration reaction with liberated lime. Compared between M30 grade and M50 grade concrete, M50 shows more strength when cement replacement level increases up to a certain level.

Table (6.1) Compressive strength of M30 grade concrete at 7, 28 and 45 days (cement replacement level (10 to 70%)

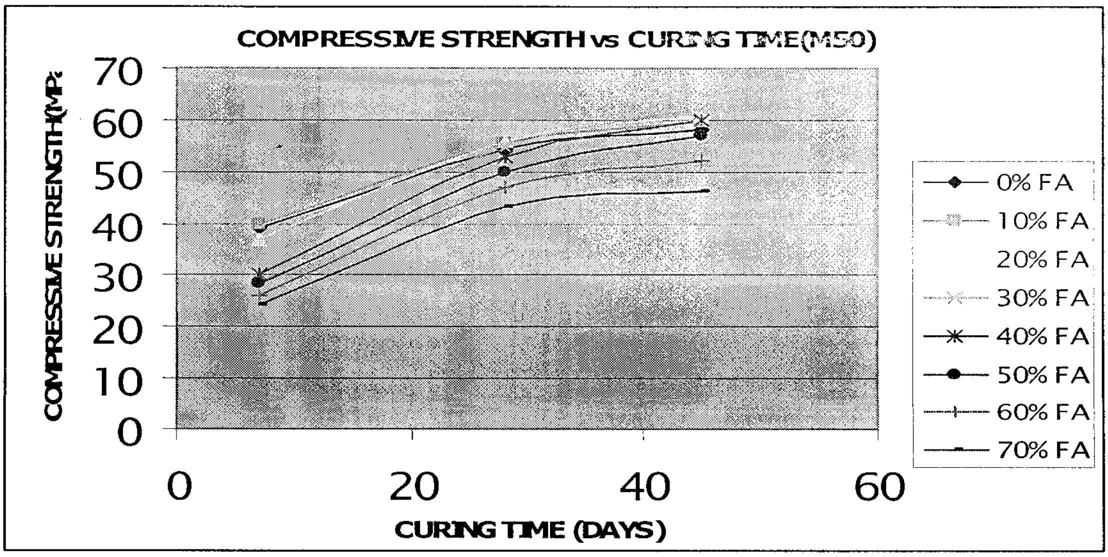
Mix designation	CRM percentage	Com. Strength (MPa) 7day	Com. Strength (MPa) 28day	Com. Strength (MPa) 45day
A	0	23.40	39.20	40.91
AFA10	10	26.75	40.41	42.17
AFA20	20	24.40	42.73	43.82
AFA30	30	20.90	38.84	43.79
AFA40	40	18.74	36.93	41.o8
AFA50	50	16.90	34.23	37.77
AFA60	60	14.45	31.27	34.84
AFA70	70	12.95	27.04	31.91



GRAPHICAL REPRESENTATION OFCOMPRESSIVE STRENGTH vs. CURING TIME (M30 GRADE)

Table (6.2) Compressive strength of M50 grade concrete at 7, 28 and 45 days (cement replacement level (10 to 70%))

Mix designation	CRM percentage	Com. Strength (MPa) 7day	Com. Strength (MPa) 28day	Com. Strength (MPa) 45day
B	0	39.22	54.43	58.19
BFA10	10	39.77	55.51	59.45
BFA20	20	36.82	56.01	60.72
BFA30	30	33.13	54.67	62.04
BFA40	40	30.14	52.71	59.97
BFA50	50	28.41	49.97	56.89
BFA60	60	26.24	46.80	53.28
BFA70	70	24.09	43.21	48.72



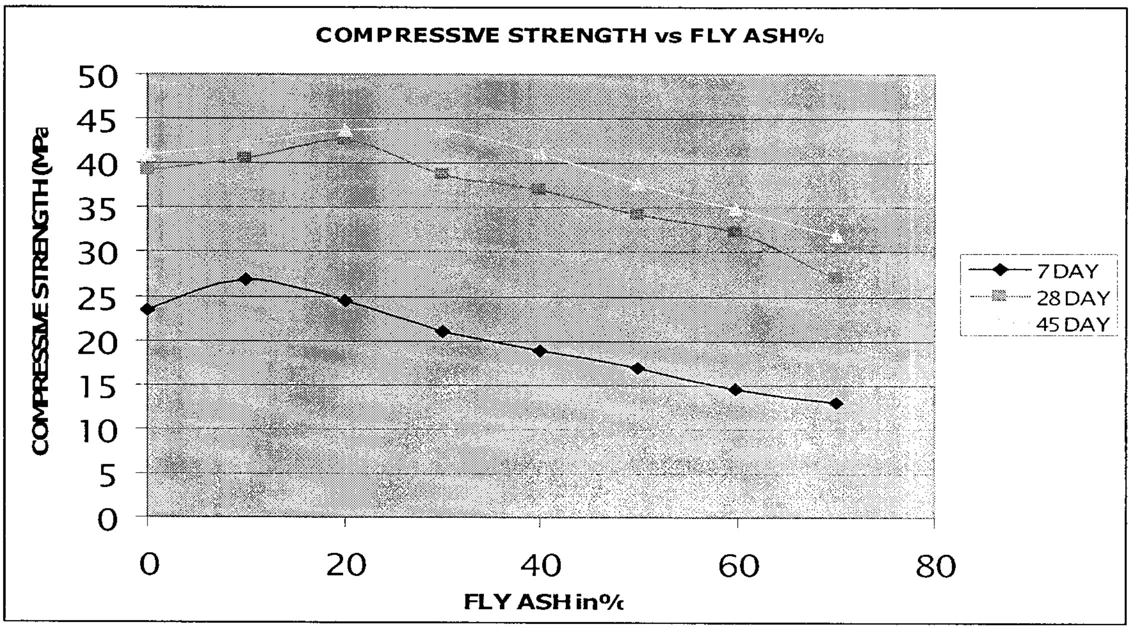
GRAPHICAL REPRESENTATION OFCOMPRESSIVE STRENGTH vs. CURING TIME(M50 GRADE)

Table (6.3) Compressivstrength of M30 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7 days com. Strength (MPa)	%differ than conventional concrete	28days com. Strength (MPa)	%differ than conventional concrete
A	0	23.40	0	39.20	0
AFA10	10	26.75	+14.31	40.41	+3.08
AFA20	20	24.40	+4.27	42.73	+9.00
AFA30	30	20.90	-10.68	38.84	+0.918
AFA40	40	18.74	-19.91	36.93	-5.79
AFA50	50	16.90	-27.77	34.23	-12.67
AFA60	60	14.45	-38.28	32.27	-17.67
AFA70	70	12.95	-44.65	27.04	-31.02

Table (6.4) Compressive strength of M30 grade concrete at 28 and 45 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	28days com. Strength (MPa)	%differ than conventional concrete	45days com. Strength (MPa)	%differ than conventional concrete
A	0	39.20	0	40.91	0
AFA10	10	40.41	+3.08	42.17	+3.07
AFA20	20	42.73	+9.00	43.82	+7.11
AFA30	30	38.84	-0.91	43.79	+7.03
AFA40	40	36.93	-5.79	41.08	+0.41
AFA50	50	34.23	-12.67	37.77	-7.67
AFA60	60	31.27	-20.22	34.84	-14.83
AFA70	70	27.04	-31.02	31.91	-21.99



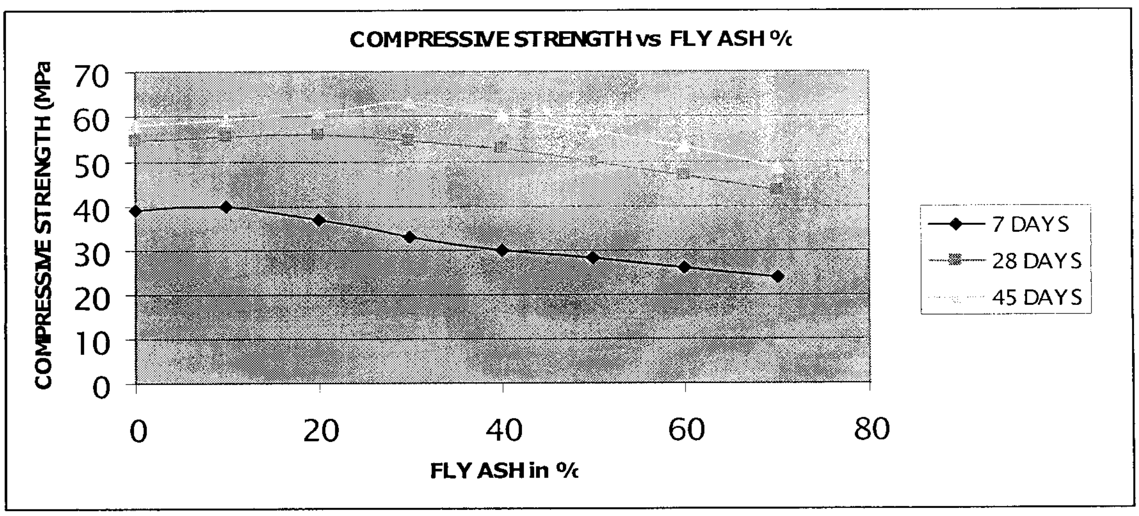
COMPRESSIVE STRENGTH OF M30 GRADE CONCRETE WITH VARYING FLY-ASH CONTENT.

