BONAFIDE CERTIFICATE

Certified that this project report titled **"EXPERIMENTAL STUDY ON XURAL BEHAVIOUR OF HIGH VOLUME FLYASH CONCRETE"** is the fide work of **G.NATARAJAN, Reg No: 71206413011,** who carried out the research under my supervision.

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ACKNOWLEDGEMEN

ACKNOWLEDGEMENT

First and foremost I submit my thanks to **The Almighty**, through whom all things are possible. This work was not by my might nor by power, but by **His Spirit**. This work not be possible without the gifts, **God** has given to me.

I take pride and immense pleasure in expressing my deep sense of gratitude indebtedness to my guide **Dr.J.Premalatha** , Professor of Civil Engineering Department for his innovative ideas continued conduce, untiring efforts and encouragements which enabled the successful completion of thesis work.

I deem great pride in expressing heartfelt gratitude to **Dr.S.L.Narasimhan,** H.O.D, Department of Civil Engineering for allowing me to do this project and the facilities extended throughout the project.

I express my profound gratefulness to **Dr.Joseph.V.Thanikal,** Principal for providing the necessary facilities for the successful completion of thesis work.

I also sincerely thank the faculty members, non-teaching staff of Civil Engineering Department.

Last but not the least; we thank our **PARENTS** for their moral support.

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as participated & presented a paper in the National Conference on "Innovative Materials & ethodologies for Disaster Resistant Structures (NCIMMDRS - 08)" sponsored by Defence Research & Development rganisation (DRDO), New Delhi and Coir Board (Govt. of India) on 10th & 11th April 2008.

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ABSTRAC

ABSTRACT

- Experimental study on enhancement in strength properties of R.C.C beams with Fly ash replacement has been carried out.
- In this thesis, 8 numbers of proto type reinforced concrete beam of size (2000*150*100) mm were casted with various % of fly ash replacement with cement.
- All beams were tested under flexure by two point loading using 30 tone loading frame.
- Companion specimen of cube of size (150*150*150)mm , cylinder of size (300mm depth and 150 mm radius) and prism of size (500*100*100)mm were also casted and tested for compressive strength, split tensile strength and flexural strength.
- Behavior of R.C.C beams with different percentages of Fly ash content under flexure are discussed in this thesis
- Test results were analyzed and the influence of Fly ash in mechanical strength of concrete such as compressive strength and tensile strength are discussed and presented in this thesis

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LIST OF SYMBOLS

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fck - Characteristic compressive strength of concrete

t - Risk factor.

s - Standard deviation.

w/c - water cement ratio.

F_a - Fine aggragate.

C_a - Coarse aggregate.

S_c - Specific gravity of cement

S_{fa} - Specific gravity of fine aggregate

S_{ca} - Specific gravity of coarse aggregate

p - Load in N/mm^2.

l - Length of the cylinder (depth).

b - Breadth of the beam.

d - Depth of the beam.

INTRODUCTION

1. INTRODUCTION

Sustainable development is a priority for the federal government. Sustainable development in this context means 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'.

The construction industry has been developing and using less energy-intensive and more environmentally friendly materials and technologies in concrete construction. "Green" concrete using supplementary cementing materials (SCMs) such as fly ash is one good example.

The production of every tone of Portland cement, an essential constituent of concrete, releases about one tone of carbon dioxide (CO_2) into the atmosphere. Partial replacement of cement with SCMs reduces greenhouse gas (GHG) emissions proportionately and results in a more "green" concrete, through reduced energy consumption (energy required to produce cement) and avoidance of process emissions (limestone calcinations). Additional benefits include minimization of waste disposal (land filling these industrial by-products), lessened pressure on natural resources (such as reduction in limestone consumption used for the production of cement) and, when SCMs are used judiciously, improved concrete properties and durability.

In Atlantic Canada, with the exception of Newfoundland, almost all concrete contains anywhere from 10 to 25% fly ash. In the Prairies and Western Canada, 80 to 90% of the concrete produced contains fly ash. In Quebec, around 5% of the cement produced is blended cement that contains silica fume, or silica fume with either fly ash or slag.

Many high profile concrete structures such as the Hibernia concrete platform and the Confederation Bridge, and high rise buildings such as the Scotia Plaza in Toronto and the Bankers Hall 2 in Calgary were made with SCMs to provide concrete technical benefits and longer service life.

EcoSmart Foundation Inc., with support of the Minerals and Metals Program of *Action Plan on Climate Change* (AP 2000), is working to maximize the use of SCMs in concrete and has participated in many concrete projects using high volumes of fly ash. However, despite these efforts, an average of only 10% of the quantity of SCMs produced in Canada is currently used in the cement and concrete industries (1).

ICON/CANMET recently conducted an extensive investigation into the "Current Situation of SCMs in Canada" (1). The study was commissioned by the Supplementary Cementing Materials components of AP 2000. The study recommended that national guidelines and specifications be developed for the wider use and acceptance of SCMs in construction by specifying authorities, concrete suppliers, users and engineering inspection/testing organizations.

In fact, it is mentioned in the above study that some specifiers in certain engineering firms or municipal, provincial, and federal authorities place restrictions on the use of SCMs in concrete based on perception, lack of technical information or knowledge of the properties of SCMs, or on bad experiences due, so often, to a lack of knowledge. Such restrictions could actually be detrimental to the long-term durability of concrete for reasons of ASR mitigation (alkali-silica reaction) among others.

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. Although 25%-35% fly ash by mass of the cementitious material is considerably higher than 15%-20%, this is not high enough to classify the mixtures as HVFA concrete according to the

1.1 Literature Review

1. Malhotra. V. M. (July 2002)[1]

A brief review is presented of the theory and construction practice withconcrete mixtures containing more than 50% fly ash by mass of the cementitiousmaterial. Mechanisms are discussed by which the incorporation of high volume of fly ash in concrete reduces the water demand, improves the workability, minimizes cracking due to thermal and drying shrinkage, and enhances durability to reinforcement corrosion, sulfate attack, and alkali-silica expansion. For countries like China and India, this technology can play an important role in meeting the huge demand for infrastructure in a sustainable manner.

2. P.J.Tikalsky, et.al, (November 1988)[2]

Fly ash contents ranging from 0 to 35 percent by weight of portland cement were used with both Class C and Class F fly ashes. Guidelines for the selection of materials and their proportions for producing concrete containing fly ash to meet existing highway specifications for concrete are presented. It is shown that concrete containing fly ash can be proportioned having equal strength properties and adequate durability when a suitable ASTM C 618 Class C or Class F fly ash is used.

3. M. M. Alasali, et.al (March 1, 1991)[3]

The results of an investigation dealing with the role of concrete incorporating high volumes of fly ash in reducing the expansion of concrete due to alkali-aggregate reaction. The concretes investigated were made using portland cement and high volumes of low-calcium fly ash (ASTM Class F). The w/c + f and the fly ash (fly ash and cement) were 0.31 and 0.58, respectively. One of the high-volume fly ash concretes incorporated additional alkalies at a dosage of 3.25 kg/m3.

4. En-Hua Yang, et.al, (November 1, 2007)[4]

The development of high-performance fiber-reinforced cementitious composites (HPFRCC), taking into account environmental sustainability considerations. Engineered cementitious composites (ECC), a unique member of HPFRCC featuring high tensile ductility with ultra-high volumes of fly ash (HVFA) replacement (up to 85% by weight) of cement, are proposed in this paper. Incorporating high volumes of recycled fly ash, can retain a long-term tensile ductility of approximately 2 to 3%. Significantly, both the crack width and free drying shrinkage are reduced with an increase of the fly ash amount, which may benefit the long-term durability of HVFA ECC structures.

5. J. G. Cabrera, et.al, (May 1, 1999)[5]

A new method for the determination of the optimum W/C plus FA for maximum compaction of no slump concrete made with high volumes of fly ash. It explores the effect of fly ash fineness and particularly, carbon content on the explores the effect of fly ash fineness an particularly, carbon content on the compressive strength of the mixtures made with 50% and 70% replacement of normal portland cement with fly ash.The strength attained at 28 days is 60 Mpa or more, and therefore these mixtures are considered to yield high-strength concrete.

6. C. Muller, et.al, (August 1, 1997)[6]

High-performance concretes can be defined as types of concretes that meet one or more performance requirements in a specific way. Usual concretes are concretes with a compressive strength up to 55 Mpa and fly ash contents of around 20 mass, percentage relative to the total binding components (c + f). In the production of high-strength concretes (compressive strength > 65 Mpa), silica fume has been used usually in order to achieve the expected strengths at low w/c. Fly ash contents of 53 and 42 mass.% relative to (c + f) were used to produce monolithic base slabs with a concrete volume between 17,000 and 22,000 m3 (production in one operation). The performance of these concretes is shown using the parameters compressive strength development, heat of hydration development and their Ca(OH)z-content.

7. L.V.A. Seshasayi, et.al, (June 1, 2005)[7]

In recent times the emphasis globally is on mixing high volume fly ash in high performance concrete. India produces 100 million tones annually, out of which only 20 % is utilized. In an ongoing program, an experimental investigation is carried out to assess the performance o three types of concrete: one with ordinary Portland cement, another with blended cement and a third with site mixed high volume fly ash (with cement replacement level of 50 %). All three are exposed to acidic environment. Concrete with high volume fly ash showed better resistance when exposed to acidic environment, though strength decreased marginally.

8. N. Bouzoubaa, et.al, (March 22, 2006)[8].

Determining the carbonation resistance of high-volume fly ash concrete. Five air-entrained concrete mixtures were studied consisting of three high-volume fly ash concrete mixtures (HVFA) incorporating 58% of fly ash by mass of the total cementitious materials made with a water-cementitious materials ratio (w/cm) of 0.32, and two control portland cement concrete mixtures, one with a similar w/cm (0.32), and the other with similar 28-d compressive strength as that of the HVFA concrete. A further increase in the moist curing from 28 to 91 days did not substantially affect the carbonation depth of the control concretes and the HVFA concrete using the high reactive fly ash. The carbonation is not an issue for HVFA concrete due mainly to its low w/cm and dense structure.

9. Raymundo Rivera-Villarreal, et.al, (June 1, 2001)[9].

The effect of using different types of curing on the compressive strength of concrete both with and without large volumes fly ash (FA). In all the concrete mixtures, the portland cement content was 200 kg/m3. The FA amount was varied from zero to 33,43,50 and 56 percent by mass of the total binder, and a superplasticizer was used to obtain 200-220 mm slump. The compressive strength of the Portland-cement concrete made at 35°C was reduced by about 11% at 28 days when compared to that of concrete made at 23°C with ASTM standard curing. With continuous moist-curing of fresh concrete, there was no strength loss o concrete made at 35°C. Higher strength was obtained as the amount of FA was increased for a given amount of the portland cement.

High-volume fly ash concrete at low unit water content does not bleed. This generally creates a problem for finishers of flatwork surfaces who are used to more bleed water at the surface during finishing.

As with any concrete, particularly with a low water-to-cementitious material ratio, care is required to prevent plastic shrinkage cracking at the surface immediately after placing by following the measures proposed by ACI 305 committee on hot weather concreting.

1.2.3 Autogenous temperature rise

The use of low-calcium fly ash as partial replacement of Portland cement in concrete will generally contribute to reducing the temperature rise in concrete compared to Portland cement concrete. This is important in mass concrete to reduce the potential for cracking associated with excessive thermal gradients. High-calcium fly ashes, depending on the total alkali content may increase the temperature rise. In general, if a Type CH fly ash is to be used as a potential means to reduce temperature in concrete, concrete mixtures should be evaluated for this particular property.

1.2.4 Setting time

For similar 28-day compressive strength and workability, the setting time of fly ash concrete may be longer than normal Portland cement concrete for a given combination of cement and chemical admixtures (especially for Type F fly ash). This may influence the schedule for finishing horizontal surfaces, especially at high levels of replacement (>~30%), and/or in cool weather. In this case, using adosage of water reducer in the lower limit of the range proposed by the manufacturer can contribute at decreasing, to some extent, the initial setting time of fly ash concrete. However, this should not be at the expense of strength development and durability of the concrete. Still, in hot weather conditions, extended setting time can be beneficial. Concrete accelerators may be used to offset increase in setting time when using fly ash.

1.2.5 Drying shrinkage

The effect of fly ash on drying shrinkage is highly dependent on how the concrete is proportioned. If full advantage is taken of the reduced water demand and the unit water content is reduced and if the W/CM is also reduced to achieve strength parity at 28 days, fly ash concrete will have significantly reduced shrinkage compared to Portland cement concrete. The Impact of fly ash on drying shrinkage also depends on the maturity of the concrete when drying commences. If drying starts at one day, fly ash concrete may shrink more. Hence the importance of proper curing of fly ash concretes.

1.2.6 Creep

The effect of fly ash on creep is mainly related to the effect that fly ash has on the ultimate strength of concrete. Since fly ash increases the ultimate strength of concrete due to the pozzolanic reaction, the creep of fly ash concrete is generally lower than that of a Portland cement concrete with similar 28-day compressive strength. However, if the fly ash concrete is loaded at an early age, the creep may be higher.

1.2.7 Resistance to freezing and thawing

The resistance to freezing and thawing cycling of concrete is not affected by the use of fly ash. This property is a direct function of the air-void spacing factor of concrete that is obtained by the proper use of air-entraining admixtures. However, fly ash concrete must have adequate strength prior to exposure to freezing as is the case for normal Portland cement concrete.

1.2.8 Alkali silica reactions (ASR)

In general, the use of fly ash can mitigate the expansion caused by alkali-silica reactions in concrete. However, the amount of fly ash to be used for controlling alkali-silica reactions depends on the type of reactive aggregate, the exposure conditions, the alkali content of the concrete, the type of fly ash and the water-to-cementing materials ratio of the mixture.

1.2.9 Carbonation

The use of fly ash decreases the permeability of concrete and thus inhibits the easy penetration of carbon dioxide into the concrete. However, it also reduces the calcium hydroxide content in concrete due to the pozzolanic reaction, and consequently shows an increased propensity for carbonation. Also, fly ash concrete usually takes longer to reach the same level of strength as concrete made without fly ash. Therefore, a fly ash concrete not properly cured may carbonate more than Portland cement concrete, especially at higher replacement levels. When carbonation is likely to be an issue, concrete with high levels of SCM requires extended curing and/or reductions in W/CM.

1.2.10 Durability in marine environment

Permeability is considered the major factor affecting the durability of concrete in seawater. Therefore, it is evident that fly ash has the potential to improve concrete durability in a marine environment provided it is well cured. In a study conducted by CANMET on fly ash concrete prisms exposed to the marine environment at Treat Island, Maine, US since 1987, the results have shown that concrete with 25% cement replacement with fly ash can be satisfactory under such severe conditions of exposure, provided the W/CM is less than 0.50. For concrete incorporating 55% Type F fly ash, the W/CM should not exceed 0.32.

1.3 Advantage of High Volume Fly Ash Concrete

- Less energy intensive manufacture
- Higher ultimate strength
- More durable
- Requires less water
- Uses a waste by-product
- Creates fewer global warming gases

EXPERIMENTA
PROGRAM

2 EXPERIMENTAL PROGRAMS

2.1 Material and Mix proportion

For preparing test specimens 43 grade ordinary Portland cement, natural River sand and stone aggregate were used. The maximum size of the coarse aggregate was limited to 19mm to get the maximum increase in compressive strength. A sieve analysis conforming to IS 383-1970 was carried out for both fine and coarse aggregates. The Concrete mix proportions M_{30}, 1:1.09:2.42 (cement: sand: coarse aggregate) with water cement ratio of 0.39 and Concrete mix proportions M_{60}, 1:1.35:2.19 (cement: sand: coarse aggregate) with water cement ratio of 0.29 was adopted. The concrete mix was designed so as to achieve cube strength of 30 MPa and 60 Mpa (28 days). Fly ash is partially replaced at 0, 25,50 and 75 % respectively.

2.2 Mixing and casting

Mixture machine mixing was used for convenient handling of Fly ash. Sand and cement were mixed dry and kept separately. Then coarse aggregates, fly ash and dry mix of cement and sand were kept in three layers and approximate amount of water was sprinkled on each layer and mixed thoroughly. Mixing procedure was felt to be extremely tedious when percentage of replacement of fly ash was increased.

The cubes (150mm x 150mm), cylinders (150mm dia & 300mm deep), flexure beams (100mm x 100mm x 500mm) and cyclic beams (2000*150*100mm) of both conventional and Fly ash concrete specimens were casted. Each layer was compacted with 25 blows with 16 mm dia steel rod. Specimens were cured for 28 days in fresh water after 24 hours of their casting and still 48 hours before testing.

2.3Test Procedure

All 8 beams were tested for 28 days strength under bending. Beams were tested under tw point loading using 30 tone loading frame. The testing arrangements is shown in fig-1

The specimens are tested for their strength properties. The cube specimen (150mm x 150mm) where placed over the compression testing machine and the load was gradually applied till the failure of the specimen. The ultimate load was noted down as collapse load and crushing strength was calculated as (load/area)

The cylinder specimen (150mm dia & 300mm deep) was tested universal testing machine (utm) in horizontal position to determine the split tensile strength of concrete.

Concrete prisms (100mm x 100mm x 500mm) were tested with the span of 40cm in the utm to determine the flexural strength of concrete. The failure load was noted down and the modulus of rupture on 28 days flexural strength was determined by $f = \frac{pl}{bd^2}$

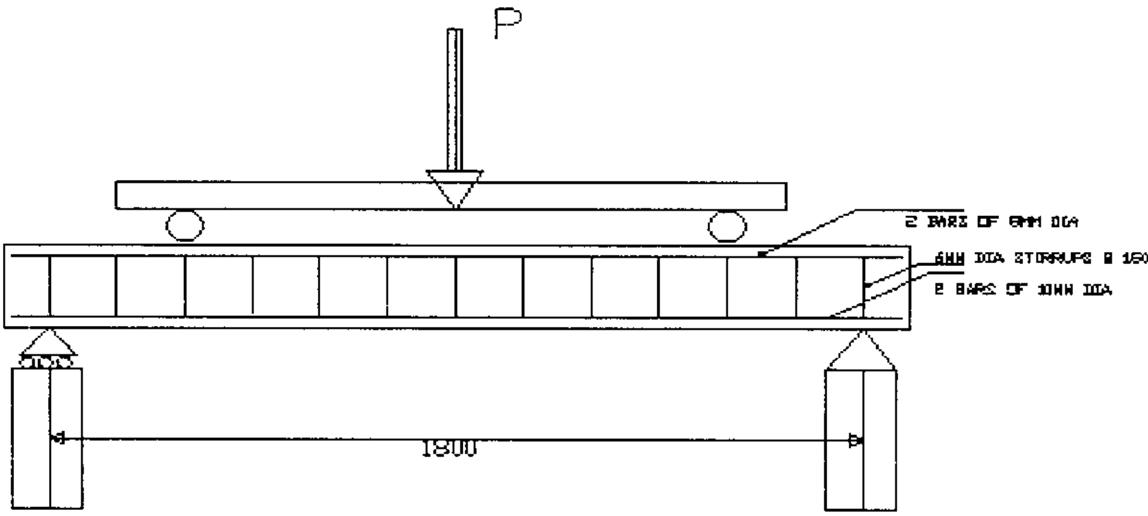


Fig-1. LOADING PATTERN DIAGRAM

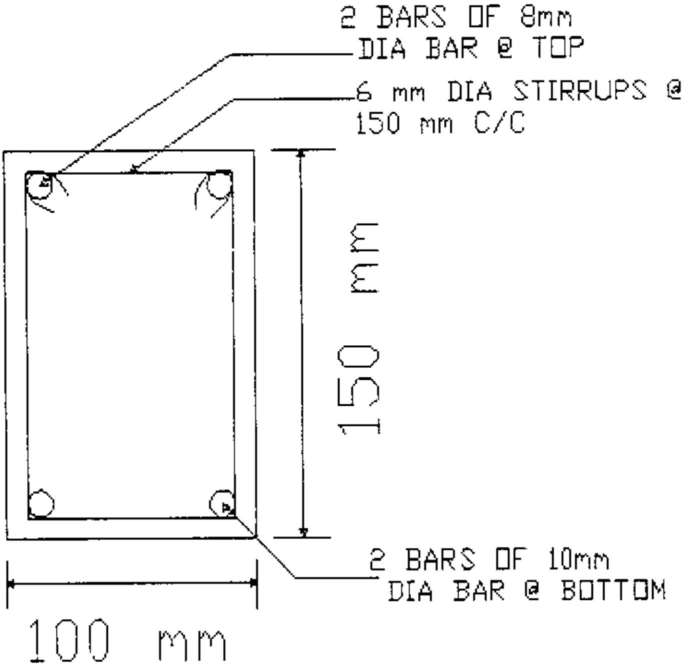


Fig-2. REINFORCEMENT DETAILS

MATERIAL PROPERTIE

3 MATERIAL PROPERTIES

3.1 Determination of Specific Gravity of Cement

The specific gravity of cement was found in the laboratory by using Pyconometer and other accessories. Values of specimen of cement is 3.15

3.2 Determination of Specific Gravity of Fine aggregate.

Definition:

The specific gravity (G) of soil grains (or solids) usually called soil is the ratio of the weight in air of the given volume of dry soil solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.