Table (6.5) Compressive strength of M50 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7 days com. Strength (MPa)	%differ than conventional concrete	28days com. Strength (MPa)	%differ than conventional concrete
B	0	39.22	0	54.43	0
BFA10	10	39.77	+1.40	55.51	+1.98
BFA20	20	36.82	-6.11	57.01	+4.74
BFA30	30	33.13	-15.52	54.67	+0.44
BFA40	40	30.14	-23.15	52.71	-3.16
BFA50	50	28.41	-27.56	49.97	-8.19
BFA60	60	26.24	-33.09	46.80	-14.01
BFA70	70	24.09	-38.57	43.21	-20.61

Table (6.6) Compressive strength of M50 grade concrete at 28 and 45 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	28 days com. Strength (MPa)	%differ than conventional concrete	45days com. Strength (MPa)	%differ than conventional concrete
B	0	54.43	0	58.19	0
BFA10	10	55.51	+1.98	59.45	+2.16
BFA20	20	57.01	+4.74	60.72	+4.34
BFA30	30	54.67	+0.44	62.04	+6.65
BFA40	40	52.71	-3.16	59.97	+3.05
BFA50	50	49.97	-8.19	56.89	-2.23
BFA60	60	46.80	-14.01	53.28	-8.43
BFA70	70	43.21	-20.61	48.72	-17.27



COMPRESSIVE STRENGTH OF M50 GRADE CONCRETE WITH VARYING FLY-ASH CONTENT.

SPLIT TENSILE STRENGTH

CYLINDER SPLITTING TENSION TEST:

Carried out by placing the cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter. When the load is applied along the generatrix, an element on the vertical diameter of the cylinder is subjected to a vertical compressive stress of $2P/\pi LD$. The loading condition produces a high compressive stress immediately below the two generators to which the load is applied. It is estimated that the compressive stress is acting for about 1/6 depth and the remaining 5/6 depth is subjected to tension. The main advantage of this method is that is simple to perform and gives more uniform result than other tension tests.

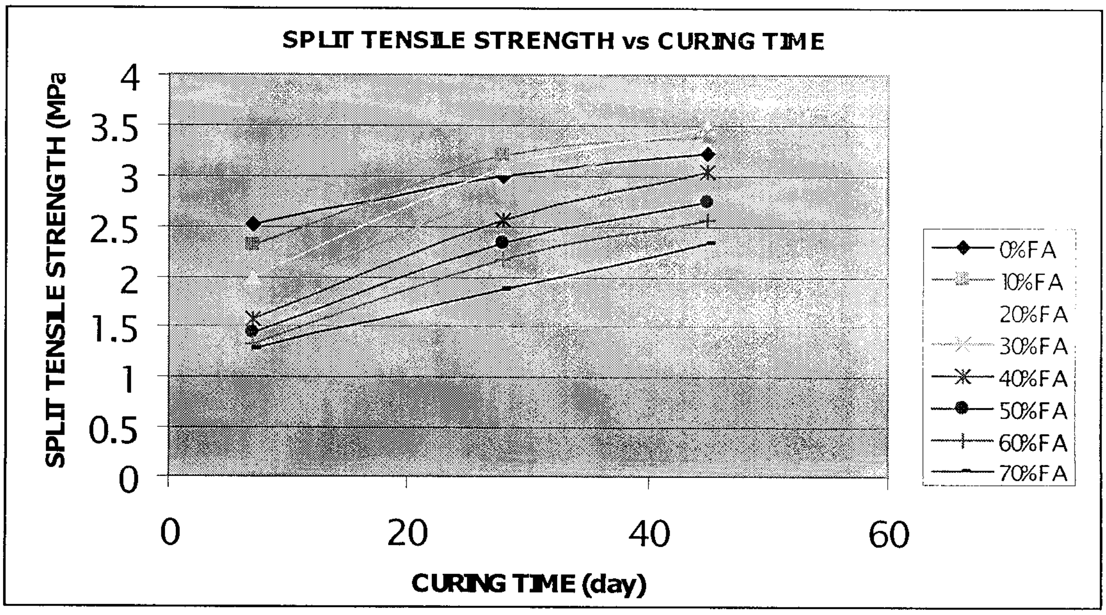
Splitting tensile strength data obtained from various concrete mixes (M30 andM50) is reported in Tables (11 to 14) for concrete made with class F fly ash. In general, splitting tensile strength increased with age for concretes made with Class F fly ash in table (15& 16). Also, in general, the tensile strength decreased with an increase in fly ash content in the concrete. However, percent decrease in tensile strength became lower at later ages. The relationship between tensile strength and age for the concrete made with the fly ash is shown in Figure.

The effect of fly ash addition on tensile strength of concrete is presented in Figure 6. Analysis of the results showed that the concrete containing 50% Class F fly ash obtained from Mettur power plant had 81% of the 28-day tensile strength of the reference concrete. A further decrease in value of the tensile strength was obtained when addition of fly ash was further increased to 60%.

The results show that the decrease in split tensile strength varies from 4.74% to 30.7% for M30 and 6.56% to 36.98% for M50 mixtures with superplastisizers having 10 to 70% cement replacement with fly ash.

Table (6.7) Split tensile strength of M30 grade concrete at 7, 28 and 45 days (cement replacement level (10 to 70%)

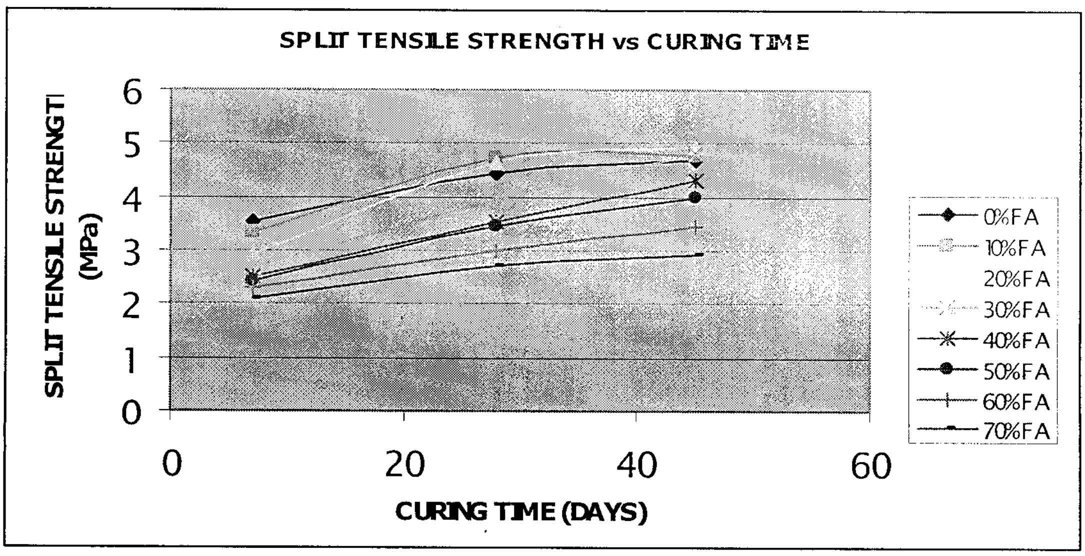
Mix designation	CRM percentage	Tensile Strength (MPa) 7day	Tensile Strength (MPa) 28day	Tensile Strength (MPa) 45day
A	0	2.51	2.99	3.23
AFA10	10	2.30	3.21	3.39
AFA20	20	1.99	3.09	3.47
AFA30	30	1.79	2.83	3.44
AFA40	40	1.58	2.56	3.04
AFA50	50	1.45	2.34	2.75
AFA60	60	1.32	2.17	2.56
AFA70	70	1.27	1.88	2.34