The specific gravity of sand was found in the laboratory by using Pyconometer and other accessories. Values of specimen of sand is 2.6

Fine aggregate

B: Wt. of pyconometer with full of water -----------1531 mg
A: Wt. of pyconometer + Coarse Agg. + Water ----1831 mg
C: Wt. of Dry Sample ----------------------------------0432 mg
D: Wt. of Oven Dry Sample---------------------------0344 mg

$$\text{Specific gravity} = \frac{D}{C-(A-B)}$$

$$= \frac{344}{432-(1831-1531)}$$

Specific Gravity of Fine aggregate = 2.6

3.3 Determination of Specific Gravity of Coarse Aggregate

Definition:

The specific gravity (G) of Coarse aggregate usually called Coarse aggregate is the ratio of the weight in air of the given volume of dry Coarse aggregate at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.

Coarse aggregate
B: Wt. of pyconometer with full of water -----------1531 mg
A: Wt. of pyconometer + Coarse Agg. + Water ----1809 mg
C: Wt. of Dry Sample ----------------------------------0446 mg
D: Wt. of Oven Dry Sample---------------------------0443 mg

$$\text{Specific gravity} = \frac{D}{C-(A-B)}$$

$$= \frac{443}{446-(1809-1531)}$$

Specific Gravity of coarse aggregate = 2.64

COARSE AGGREGATE—20MM

Sample Taken=2000 gm

Is Sieve Size in mm	Weight Retained gm	Cumulative Wt. Retained gm	Cumulative % Wt. Retained	Cumulative % Passing	IS 383 1970 Single sized aggregate
40	0	0	0	100	100
20	469	469	23.45	76.55	85-100
10	1507	1976	98.8	1.2	-
4.75	24	2000	-	-	

Cumulative % wt. retained = $\frac{x * 100}{2000}$

Fine Modulus =

Is Sieve Size in mm	Weight Retained gm	Cumulative Wt. Retained gm	Cumulative % Wt. Retained	Cumulative % Passing	IS 383 1970 Single sized aggregate
20	-	-	-	-	100
16	0	0	0	100	85-100
12.5	155	195	7.75	92.25	-
10	1191	1346	67.3	32.70	
4.75	640	1986	99.3	0.7	
PAN	14	2000	-	-	

3.4 CONCRETE MIX DESIGN -GRADE M_{30}

(a) DESIGN STIPULATION:-

i) Characteristic compressive Strength required

In the field at 28 days = 30MPa

ii) Maximum size of Aggregates = 20mm

iii) Degree of Workability = 0.80 C.F.

iv) Degree of Quality control = Fair

v) Types of Exposure = mild

(b) DATA FOR TESTED

i) Specific gravity of cement = 3.15

ii) Compressive strength of cement at 7 days = satisfies the requirement IS 269- 1989

iii) 1. Specific gravity of coarse aggregate = 2.64

2. Specific gravity of fine aggregate = 2.60

iv) Water absorption

1. Coarse Aggregate = 0.5%

2. Fine Aggregate = 1%

v) Free (surface) Moisture

1. Coarse Aggregate = Nil

2. Fine Aggregate = 2%

i) TARGET MEAN STRENGH OF CONCRETE

The target mean strength for specified characteristic cube strength is

30+1.65x5 = 38.25 MPa

ii) SELECTION OF WATER CEMENT – RATIO

The water-cement ratio required for the target mean strength of 38.25MPa is 0.39, for durability requirements, the maximum W/C ratio for moderate exposure for plain concrete = 0.70. Hence a lower value is selected.

iii) SELECTION OF WATER AND SAND CONTENT

For 20 mm maximum size aggregate, sand conforming to grading Zone II, water content per cubic meter of concrete = 186 kg and sand content as percentage of total aggregate by absolute volume = 35%.

For change in value of water-cement ratio, compacting factor, and sand belonging to Zone III, following adjustment is required

Change in Condition	Percent adjustment required	
	Water Content	Sand in total aggregate
For decrease in water-cement ratio by (0.6-0.39) that is 0.21 No correction since compacting factor is 0.80	0 %	-4.2%
Total	0 %	-4.2 %

Therefore, required sand content as percentage of total aggregate by absolute volume = 35-3=30.8%

Required water content = 186 + 0 = 186 litre/cu.m.

iv) DETERMINATION OF CEMENT CONTENT

Water-cement ratio = 0.395

Water = 186 litre

Cement = 186/ 0.39 = 476.9 kg/m^3

This cement content is adequate for 'mild' exposure condition, which is greater than 220 kg/m^3 form Appendix-A as per IS 456-1978.

v) DETERMINATION OF COARSE AND FINE AGGREGATE CONTENTS

From Table 11.23, for the specified maximum size of aggregate of 20 mm, the amount of entrapped air in the wet concrete is 2 per cent. Taking this into account and applying equations on

$$V = \{(W + C/S_e + (1/p)\ (f_a/Sf_a)\} \text{ x } (1/1000)$$

$$C_A = \{(1-(P/P)) \text{ x } f_a \text{ x } (S_{ca} / S_{fa})\}$$

Where,

V = absolute volume of fresh concrete, which is equal to gross volume (m^3) minus the volume of entrapped air,

W = Mass of Water (Kg) per m^3 of concrete

C = Mass of Cement (Kg) per m^3 of concrete

S_e = Specific gravity of cement

P = Ratio of FA to total aggregate by absolute volume

C_a, F_a = total mass of CA and FA (Kg) per m^3 of concrete respectively and

S_{fa}, S_{ca} = specific gravity of saturated, surface dry fine aggregates and coarse aggregates respectively.

$0.98 = \{186 + (476.9/3.15) + (1/0.35 \times (f_a / 2.6))\} \times (1/1000)$

$F_a = 520.14\ kg/m^3$

$C_a = ((1 - 0.35) / 0.35)) \times 520.14 \times (2.64 / 2.6)$

$= 1156.68\ Kg / m^3$

The mix proportion then becomes:

WATER		**CEMENT**		**F.A**		**C.A**
186kg		476.9kg		520.14kg		1156.68kg
0.39	:	1	:	1.09	:	2.42

ACTUAL QUANTITIES REQUIRED FOR THE MIX

1. Extra quantity of water to be added for absorption in case of CA, at 0.5 percent mass. = 5.90 litres.
2. Quantity of water to be deducted for moisture present in sand, at 2 Percent by mass. = 10.95 litres.

3. Actual quantity of water required to be added

=186+5.90-10.95 = 180.95 liters

Actual quantity of sand required = 520.14+10.95 =531.09 kg

Actual quantity of coarse aggregate required = 1156.68-5.90=1151.78 kg

ix) ACTUAL QUANTITY OF COARSE AGGREGATE

1. Fraction I (60% of 20 MM) = 692.06Kg
2. Fraction II (40% of 12.5 MM) = 460.99Kg

PROPORTION BY WEIGHT

WATER	CEMENT	F.A	20MM C.A	12.5 MM C.A
180.95kg	476.9kg	531.09kg	692.06kg	460.99kg

PROPORTION BY RATIO

0.39 : 1 : 1.11 : 1.45 : 0.96

3.5 CONCRETE MIX DESIGN -GRADE M_{60}

DESIGN STIPULATION:-

- Target strength = 60Mpa
- Max size of aggregate used = 12.5 mm
- Specific gravity of cement = 3.15
- Specific gravity of fine aggregate (F.A) = 2.6
- Specific gravity of Coarse aggregate (C.A) = 2.64
- Dry Rodded Bulk Density of fine aggregate = 1726 Kg/m^3
- Dry Rodded Bulk Density of coarse aggregate = 1638 Kg/m^3

Step-1

Calculation for weight of Coarse Aggregate:

From ACI 211.4R Table 4.3.3 Fractional volume of oven dry Rodded C.A for 12.5mm size aggregate is $0.68m^3$

Weight of C.A = 0.68*1638 = 1108.13 Kg/m^3

Step-2

Calculation for Quantity of Water:

From ACI 211.4R Table 4.3.4

Assuming Slump as 50 to 75mm and for C.A size 12.5 mm the Mixing water = 148 ml

Void content of FA for this mixing water = 35%

Void content of FA (V)

V = {1-(Dry Rodded unit wt / specific gravity of FA*1000)}*100

= [1-(1726/2.6*1000)]*100

= 34.62%

Adjustment in mixing water = (V-35)* 4.55

= (34.62 – 35)*4.55

= -1.725 ml

Total water required = 148 + (-1.725) = 146.28 ml

Step-3

Calculation for weight of cement

From ACI 211.4R Table 4.3.5(b)

Take W / C ratio = 0.29

Weight of cement = 146.28 / 0.29 = 504.21 kg/m^3

Step-4

Calculation for weight of Fine Aggregate:

Cement	= 504.21 / 3.15*1000	= 0.1616
Water	= 146.28 / 1*1000	= 0.1462
C.A	= 1108.13 / 3*1000	= 0.3690
Entrapped Air	= 2 / 100	= 0.020
	Total	= 0.7376m^3
Volume of F.A	= 1-0.7376	
Weight of F.A	= 0.2624*2.6*1000	
F.A	= 683.24 kg/m^3	

Step-5

Super plasticizer:

For 0.8% = (0.8 / 100)*583.53 = 4.668 ml

Step-6

Correction for water:

Weight of water (For 0.8%) =146.28 – 4.668 =141.61 kg/m^3

Step-7

Requirement of materials per Cubic meter

Cement	504.21 Kg/m^3
Fine Aggregate	683.24 Kg/m^3
Coarse Aggregate	1108.13 Kg/m^3
Water	141.61 Kg/ m^3
Super plasticizers	4.6681 / m3

Cement (Kg/m^3)	Fine agg (Kg/ m^3)	Coarse agg (Kg/ m^3)	Water (l/m^3)	Super Plasticizer (l/m^3)
504.21	683.24	1108.13	141.61	4.6681
1	1.35	2.19	0.29	0.8

TEST RESULTS AN
EVALUATIO

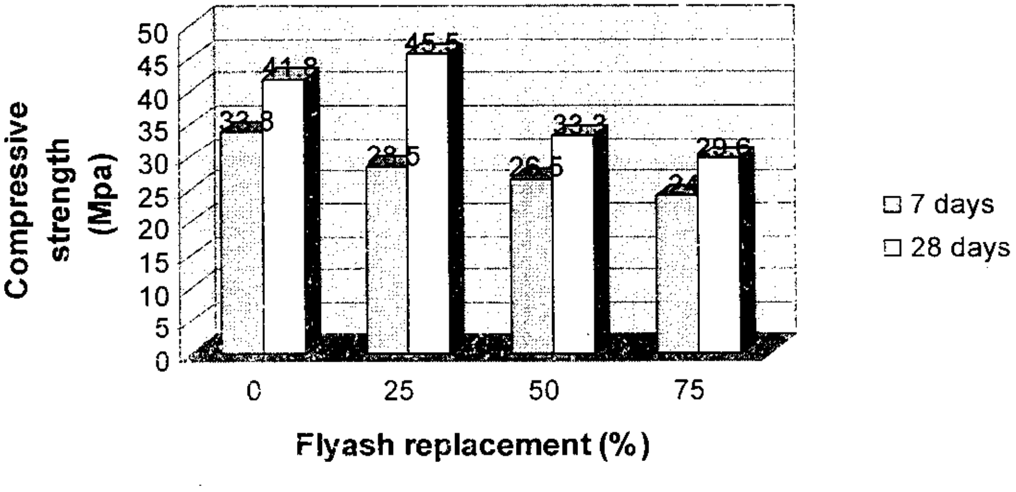
4. TEST RESULTS AND EVALUATION

4.1 COMPARISION OF TEST RESULTS

COMPARISON OF COMPRESSIVE STRENGTH FOR M30 GRADE CONCRETE:

Table-4.1. COMPARISON OF COMPRESSIVE STRENGTH FOR M30 GRADE CONCRETE

S.NO	Fly Ash %	W/C Ratio	Compressive Strength, (Mpa)	
			7 Days	28 Days
1	0	0.39	33.8	41.8
2	25	0.39	28 .5	45.5
3	50	0.39	26.5	33.3
4	75	0.39	24	29.6



COMPARISON OF SPLIT TENSILE STRENGTH FOR M30 GRADE CONCRETE:

Table-4.2. COMPARISON OF SPLIT TENSILE STRENGTH FOR M30 GRADE CONCRETE

S.NO	Fly Ash %	W/C Ratio	Split Tensile Strength (Mpa)	
			7 days	28 days
1	0	0.39	2.9	3.3
2	25	0.39	2.4	3.6
3	50	0.39	2.6	3.5
4	75	0.39	2.8	3.15

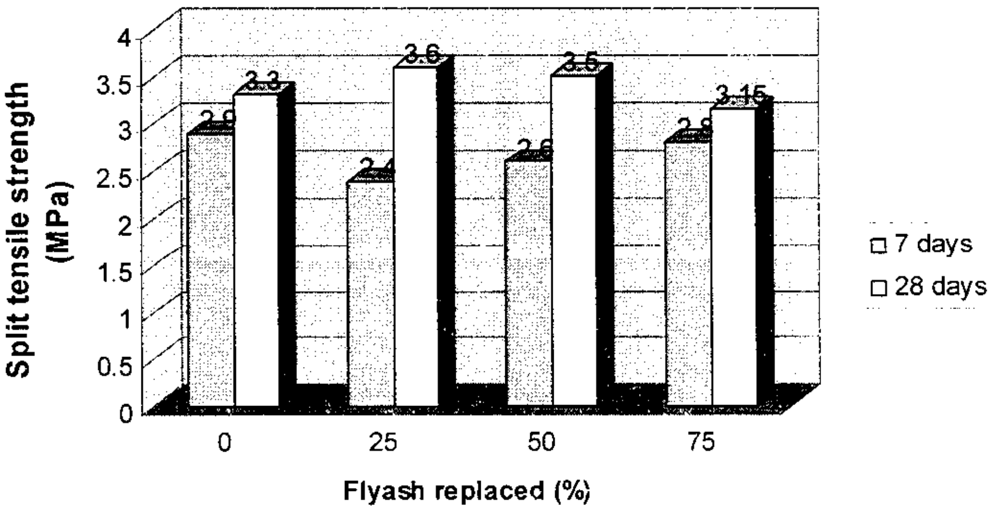


Fig-4.2. COMPARISON OF SPLIT TENSILE STRENGTH FOR M30 GRADE CONCRETE

COMPARISON OF FLEXURAL STRENGTH FOR M30 GRADE CONCRETE:

Table-4.3. COMPARISON OF FLEXURAL STRENGTH FOR M30 GRADE CONCRETE

S.NO	Fly Ash %	W/C Ratio	Flexural strength (Mpa)	
			7 days	28 days
1	0	0.39	3.8	5.1
2	25	0.39	3.4	6.3
3	50	0.39	3.9	4.8
4	75	0.39	3.3	4.6

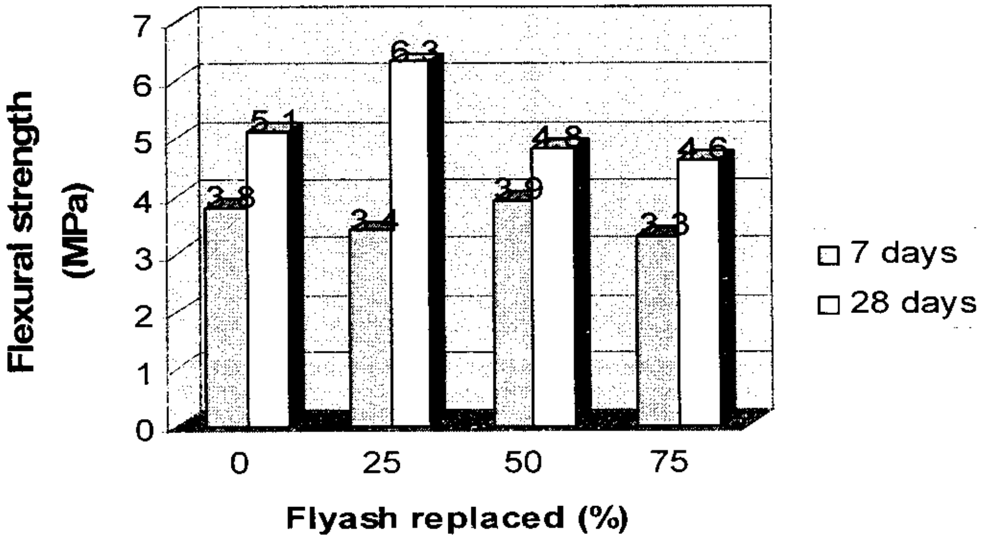


Fig-4.3. COMPARISON OF FLEXURAL STRENGTH FOR M30 GRADE CONCRETE

COMPARISON OF COMPRESSIVE STRENGTH FOR M60 GRADE CONCRETE:

Table-4.4. COMPARISON OF COMPRESSIVE STRENGTH FOR M60 GRADE CONCRETE

S.NO	Fly Ash %	W/C Ratio	Compressive Strength, (Mpa)	
			7 Days	28 Days
1	0	0.29	52.8	60.6
2	25	0.29	46.3	68.1
3	50	0.29	36.9	58.6
4	75	0.29	33.6	53.9

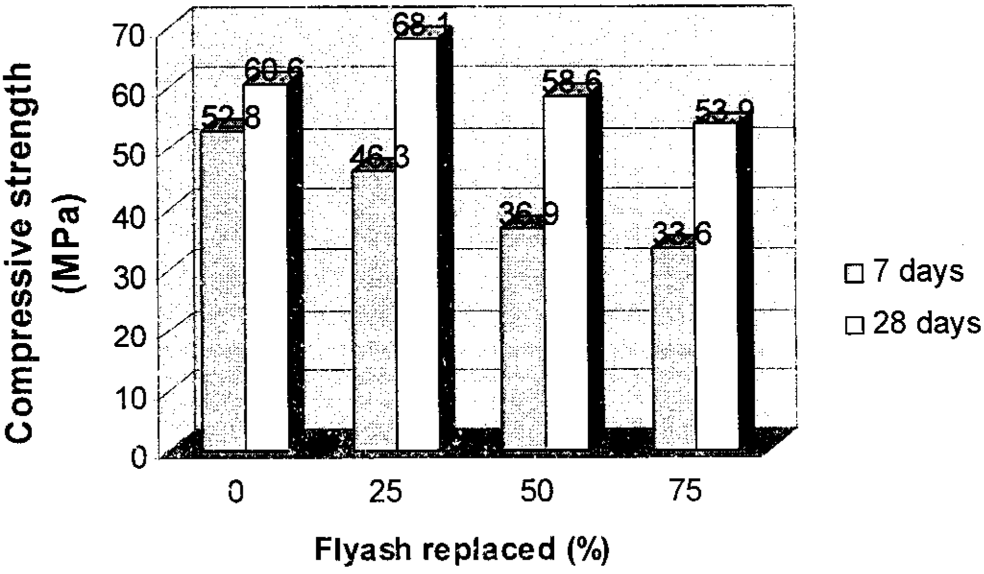


Fig-4.4. COMPARISON OF COMPRESSIVE STRENGTH FOR M60 GRADE CONCRETE

COMPARISON OF SPLIT TENSILE STRENGTH FOR M60 GRADE CONCRETE:

Table-4.5. COMPARISON OF SPLIT TENSILE STRENGTH FOR M60 GRADE CONCRETE

S.NO	Fly Ash %	W/C Ratio	Split Tensile Strength (MPa)	
			7 Days	28 Days
1	0	0.29	3.5	4.5
2	25	0.29	3.8	4.9
3	50	0.29	3.18	4.4
4	75	0.29	3.3	4.1