GRAPHICAL REPRESENTATION OF
SPLIT TENSILE STRENGTH vs. CURING TIME (M30 GRADE)

Table (6.8) Split tensile strength of M50 grade concrete at 7, 28 and 45 days (cement replacement level (10 to 70%)

Mix designation	CRM percentage	Tensile Strength (MPa) 7day	Tensile Strength (MPa) 28day	Tensile Strength (MPa) 45day
B	0	3.52	4.42	4.68
BFA10	10	3.31	4.71	4.75
BFA20	20	2.92	4.66	4.93
BFA30	30	2.69	3.94	4.79
BFA40	40	2.52	3.52	4.30
BFA50	50	2.44	3.46	3.97
BFA60	60	2.31	2.99	3.46
BFA70	70	2.09	2.72	2.92



GRAPHICAL REPRESENTATION OF

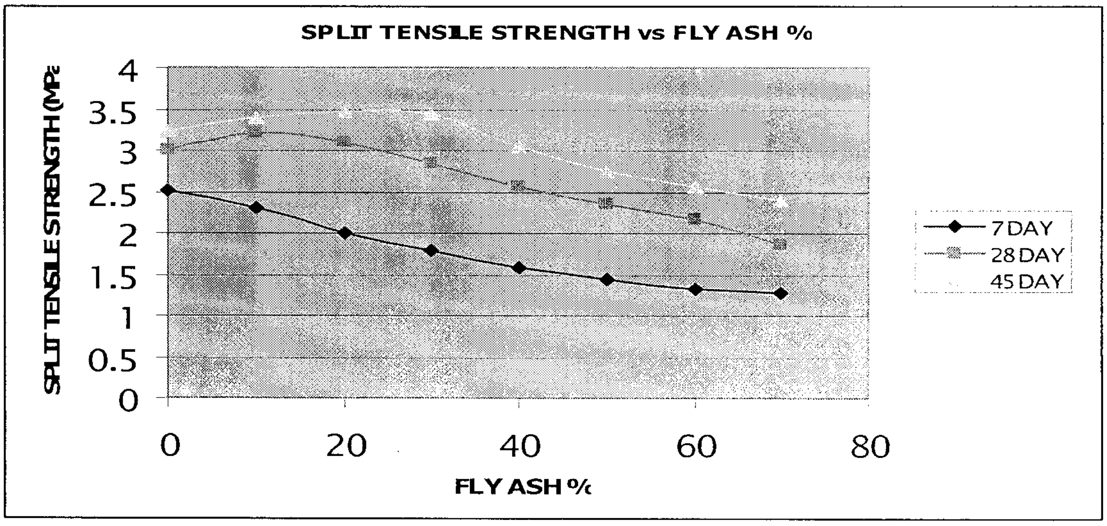
SPLIT TENSILE STRENGTH vs. CURING TIME (M50 GRADE)

Table (6.9) Split tensile strength of M30 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7daystensile Strength (MPa)	%differ than conventional concrete	28daystensile Strength (MPa)	%differ than conventional concrete
A	0	2.51	0	2.99	0
AFA10	10	2.30	-8.36	3.21	+7.35
AFA20	20	1.99	-20.71	3.09	+3.34
AFA30	30	1.79	-28.68	2.83	-5.35
AFA40	40	1.58	-37.05	2.56	-14.38
AFA50	50	1.45	-42.23	2.34	-21.73
AFA60	60	1.32	-47.41	2.17	-27.42
AFA70	70	1.27	-49.40	1.88	-37.12

Table (6.10) Split tensile strength of M30 grade concrete at 28 and 45 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	28daystensile Strength (MPa)	%differ than conventional concrete	45daystensile Strength (MPa)	%differ than conventional concrete
A	0	2.99	0	3.23	0
AFA10	10	3.21	+7.35	3.39	+4.95
AFA20	20	3.09	+3.34	3.47	+7.43
AFA30	30	2.83	-5.35	3.44	+6.50
AFA40	40	2.56	-14.38	3.04	-5.88
AFA50	50	2.34	-21.73	2.75	-14.86
AFA60	60	2.17	-27.42	2.56	-20.74
AFA70	70	1.88	-37.12	2.34	-27.55



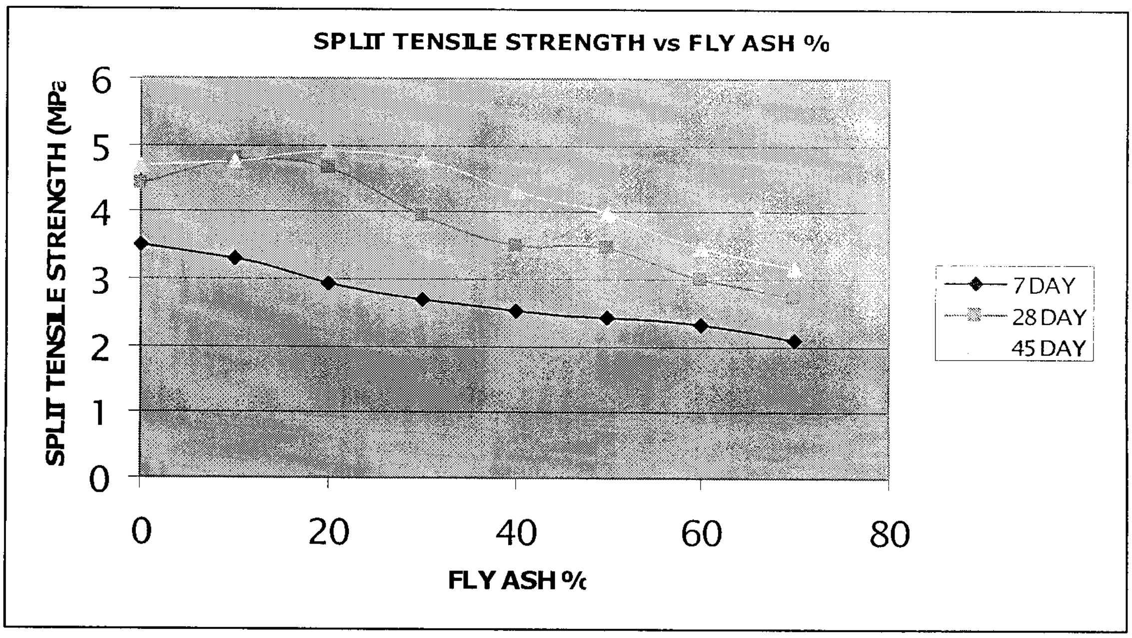
SPLIT TENSILE STRENGTH OF M30 GRADE CONCRETE WITH VARYING FLY-ASH CONTENT.

Table (6.11) Split tensile strength of M50 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7daystensile Strength (MPa)	%differ than conventional concrete	28daystensile Strength (MPa)	%differ than conventional concrete
B	0	3.52	0	4.42	0
BFA10	10	3.31	-5.96	4.71	+6.56
BFA20	20	2.92	-17.04	4.66	+5.42
BFA30	30	2.69	-23.57	3.94	-10.85
BFA40	40	2.52	-28.40	3.52	-20.36
BFA50	50	2.44	-30.68	3.46	-21.71
BFA60	60	2.31	-34.37	2.99	-32.35
BFA70	70	2.09	-40.62	2.72	-38.46

Table (6.12 Split tensile strength of M50 grade concrete at 28 and 45 days by varying fly-ash content from 10-70 % by weight of cement.)

Mix designation	CRM percentage	28daystensile Strength (MPa)	%differ than conventional concrete	45daystensile Strength (MPa)	%differ than conventional concrete
B	0	4.42	0	4.68	0
BFA10	10	4.71	+6.56	4.75	+1.49
BFA20	20	4.66	+5.42	4.93	+5.34
BFA30	30	3.94	-10.85	4.79	+2.35
BFA40	40	3.52	-20.36	4.30	-8.11
BFA50	50	3.46	-21.71	3.97	-15.17
BFA60	60	2.99	-32.35	3.46	-26.06
BFA70	70	2.72	-38.46	3.18	-32.05



SPLIT TENSILE STRENGTH OF M50 GRADE CONCRETE WITH VARYING FLY-ASH CONTENT.

FLEXURAL STRENGTH

The flexural strength of the specimen is 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 center line of the tensile side of the specimen, in cm. flexural strength, $f_b = 3pa/bd^2$, when "a" is less than 20cm but greater than 17cm for 150mm specimen.

Where, b = measured width in cm of the specimen

d = measured depth in cm of the specimen at the point of failure

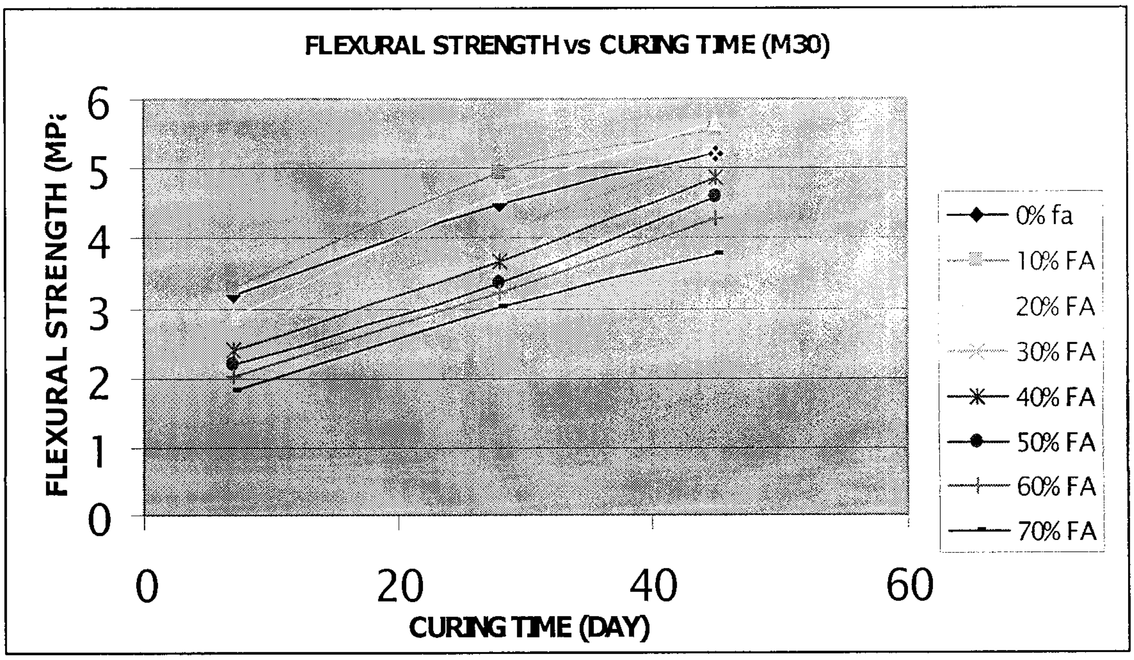
l = length in cm of the span on which the specimen was supported

p = maximum load in kg applied on the specimen.

The flexural strength data for OPC concrete and fly ash blended concrete at 10%, 20%, 30%, 40%, 50%, 60% and 70% replacement levels are shown in table. From the table it is found that the flexural strength both in OPC and fly ash blended concrete is increased with curing period. The flexural strength of OPC were found to be 3.18 MPa and 4.50 MPa for M30 grade concrete and 5.01 MPa and 7.75 MPa for M50 grade concrete at 7 and 28 days respectively. A slight increase in flexural strength was observed at 45 days of curing period. It was observed that as the percentage of replacement level increased beyond a certain limit cause the decrease in flexural strength.

Table (6.13) Flexural strength of M30 grade concrete at 7, 28 and 45 days (cement replacement level (10 to 70%)

Mix designation	CRM percentage	Flexural Strength (MPa) 7day	Flexural Strength (MPa) 28day	Flexural Strength (MPa) 45day
A	0	3.18	4.50	5.21
AFA10	10	3.30	4.95	5 55
AFA20	20	2.87	4.64	5.67
AFA30	30	2.64	4.07	5.20
AFA40	40	2.39	3.67	4.87
AFA50	50	2.18	3.36	4.61
AFA60	60	2.o3	3.21	4.29
AFA70	70	1.81	3.03	3.77

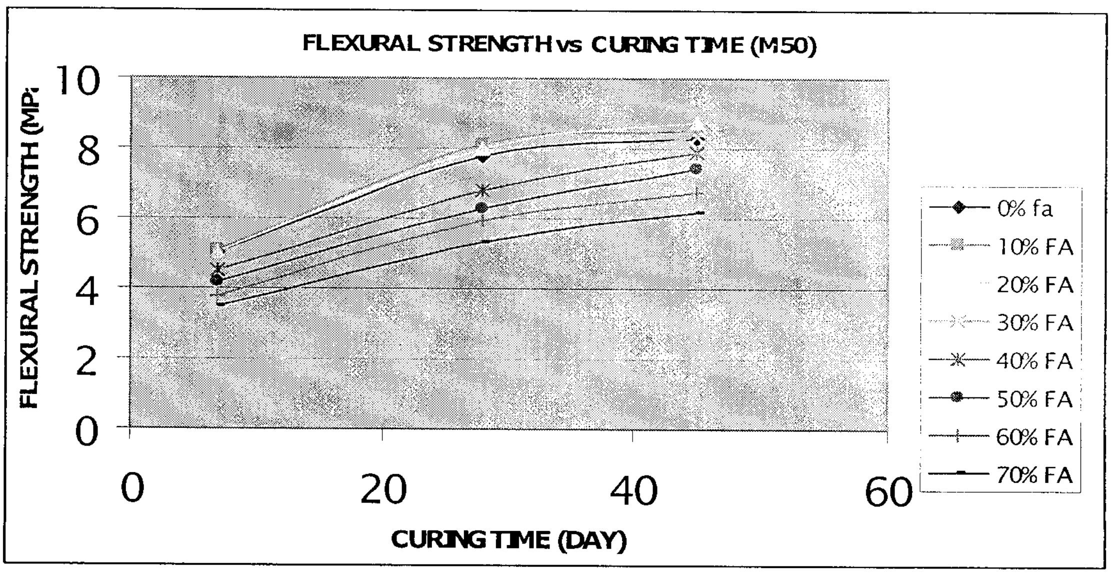


GRAPHICAL REPRESENTATION OF

FLEXURAL STRENGTH vs. CURING TIME (M30 GRADE)

Table (6.14) Flexural strength of M50 grade concrete at 7, 28 and 45 days (cement replacement level (10 to 70%)

Mix designation	CRM percentage	Flexural Strength (MPa) 7day	Flexural Strength (MPa) 28day	Flexural Strength (MPa) 45day
B	0	5.01	7.75	8.28
BFA10	10	5.11	8.11	8.49
BFA20	20	5.03	7.99	8.77
BFA30	30	4.71	7.23	8.33
BFA40	40	4.49	6.78	7.89
BFA50	50	4.18	6.27	7 43
BFA60	60	3.76	5.94	6.75
BFA70	70	3.48	5.31	6.17



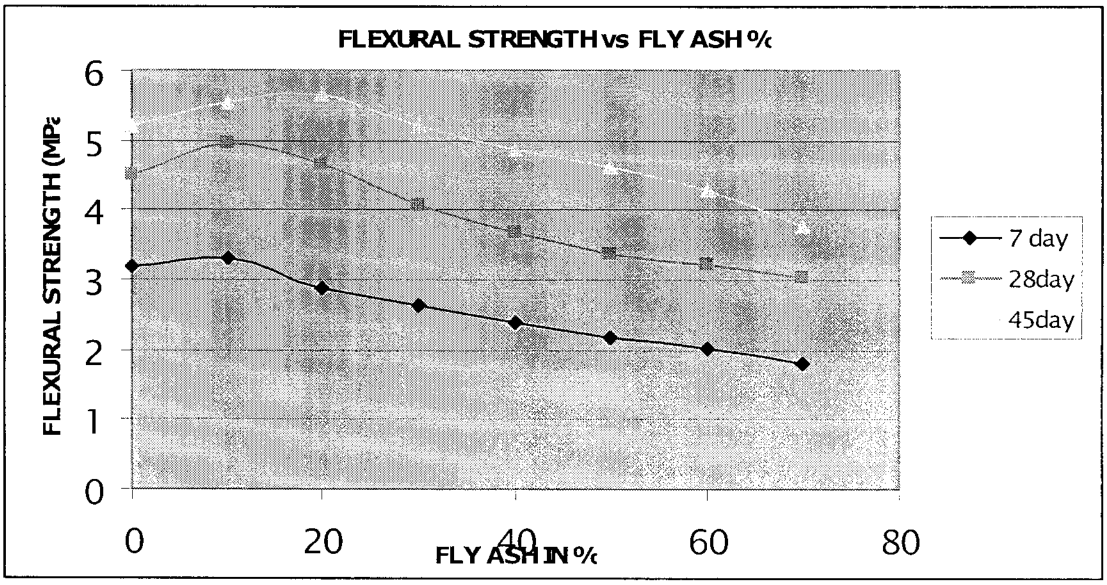
GRAPHICAL REPRESENTATION OF FLEXURAL STRENGTH vs. CURING TIME (M50 GRADE)