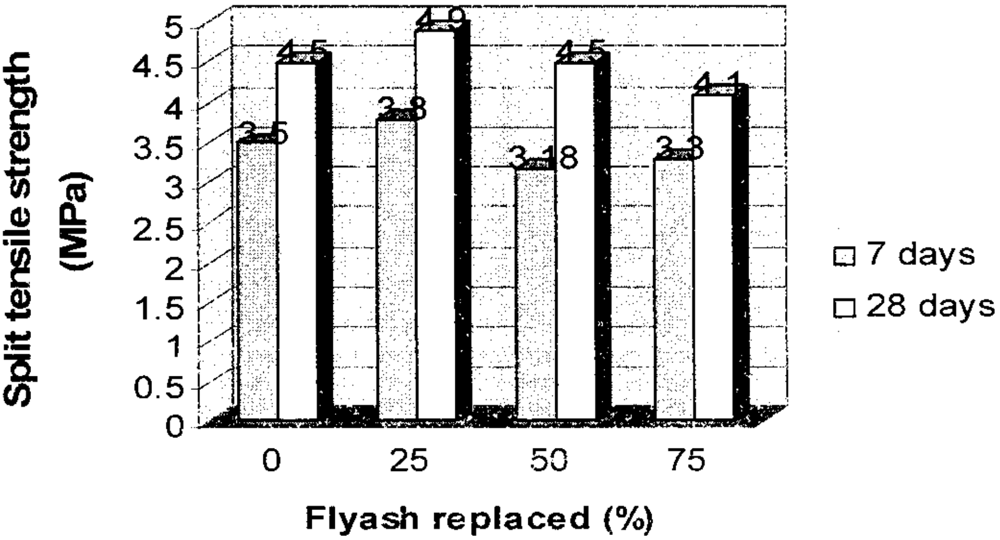


Fig-4.5. COMPARISON OF SPLIT TENSILE STRENGTH FOR M60 GRADE CONCRETE

COMPARISON OF FLEXURAL STRENGTH FOR M60 GRADE CONCRETE:

Table-4.6. COMPARISON OF FLEXURAL STRENGTH FOR M60 GRADE CONCRETE

S.NO	Fly Ash %	W/C Ratio	Flexural strength (Mpa)	
			7 days	28 days
1	0	0.29	4.1	7.5
2	25	0.29	4.8	9
3	50	0.29	3.9	7.1
4	75	0.29	3.6	6.8

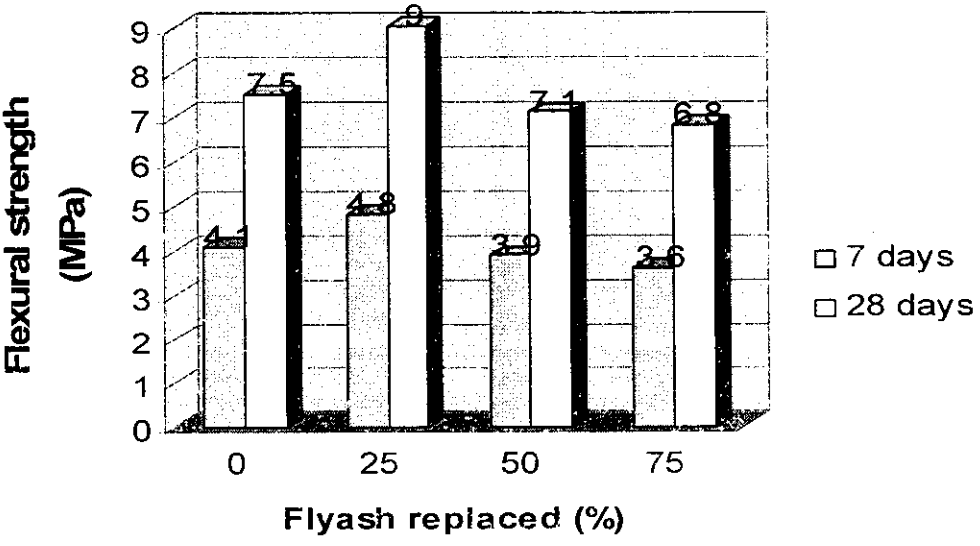


Fig-4.6. COMPARISON OF FLEXURAL STRENGTH FOR M60 GRADE CONCRETE

COMPARISON OF PERCENTAGE INCREASE IN COMPRESSIVE STRENGTH M_{30} GRADE CONCRETE AT 28 DAYS:

Table-4.7. COMPARISON OF PERCENTAGE INCREASE IN COMPRESSIVE STRENGTH M_{30} GRADE CONCRETE AT 28 DAYS

S.NO	Flyash %	W/C Ratio	% increase at 28 days
1	0	0.39	0
2	25	0.39	8.85
3	50	0.39	-20.33
4	75	0.39	-29.2

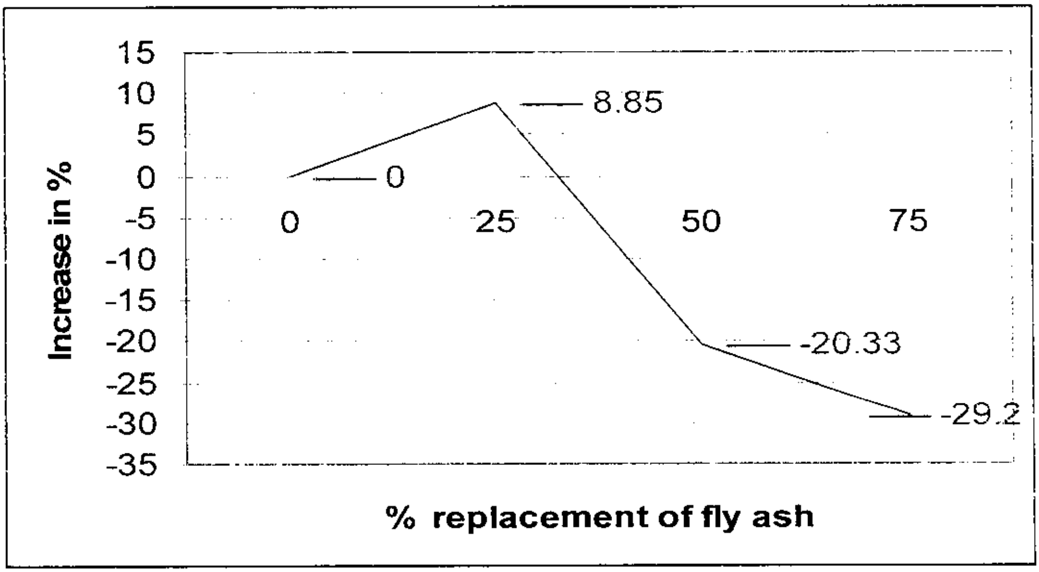


Fig-4.7. COMPARISON OF PERCENTAGE INCREASE IN COMPRESSIVE STRENGTH M_{30} GRADE CONCRETE AT 28 DAYS

COMPARISON OF PERCENTAGE INCREASE IN SPLIT TENSILE STRENGTH OF M_{30} GRADE CONCRETE AT 28 DAYS:

Table-4.8. COMPARISON OF PERCENTAGE INCREASE IN SPLIT TENSILE STRENGTH OF M_{30} GRADE CONCRETE AT 28 DAYS

S.NO	Flyash %	W/C Ratio	% increase at 28 days
1	0	0.39	0
2	25	0.39	9.09
3	50	0.39	6.06
4	75	0.39	-4.5

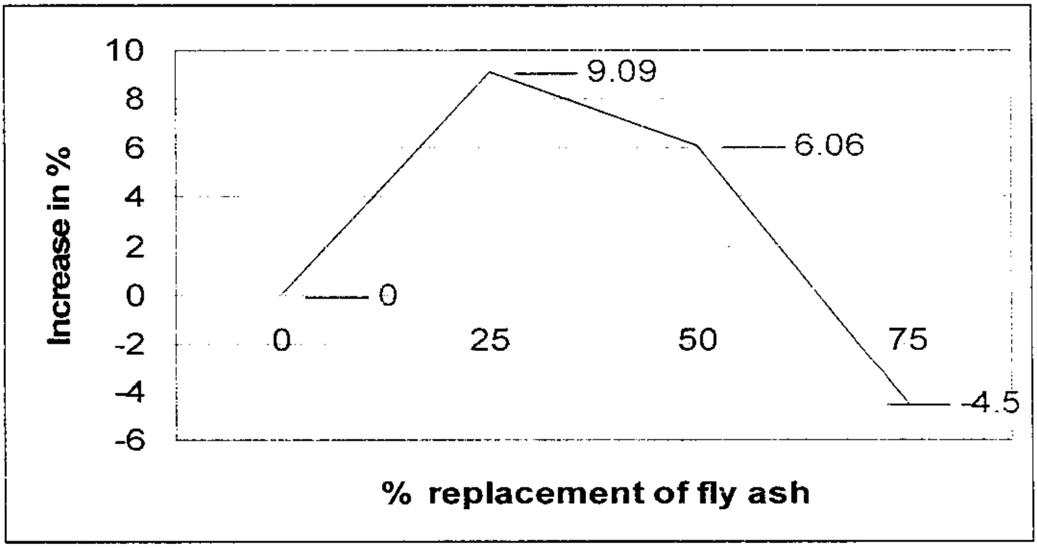


Fig-4.8 . COMPARISON OF PERCENTAGE INCREASE IN SPLIT TENSILE STRENGTH OF M_{30} GRADE CONCRETE AT 28 DAYS

COMPARISON OF PERCENTAGE INCREASE IN FLEXURAL STRENGTH OF M_{30} GRADE CONCRETE AT 28 DAYS:

Table-4.9. COMPARISON OF PERCENTAGE INCREASE IN FLEXURAL STRENGTH OF M_{30} GRADE CONCRETE AT 28 DAYS

S.NO	Flyash %	W/C Ratio	% increase at 28 days
1	0	0.39	0
2	25	0.39	23.53
3	50	0.39	-5.88
4	75	0.39	-9.8