Table (6.15) Flexural strength of M30 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7daysflexural Strength (MPa)	%differ than conventional concrete	28daysflexuralStrength (MPa)	%differ than conventional concrete
A	0	3.18	0	4.50	0
AFA10	10	3.30	+3.77	4.95	+10.00
AFA20	20	2.87	-9.74	4.64	+3.11
AFA30	30	2.64	-16.96	4.07	-9.33
AFA40	40	2.39	-24.84	3.67	-18.44
AFA50	50	2.18	-31.44	3.36	-25.33
AFA60	60	2.o3	-36.16	3.21	-28.66
AFA70	70	1.81	-42.97	3.03	-32.67

Table (6.16) Flexural strength of M30 grade concrete at 28 and 45 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	28daysflexural Strength (MPa)	%differ than conventional concrete	45daysflexural Strength (MPa)	%differ than conventional concrete
A	0	4.50	0	5.21	0
AFA10	10	4.95	+10.00	5 55	+6.52
AFA20	20	4.64	+3.11	5.67	+8.82
AFA30	30	4.07	-9.33	5.20	-0.191
AFA40	40	3.67	-18.44	4.87	-6.52
AFA50	50	3.36	-25.33	4.61	-11.51
AFA60	60	3.21	-28.66	4.29	-17.65
AFA70	70	3.03	-32.67	3.77	-27.63



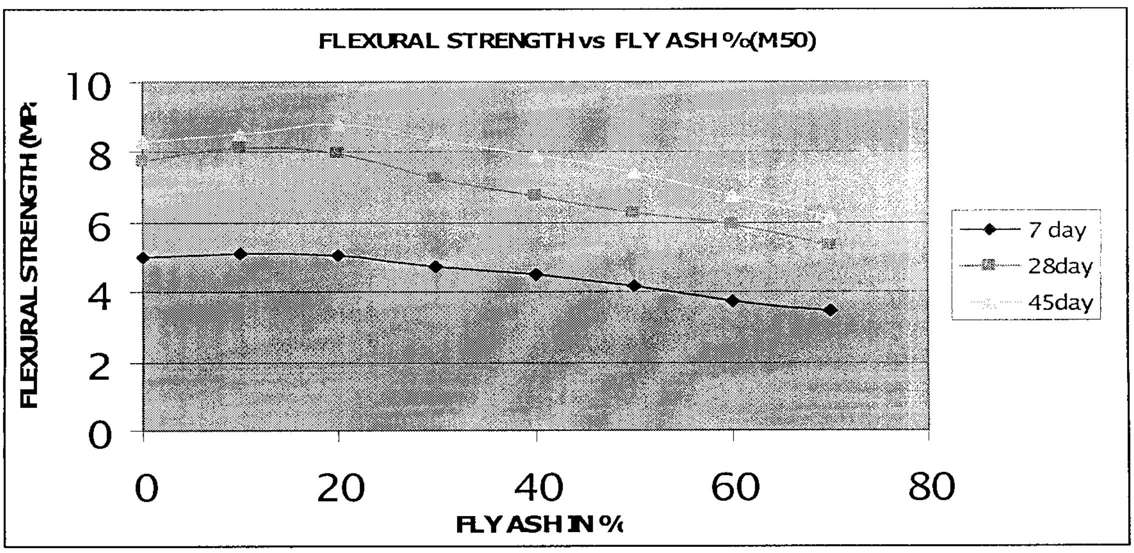
FLEXURAL STRENGTH OF M30 GRADE CONCRETE WITH VARYING FLY-ASH CONTENT.

Table (6.17) Flexural strength of M50 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7daysflexural Strength (MPa)	%differ than conventional concrete	28daysflexuralStrength (MPa)	%differ than conventional concrete
B	0	5.01	0	7.75	0
BFA10	10	5.11	+2.0	8.11	+4.74
BFA20	20	5.03	+0.39	7.99	+3.09
BFA30	30	4.71	-5.48	7.23	-6.70
BFA40	40	4.49	-10.37	6.78	-12.50
BFA50	50	4.18	-23.35	6.27	-19.09
BFA60	60	3.76	-24.95	5.94	-23.35
BFA70	70	3.48	-32.53	5.31	-30.70

Table (6.18)Flexural strength of M50 grade concrete at 28 and 45 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	28daysflexural Strength (MPa)	%differ than conventional concrete	45daysflexural Strength (MPa)	%differ than conventional concrete
B	0	7.75	0	8.28	0
BFA10	10	8.11	+4.74	8.49	+2.53
BFA20	20	7.99	+3.09	8.77	+5.91
BFA30	30	7.23	-6.70	8.33	+0.603
BFA40	40	6.78	-12.50	7.89	-4.95
BFA50	50	6.27	-19.09	7 43	-10.52
BFA60	60	5.94	-23.35	6.75	-18.47
BFA70	70	5.31	-30.70	6.17	-25.48



FLEXURAL STRENGTH OF M50 GRADE CONCRETE WITH VARYING FLY-ASH CONTENT.

MODULUS OF ELASTICITY

The modulus of elasticity is defined as the change of stress with respect to elastic strain (deformation) and may be computed from the equation. Modulus of elasticity is a measure of the stiffness or of the resistance of the material to deformation.

Modulus of elasticity = Unit stress/ Unit strain

The cylinder of size 150mmx300mm was used for testing modulus of elasticity. The test specimens for compressive strength shall be first tested and the average compressive strength shall be recorded. Immediately on removing the cylinder from the water and while it is still in a wet condition the extensometer shall be attached at the ends or on opposite sides of the specimen and parallel to the axis, in such a way that the gauge points are symmetrically about the center of the specimen and in no case are nearest to either end of the specimen. The specimen shall be immediately placed in the testing machine and accurately centered. The load shall be applied continuously and without shock at a rate of 14N/mm^2/minute, up to the stress is reached one third of the average compressive strength of the cylinder calculated.

The load shall be maintained at this stress for at least one minute and then be reduced gradually to an average stress of 0.15 N/mm2 , the load shall be maintained at this figure while extensometer are taken. The load again shall be reduced gradually and readings again taken.

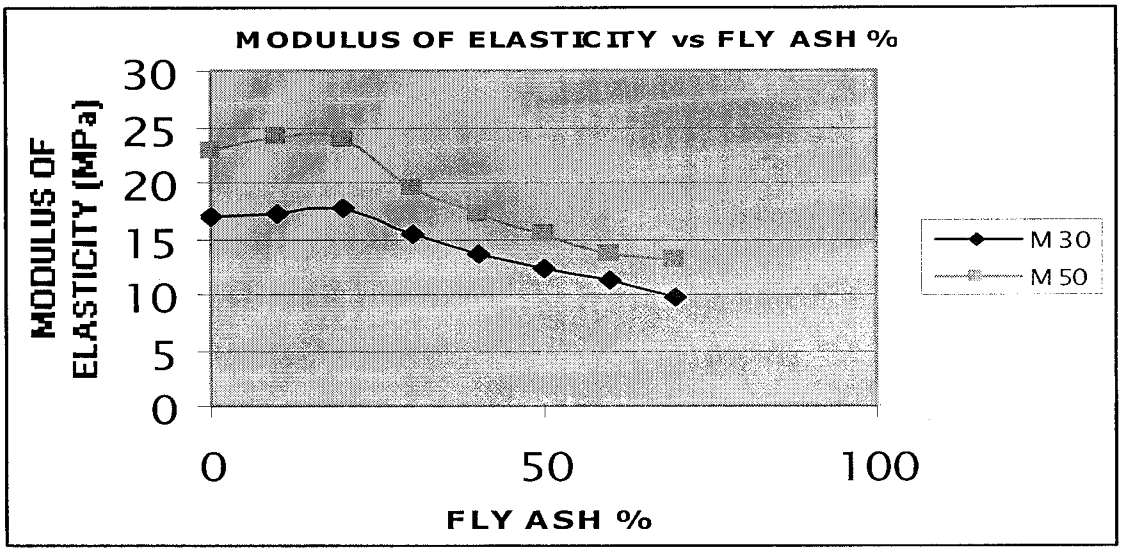
The modulus of elasticity data for OPC concrete and fly ash blended concrete at 10%, 20%, 30%, 40%, 50%, 60% and 70% replacement levels are shown in table. From the table it is found that the modulus of elasticity both in OPC and fly ash blended concrete is increased with curing period. The modulus of elasticity of OPC were found to be 16.99x10^3 N/mm^2 for M30 grade concrete and 22.72 x10^{3}N/mm^2 for M50 grade concrete after 28 days of curing. A slight increase in modulus of elasticity was observed up to 20% cement replacement by fly ash. It was observed that as the percentage of replacement level increased beyond a certain limit cause the decrease modulus of elasticity.

Table (6.19) Modulus of elasticity of M30 grade concrete after 28 days curing

Mix designation	CRM percentage	Stress (N/mm^2)	Strain 10^{-6}	Modulus of Elasticity (N/mm^2)x 10^3
A	0	4.16	245	16.99
AFA10	10	4.51	239	17.17
AFA20	20	3.78	214	17.68
AFA30	30	4.21	272	15.47
AFA40	40	3.93	293	13.53
AFA50	50	3.77	302	12.42
AFA60	60	3.59	319	11.25
AFA70	70	3.20	337	9.73

Table (6.20) Modulus of elasticity of M50 grade concrete after 28 days curing

Mix designation	CRM percentage	Stress (N/mm^2)	Strain 10^{-6}	Modulus of Elasticity (N/mm^2)x 10^3
A	0	5.74	252	22.72
AFA10	10	5.93	245	24.21
AFA20	20	5.89	259	23.97
AFA30	30	5.62	288	19.58
AFA40	40	5.41	313	17.24
AFA50	50	5.18	337	15.39
AFA60	60	4.56	351	13.49
AFA70	70	4.69	364	13.01



GRAPHICAL REPRESENTATION OF MODULUS OF ELASTICITY OF M30 & M50 GRADE CONCRET

Concrete specimens such as cubes (150mmx150mmx150mm), cylinders(150mmx300mm) and prisms (100mmx100mmx500mm) were casted for all the design mix given in table_(4.3) and (4.4). The strength characteristics of these specimens were tested after 7, 28 and 45 days of curing.

From the test results, optimum strength was obtained for the specimens with 30% 0f cement replaced by fly ash of M30 and M50 grade of concrete after 45 days of curing. The term high volume fly ash concrete represents mixture contains more than 50% fly ash by mass of cementitious material.

The same grade of concrete (M30 and M50) was used, by reducing only the mass of coarse aggregate 10%, 20% and 30% and size of coarse aggregate decreases to 16mm (60%) and 10mm (40%). After 28 days of curing the compressive strength, split tensile strength and flexural strength was tested. Enhancement in strength properties of high volume flyash concrete was observed with decrease in size of the coarse aggregate.

The compressive strength, split tensile strength and flexural strength data for OPC concrete and fly ash blended concrete at 10%, 20%, 30%, 40%, 50%, 60% and 70% replacement levels of fly ash with reducing coarse aggregate contents in the range of 10% 20% and 30% are shown in table (6.21) to (6.32).

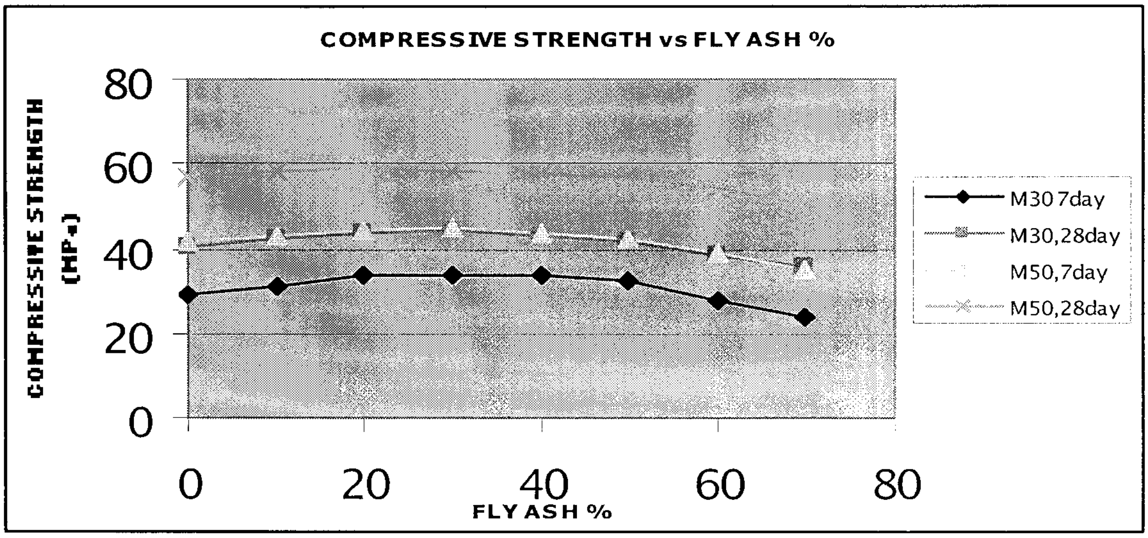
Compressive strength of M30 & M50 grade concrete with coarse aggregate reducing 10%

Table (6.21) Compressive strength of M30 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	Flyash content %	7 days com. Strength (MPa)	%differ than conventional concrete	28days com. Strength (MPa)	%differ than conventional concrete
A	0	29.40	0	40.57	0
AFA10	10	31.28	+6.39	42.03	+3.59
AFA20	20	33.73	+14.72	43.34	+6.82
AFA30	30	33.91	+15.34	44.26	+9.09
AFA40	40	33.44	+13.82	42.81	+5.52
AFA50	50	32.09	+9.14	41.70	+2.78
AFA60	60	27.78	-5.51	38.11	-6.06
AFA70	70	23.79	-19.08	35.98	-11.31

Table (6.22) Compressive strength of M50 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7 days com. Strength (MPa)	%differ than conventional concrete	28days com. Strength (MPa)	%differ than conventional concrete
B	0	41.54	0	56.78	0
BFA10	10	43.21	+4.02	57.94	+2.04
BFA20	20	43.97	+5.84	59.01	+3.92
BFA30	30	44.83	+7.92	58.47	+2.97
BFA40	40	43.59	+4.93	57.52	+1.26
BFA50	50	42.01	+1.13	56.79	+0.277
BFA60	60	38.76	-6.69	54.07	-4.77
BFA70	70	34.95	-15.86	50.54	-10.98



COMPRESSIVE STRENGTH OF M30 & M50 GRADE CONCRETE WITH VARING FLY ASH CONTENT

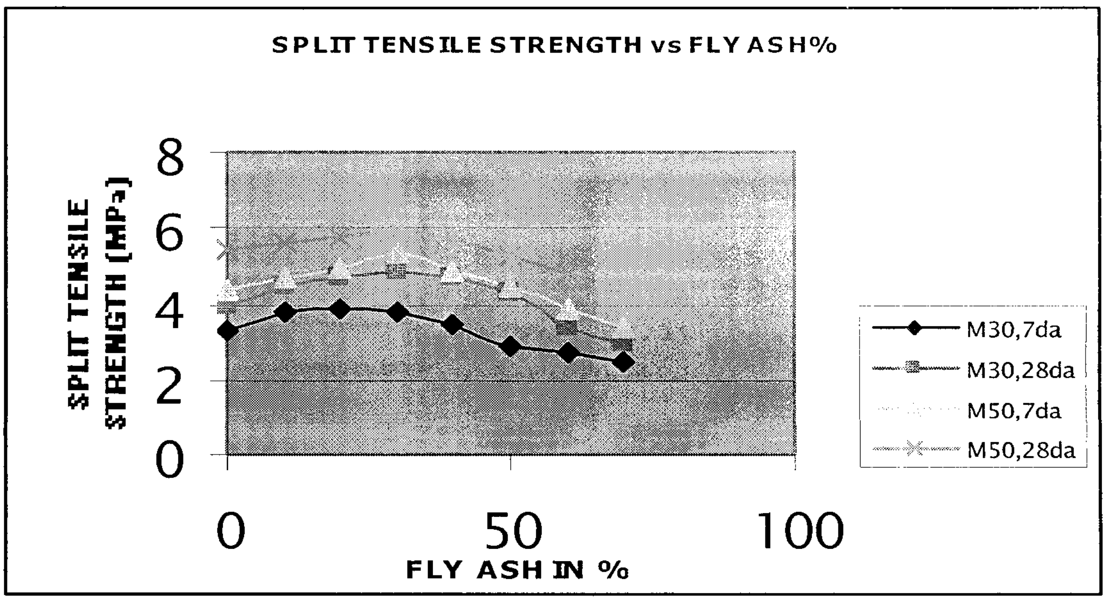
Split Tensile strength of M30 & M50 grade concrete with coarse aggregate reducing 10%