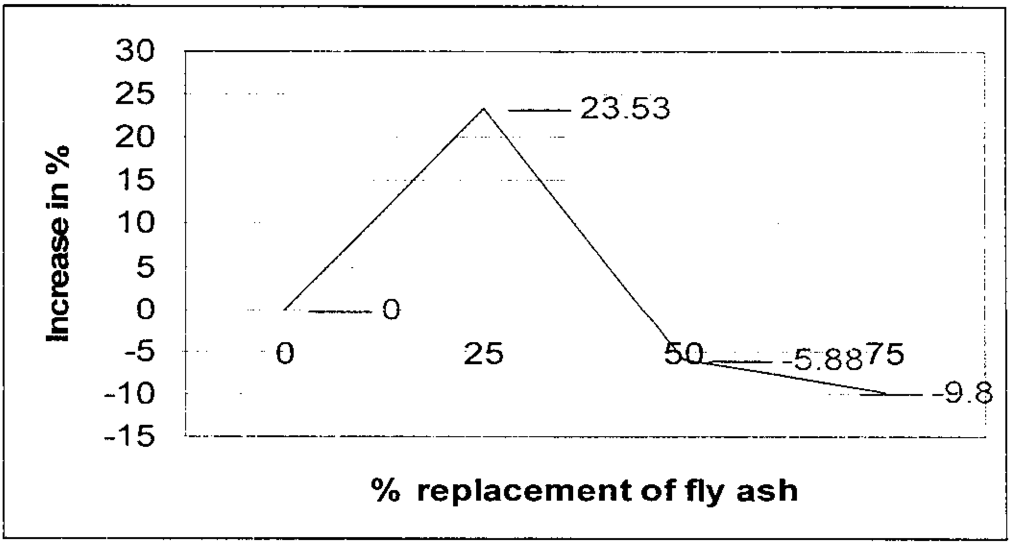


Fig-4.9. COMPARISON OF PERCENTAGE INCREASE IN FLEXURAL STRENGTH OF M_{30} GRADE CONCRETE AT 28 DAYS

COMPARISON OF PERCENTAGE INCREASE IN COMPRESSIVE STRENGTH M_{60} GRADE CONCRETE AT 28 DAYS:

Table-4.10. COMPARISON OF PERCENTAGE INCREASE IN COMPRESSIVE STRENGTH M_{60} GRADE CONCRETE AT 28 DAYS

S.NO	Flyash %	W/C Ratio	% increase at 28 days
1	0	0.29	0
2	25	0.29	12.38
3	50	0.29	-3.30
4	75	0.29	-11.06

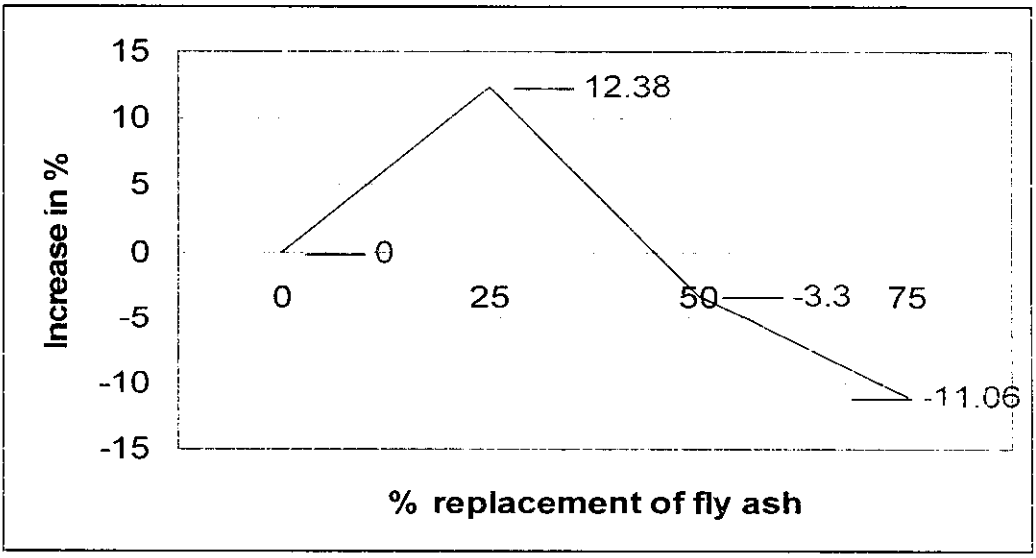


Fig-4.10. COMPARISON OF PERCENTAGE INCREASE IN COMPRESSIVE STRENGTH M_{60} GRADE CONCRETE AT 28 DAYS

COMPARISON OF PERCENTAGE INCREASE IN SPLIT TENSILE STRENGTH OF M_{60} GRADE CONCRETE AT 28 DAYS:

Table-4.11. COMPARISON OF PERCENTAGE INCREASE IN SPLIT TENSILE STRENGTH OF M_{60} GRADE CONCRETE AT 28 DAYS

S.NO	Fly ash %	W/C Ratio	% increase at 28 days
1	0	0.29	0
2	25	0.29	8.90
3	50	0.29	-2.22
4	75	0.29	-8.9

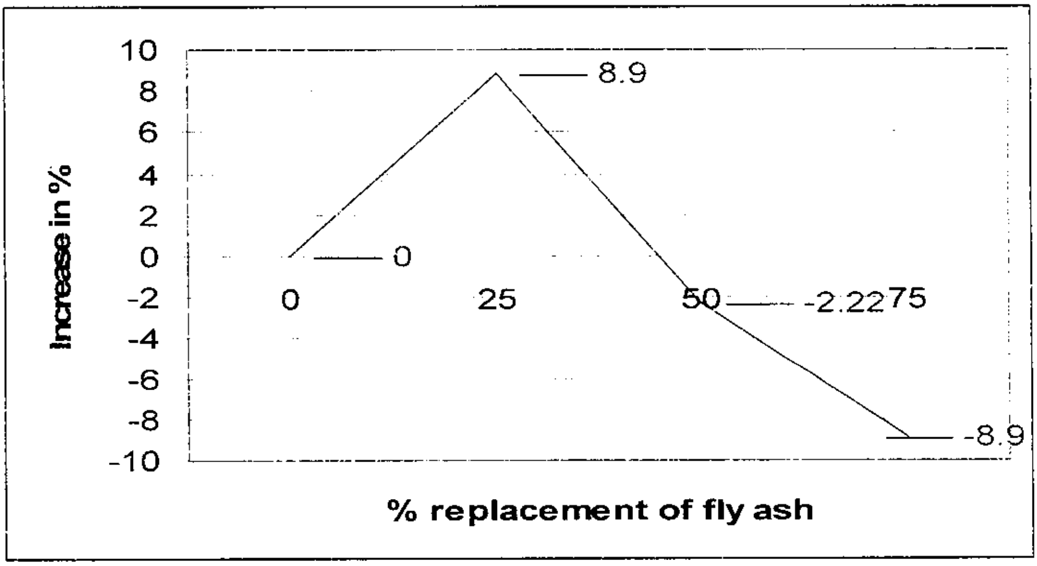


Fig-4.11. COMPARISON OF PERCENTAGE INCREASE IN SPLIT TENSILE STRENGTH OF M_{60} GRADE CONCRETE AT 28 DAYS

COMPARISON OF PERCENTAGE INCREASE IN FLEXURAL STRENGTH OF M_{60} GRADE CONCRETE AT 28 DAYS:

Table-4.12. COMPARISON OF PERCENTAGE INCREASE IN FLEXURAL STRENGTH OF M_{60} GRADE CONCRETE AT 28 DAYS

S.NO	Flyash %	W/C Ratio	% increase at 28 days
1	0	0.29	0
2	25	0.29	20
3	50	0.29	-5.30
4	75	0.29	-9.33

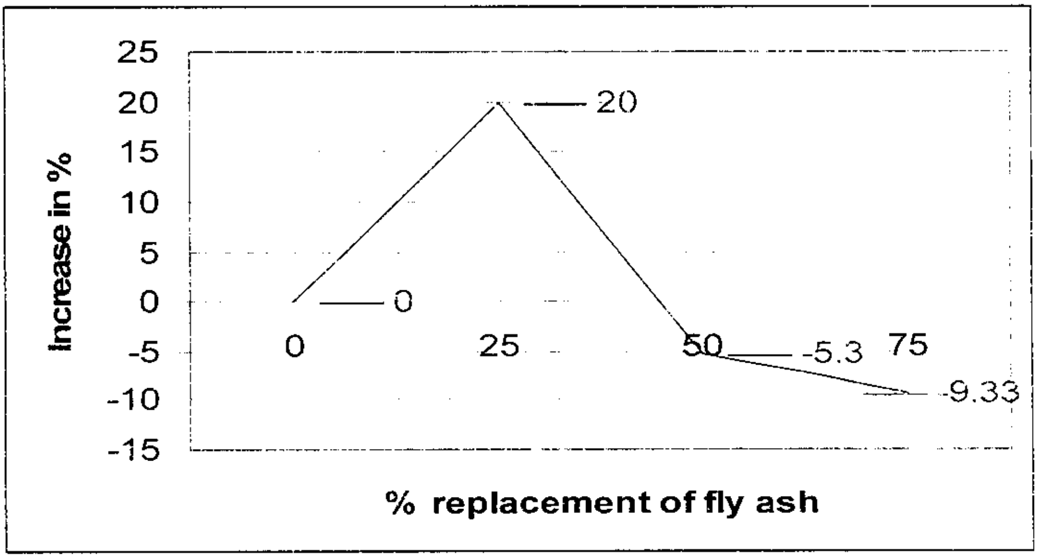


Fig-4.12. COMPARISON OF PERCENTAGE INCREASE IN FLEXURAL STRENGTH OF M_{60} GRADE CONCRETE AT 28 DAYS

LOAD Vs DEFLECTION FOR M_{30} GRADE CONCRETE

Table-4.13. LOAD Vs DEFLECTION FOR M_{30} GRADE CONCRETE

Load (KN)	Deflection at Midspan (mm)
0	0
5	0.23
10	0.54
15	0.95
20	1.01
25	1.68
30	2.00
35	2.61
40	3.17
45	3.59
50	4.11
55	5.53

Ultimate load	59.91 KN
Initial crack	30 KN

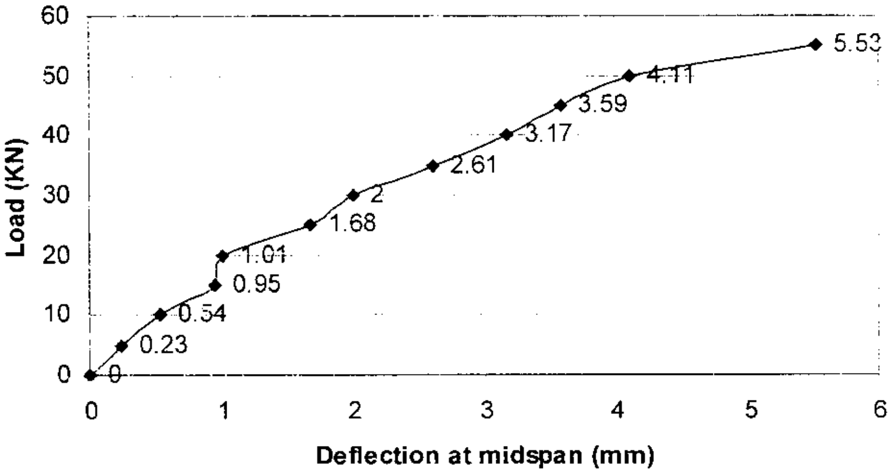


Fig.4.13. Load Vs Deflection curve for M_{30} grade concrete

LOAD Vs DEFLECTION FOR 25 % PARTIAL REPLACEMENT OF FLY ASH FOR M_{30} GRADE CONCRETE

Table-4.14. LOAD Vs DEFLECTION FOR 25 % PARTIAL REPLACEMENT OF FLY ASH FOR M_{30} GRADE CONCRETE

Load (KN)	Deflection at Midspan (mm)
0	0
5	1.18
10	1.54
15	1.85
20	2.48
25	2.65
30	3.21
35	3.85
40	4.5
45	4.85
50	4.94
55	5.03