Table (6.23 Split tensile strength of M30 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7daystensile Strength (MPa)	%differ than conventional concrete	28daystensile Strength (MPa)	%differ than conventional concrete
A	0	3.33	0	3.98	0
AFA10	10	3.76	+12.91	4.42	+11.05
AFA20	20	3.88	+16.51	4.71	+18.34
AFA30	30	3.83	+15.01	4..89	+22.86
AFA40	40	3.47	+4.20	4.67	+17.33
AFA50	50	2.91	-12.60	4.29	+7.78
AFA60	60	2.73	-18.01	3.41	-14.32
AFA70	70	2.48	-24.5	2.97	-23.44

Table (6.24) Split tensile strength of M50 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7daystensile Strength (MPa)	%differ than conventional concrete	28daystensile Strength (MPa)	%differ than conventional concrete
B	0	4.39	0	5.44	0
BFA10	10	4.74	+7.97	5.61	+3.12
BFA20	20	4.98	+13.43	5.78	+6.25
BFA30	30	5.32	+21.18	5.96	+9.55
BFA40	40	4.84	+10.25	5.68	+4.41
BFA50	50	4.47	+1.822	5.27	-3.12
BFA60	60	3.85	-12.30	4.79	-11.94
BFA70	70	3.37	-23.23	4.43	-18.56



SPLIT TENSILE STRENGTH OF M30 & M50 GRADE CONCRETE WITH VARING FLY ASH CONTENT

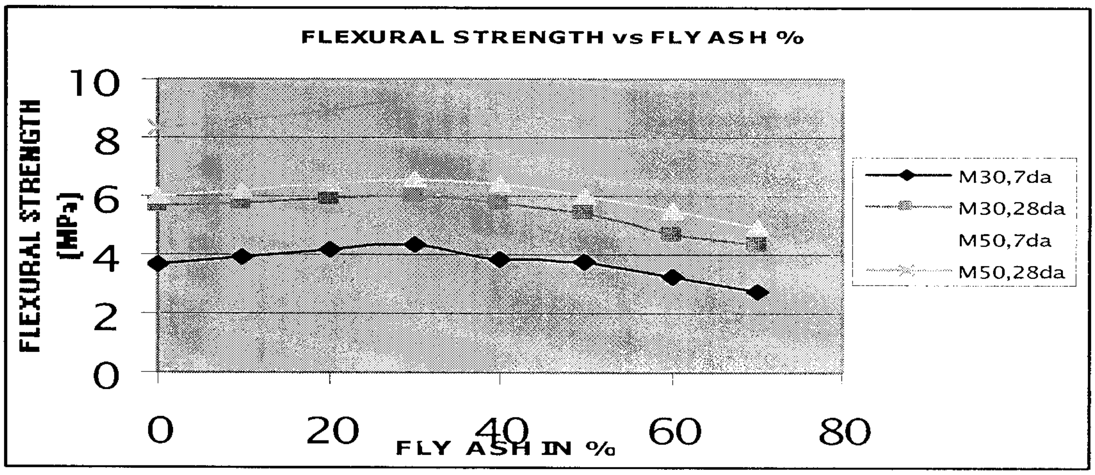
Flexural strength of M30 & M50 grade concrete with coarse aggregate reducing 10%

Table (6.25) Flexural strength of M30 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7daysflexural Strength (MPa)	%differ than conventional concrete	28daysflexuralStrength (MPa)	%differ than conventional concrete
A	0	3.67	0	5.64	0
AFA10	10	3.94	+7.35	5.75	+1.95
AFA20	20	4.14	+12.80	5.91	+4.78
AFA30	30	4.37	+19.07	6.04	+7.09
AFA40	40	3.87	+5.44	5.73	+1.59
AFA50	50	3.72	+1.36	5.39	-4.43
AFA60	60	3.29	-10.35	4.64	-17.73
AFA70	70	2.78	-22.32	4.36	-21.34

Table (6.26) Flexural strength of M50 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7daysflexural Strength (MPa)	%differ than conventional concrete	28daysflexuralStrength (MPa)	%differ than conventional concrete
B	0	6.04	0	8.34	0
BFA10	10	6.17	+2.15	8.57	+2.75
BFA20	20	6.38	+5.62	8.88	+6.47
BFA30	30	6.62	+9.60	9.24	+10.73
BFA40	40	6.41	+6.12	8.71	+4.43
BFA50	50	5.98	-0.99	8.46	+1.43
BFA60	60	5.49	-9.10	7.74	-7.19
BFA70	70	4.90	-18.87	7.27	-12.84



FLEXURAL STRENGTH OF M30 & M50 GRADE CONCRETE WITH VARING FLY ASH CONTENT

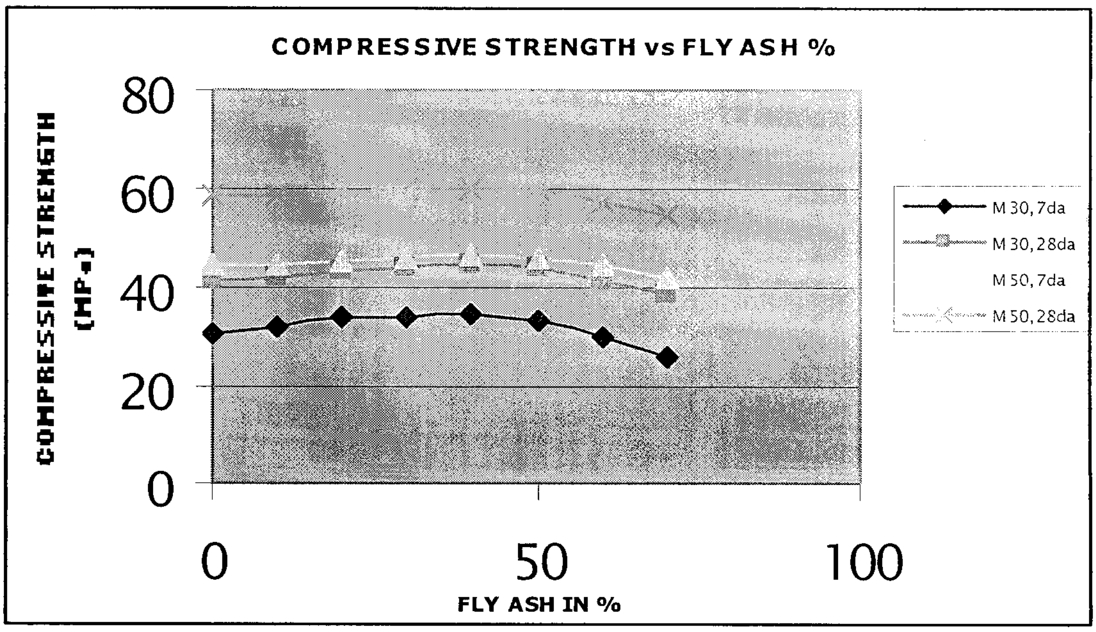
Compressive strength of M30 & M50 grade concrete with coarse aggregate reducing 20%

Table (6.27) Compressive strength of M30 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7 days com. Strength (MPa)	%differ than conventional concrete	28days com. Strength (MPa)	%differ than conventional concrete
A	0	30.40	0	41.37	0
AFA10	10	32.28	+6.18	42.03	+1.59
AFA20	20	33.73	+10.95	43.34	+4.76
AFA30	30	33.91	+11.54	44.26	+6.98
AFA40	40	34.44	+13.28	44.51	+7.59
AFA50	50	33.09	+8.84	43.70	+5.63
AFA60	60	29.78	-2.03	41.11	-0.62
AFA70	70	25.79	-13.98	38.58	-6.74

Table (6.28) Compressive strength of M50 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7 days com. Strength (MPa)	%differ than conventional concrete	28days com. Strength (MPa)	%differ than conventional concrete
B	0	44.75	0	58.34	0
BFA10	10	44.97	+0.49	58.68	0.582
BFA20	20	45.66	+2.033	59.01	+1.14
BFA30	30	45.90	+2.56	59.78	+2.46
BFA40	40	46.84	+4.67	60.19	+3.17
BFA50	50	46.02	+2.83	60.04	+2.91
BFA60	60	44.45	-0.67	57.07	-2.17
BFA70	70	42.17	-5.76	54.58	-6.44