Initial crack	31.68 KN
Ultimate load	62.38 KN
60	6.83

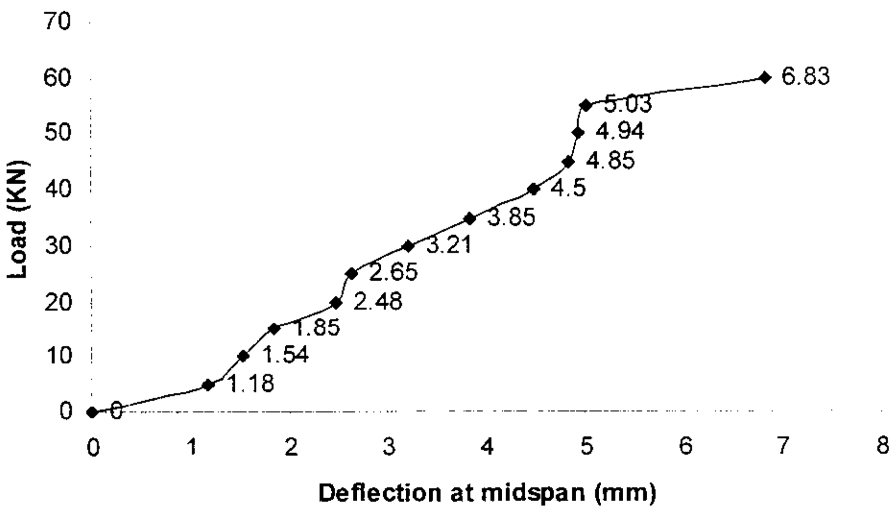


Fig.4.14. Load Vs Deflection curve for 25 % Partial Replacement of Fly

LOAD Vs DEFLECTION FOR 50 % PARTIAL REPLACEMENT OF FLY ASH FOR M_{30} GRADE CONCRETE

Table-4.15. LOAD Vs DEFLECTION FOR 50 % PARTIAL REPLACEMENT OF FLY ASH FOR M_{30} GRADE CONCRETE

Load (KN)	Deflection at Midspan (mm)
0	0
5	0.26
10	0.54
15	1.34
20	1.68
25	1.85
30	2.44
35	2.99
40	3.59
45	5.34
50	6.38
55	6.54

Ultimate load	56.8 KN
Initial crack	30.81 KN

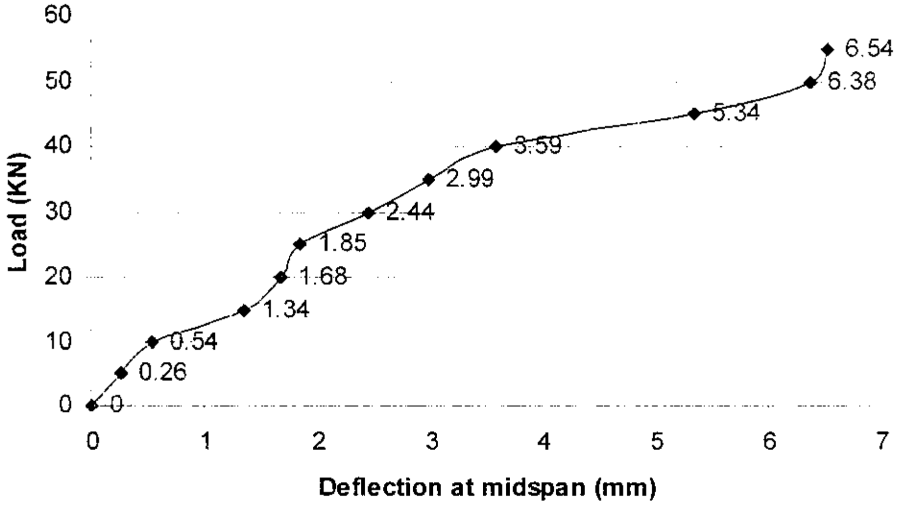


Fig.4.15. Load Vs Deflection curve for 50 % Partial Replacement of Fly Ash for M_{30} grade concrete

LOAD Vs DEFLECTION FOR 75 % PARTIAL REPLACEMENT OF FLY ASH FOR M_{30} GRADE CONCRETE

Table-4.16. LOAD Vs DEFLECTION FOR 75 % PARTIAL REPLACEMENT OF FLY ASH FOR M_{30} GRADE CONCRETE

Load (KN)	Deflection at Midspan (mm)
0	0
5	0.8
10	1.16
15	1.32
20	2.24
25	3.05
30	3.5
35	3.99
40	4.46
45	5.36
50	5.71
55	6.26

Ultimate load	54.71 KN
Initial crack	29.22 KN

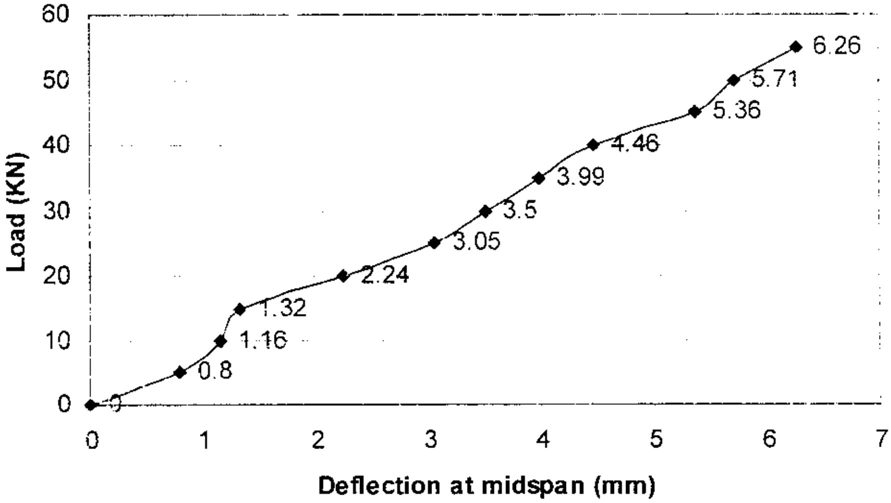


Fig.4.16. Load Vs Deflection curve for 75 % Partial Replacement of Fly Ash for M_{30} grade concrete

LOAD Vs DEFLECTION FOR M_{60} GRADE CONCRETE

Table-4.17. LOAD Vs DEFLECTION FOR M_{60} GRADE CONCRETE

Load (KN)	Deflection at Midspan (mm)
0	0
5	0.33
10	0.8
15	0.95
20	1.16
25	1.81
30	2.03
35	2.74
40	3.28
45	3.59
50	4.24
55	6.35
60	7.82

Ultimate load	61.38 KN
Initial crack	30.51 KN

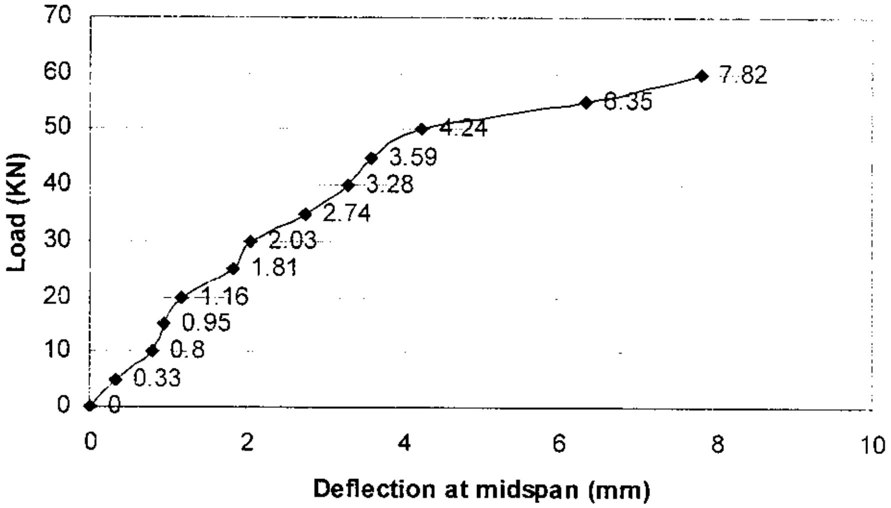


Fig.4.17. Load Vs Deflection curve for M_{60} grade concrete

LOAD Vs DEFLECTION FOR 25 % PARTIAL REPLACEMENT OF FLY ASH FOR M_{60} GRADE CONCRETE

Table-4.18. LOAD Vs DEFLECTION FOR 25 % PARTIAL REPLACEMENT OF FLY ASH FOR M_{60} GRADE CONCRETE

Load (KN)	Deflection at Midspan (mm)
0	0
5	0.18
10	0.54
15	0.89
20	1.14
25	1.68
30	2.00
35	2.61
40	3.3
45	3.59
50	4.11
55	4.74
60	7.55
65	9.82