COMPRESSIVE STRENGTH OF M30 & M50 GRADE CONCRETE WITH VARING FLY ASH CONTENT

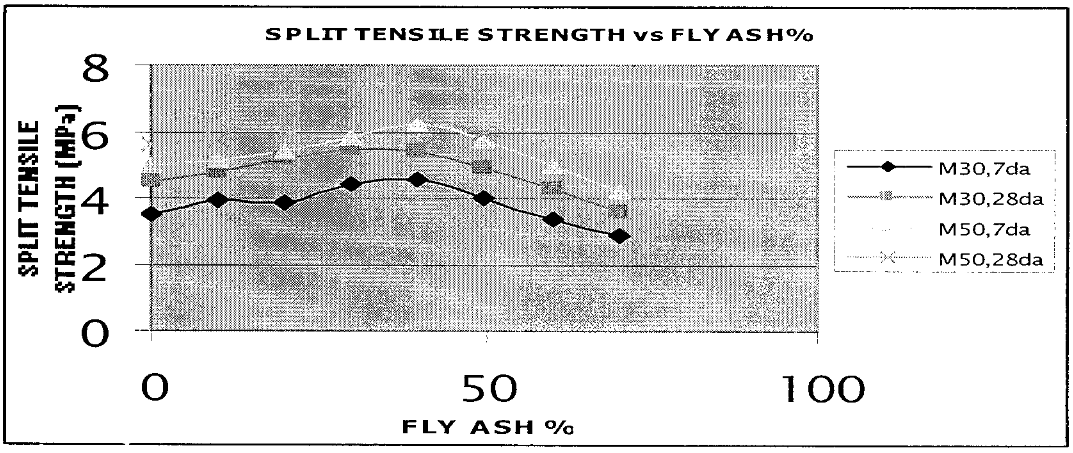
Split Tensile strength of M30 & M50 grade concrete with coarse aggregate reducing 20%

Table (6.29) Split tensile strength of M30 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7daystensile Strength (MPa)	%differ than conventional concrete	28daystensile Strength (MPa)	%differ than conventional concrete
A	0	3.54	0	4.52	0
AFA10	10	3.96	+11.86	4.74	+4.86
AFA20	20	3.88	+9.60	5.18	+14.60
AFA30	30	4.43	+22.14	5.49	+21.46
AFA40	40	4.56	+25.98	5.37	+18.80
AFA50	50	3.99	+12.71	4.91	+8.62
AFA60	60	3.37	-4.80	4.28	-5.30
AFA70	70	2.86	-19.20	3.56	-21.23

Table (6.30) Split tensile strength of M50 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7daystensile Strength (MPa)	%differ than conventional concrete	28daystensile Strength (MPa)	%differ than conventional concrete
B	0	4.96	0	5.64	0
BFA10	10	5.09	+2.62	5.73	+1.59
BFA20	20	5.37	+8.26	5.91	+4.78
BFA30	30	5.82	+17.33	6.47	+14.71
BFA40	40	6.24	+22.80	6.28	+11.34
BFA50	50	5.74	+15.72	5.84	+3.54
BFA60	60	4.99	+0.60	5.06	-10.28
BFA70	70	4.23	-14.71	4.59	-18.61



SPLIT TENSILE STRENGTH OF M30 & M50 GRADE CONCRETE WITH VARING FLY ASH CONTENT

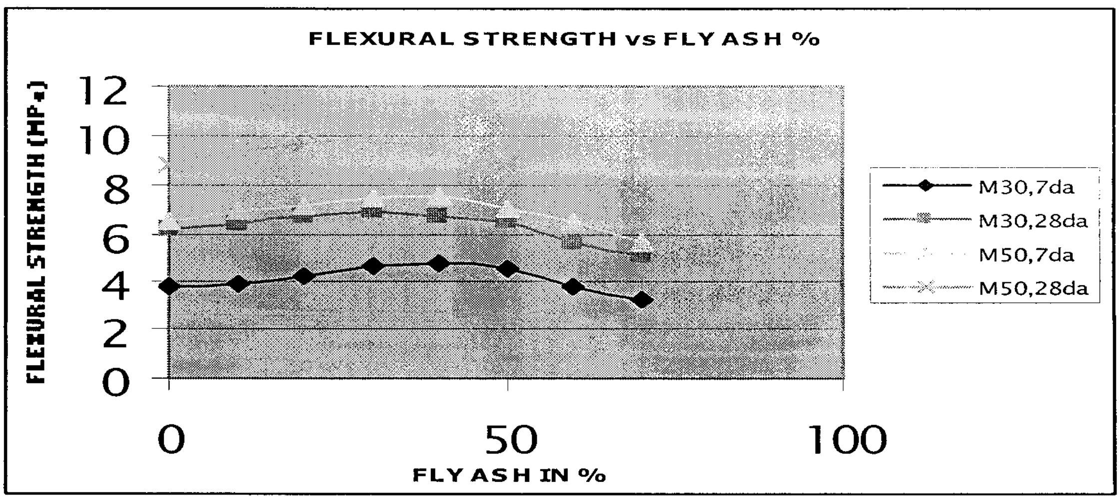
Flexural strength of M30 & M50 grade concrete with coarse aggregate reducing 20%

Table (6.31) Flexural strength of M50 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7daysflexural Strength (MPa)	%differ than conventional concrete	28daysflexuralStrength (MPa)	%differ than conventional concrete
A	0	3.79	0	6.17	0
AFA10	10	3.94	+3.98	6.34	+2.42
AFA20	20	4.24	+11.87	6.67	+8.10
AFA30	30	4.65	+23.48	6.94	+12.47
AFA40	40	4.77	+25.85	6.72	+8.91
AFA50	50	4.52	+19.26	6.49	+5.18
AFA60	60	3.86	-1.84	5.64	-8.58
AFA70	70	3.29	13.19	5.06	-17.99

Table (6.32) Flexural strength of M50 grade concrete at 7 and 28 days by varying fly-ash content from 10-70 % by weight of cement.

Mix designation	CRM percentage	7daysflexural Strength (MPa)	%differ than conventional concrete	28daysflexuralStrength (MPa)	%differ than conventional concrete
B	0	6.43	0	8.84	0
BFA10	10	6.89	+7.15	9.34	+5.65
BFA20	20	7.14	+11.04	9.65	+9.16
BFA30	30	7.46	+16.06	9.81	+10.97
BFA40	40	7.52	+16.95	9.47	+7.12
BFA50	50	6.98	+8.55	8.86	+0.22
BFA60	60	6.49	+0.933	8.27	-6.44
BFA70	70	5.63	-12.44	7.69	-13.00



FLEXURAL STRENGTH OF M30 & M50 GRADE CONCRETE WITH VARING FLY ASH CONTENT

CHAPTER 7
CONCLUSION

Based on the results of the investigation made in this work the following conclusion may be drawn.

1. Experimental study on the mechanical strength of High volume flyash concrete such as compressive strength, flexural strength and split tensile strength was carried out.
2. The test results showed that all mixes, containing fly-ash up to 30%, were **able to develop a higher compressive, tensile & flexural strength than the control mixes after 28 days of curing.**
3. The compressive strength of M30 and M50 grade concrete increased to 7.03% and 6.6% than conventional concrete when cement replacement level was 30% with fly ash.
4. The split tensile strength also shows better results when the cement replacement levels up to 30%.
5. The same grade of concrete (M30 and M50), by reducing only the mass of coarse aggregate 10%, 20% and 30% and size of coarse aggregate decreases to 16mm (60%) and 10mm (40%) improved mechanical properties of HVFA concrete.
6. The optimum results obtained when the cement replacement level was 30 to 50% and also coarse aggregate content reduced to 20% by weight of actual coarse aggregate required.
7. The mechanical properties such as compressive strength, split tensile strength and flexural strength got maximum results when cement replacement level 40% and coarse aggregate reduced 20%. Also cement replacement level 50% shows more strength than conventional concrete.
8. With increase in curing period of 45 days from 28 days, +7.94 % and +6.99% of increase in compressive strength were observed for M30 and M50 concrete with 30% replacement of cement with flyash.
9. Graphs showing the influence of different % of flyash content in strength properties of concrete have been presented (fig 1 to 20).

CHAPTER 8

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