Ultimate load	54.71 KN
Initial crack	29.22 KN

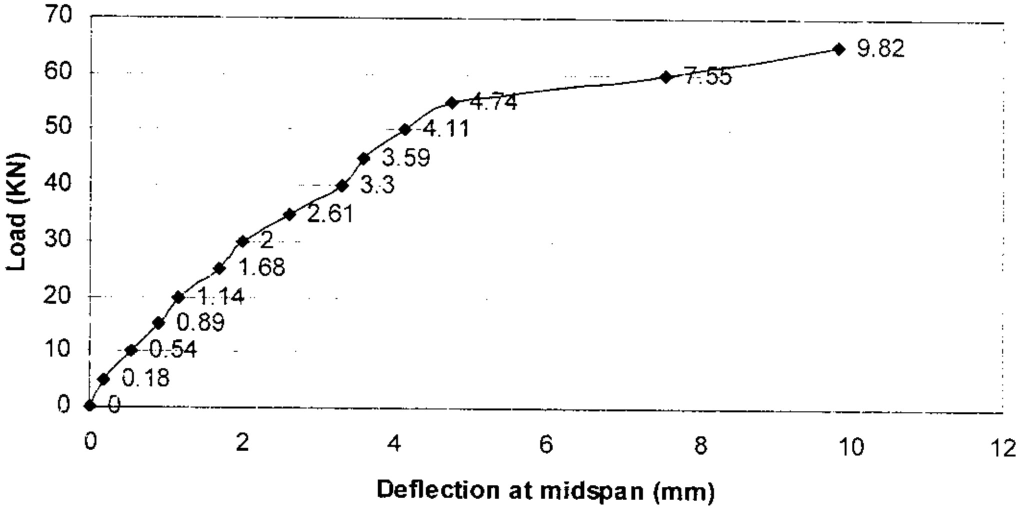


Fig.4.18. Load Vs Deflection curve for 25 % Partial Replacement of Fly Ash for M_{60} grade concrete

LOAD Vs DEFLECTION FOR 50 % PARTIAL REPLACEMENT OF FLY ASH FOR M_{60} GRADE CONCRETE

Table-4.19. LOAD Vs DEFLECTION FOR 50 % PARTIAL REPLACEMENT OF FLY ASH FOR M_{60} GRADE CONCRETE

Load (KN)	Deflection at Midspan (mm)
0	0
5	0.4
10	0.71
15	1.09
20	1.35
25	1.85
30	2
35	2.94
40	3.38
45	3.6
50	4.2
55	4.61
60	4.78

Ultimate load	59.91 KN
Initial crack	29.2 KN

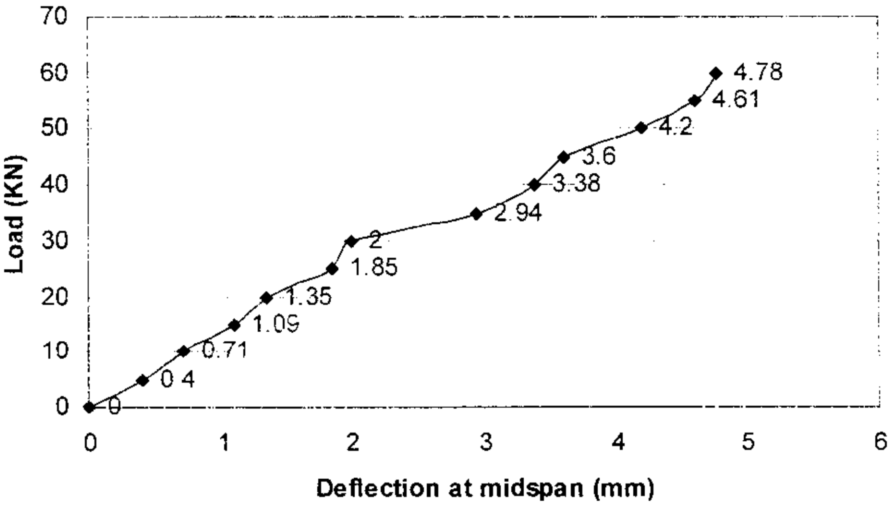


Fig.4.19. Load Vs Deflection curve for 50 % Partial Replacement of Fly Ash for M_{60} grade concrete

LOAD Vs DEFLECTION FOR 75 % PARTIAL REPLACEMENT OF FLY ASH FOR M_{60} GRADE CONCRETE

Table-4.20. LOAD Vs DEFLECTION FOR 75 % PARTIAL REPLACEMENT OF FLY ASH FOR M_{60} GRADE CONCRETE

Load (KN)	Deflection at Midspan (mm)
0	0
5	0.26
10	0.8
15	0.94
20	1.73
25	1.95
30	2.35
35	2.94
40	3.48
45	3.73
50	4.41
55	4.56

Ultimate load	56.98 KN
Initial crack	25.98 KN

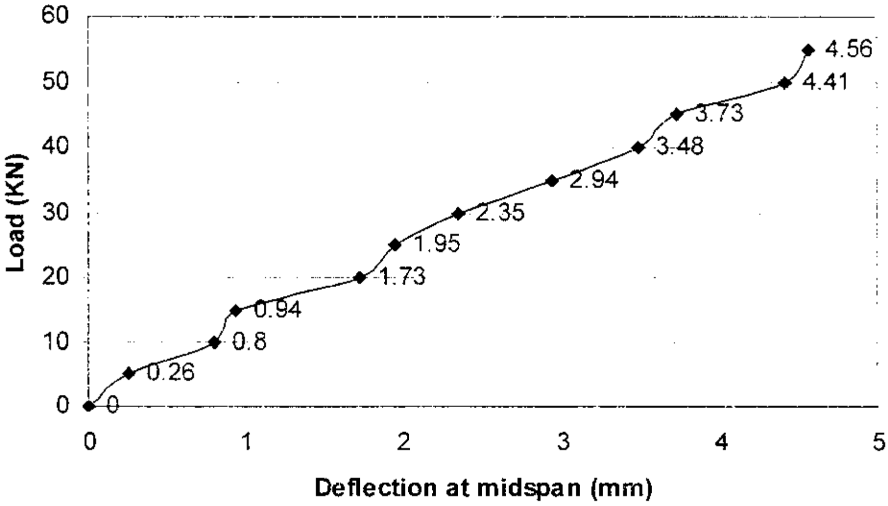


Fig.4.20. Load Vs Deflection curve for 75 % Partial Replacement of Fly Ash for M_{60} grade concrete

4.2 DISCUSSION ON TEST RESULTS:

- Compressive strength, split tensile strength, flexural strength of 25 % partial replacement of fly ash M_{30} grade concrete has increased when compared to conventional concrete.
- Compressive strength, split tensile strength, flexural strength of 25 % partial replacement of fly ash M_{60} grade concrete has increased when compared to conventional concrete.
- Load caring capacity of 25 % partial replacement of fly ash M_{30} grade concrete beam has increased when compared to control concrete beam.
- Load caring capacity of 25 % partial replacement of fly ash M_{60} grade concrete beam has increased when compared to control concrete beam.

CONCLUSIONS

5. CONCLUSION

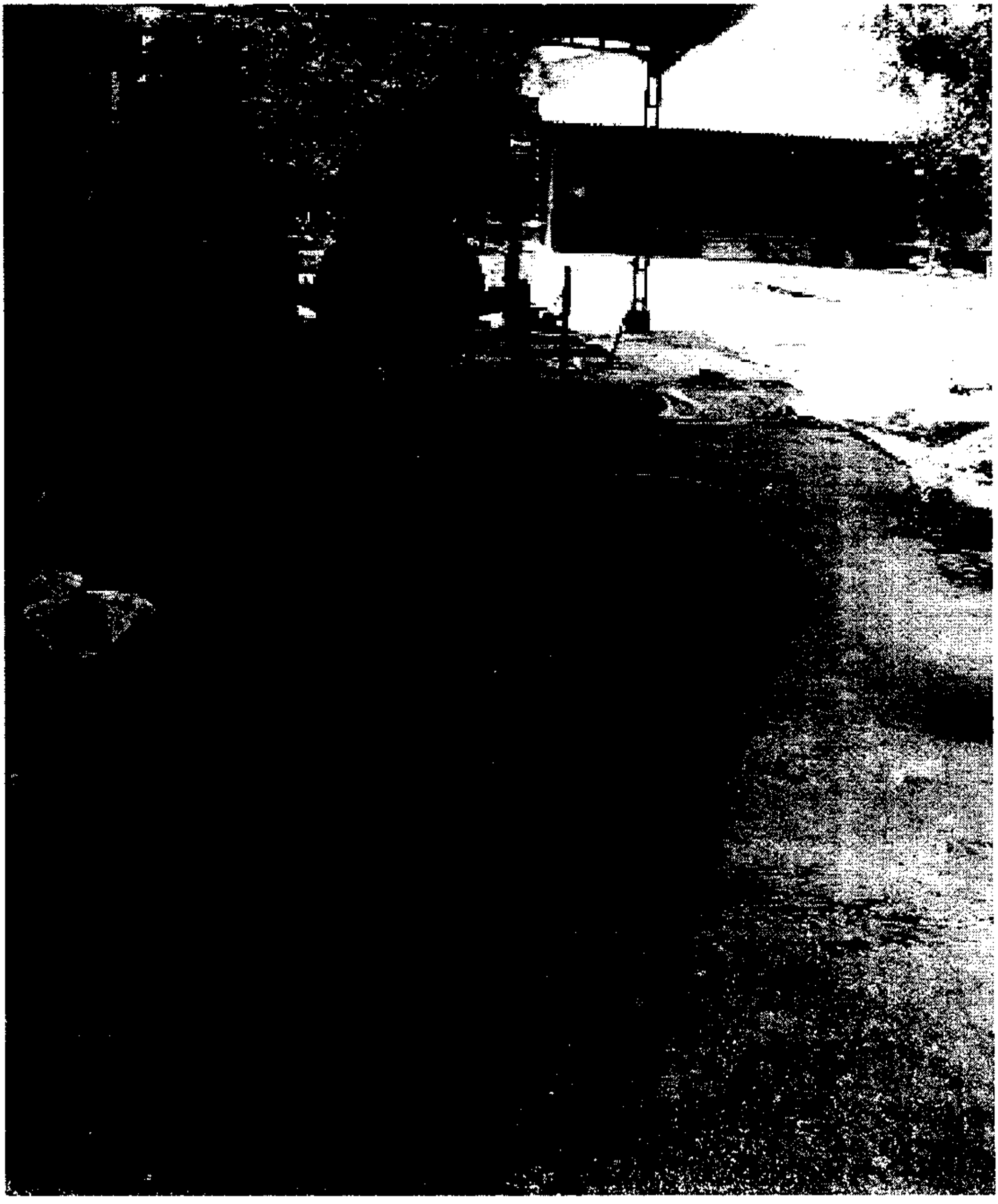
5.1. CONCLUSION

- For M30 grade concrete the compressive strength increase up to 8.85 % for 25% replacement by Fly ash.
- For M60 grade concrete the compressive strength increase up to 12.38 % for 25% replacement by Fly ash.
- There is an 9.09% increase in split tensile strength with 25% of replacement of cement with fly ash in M30 grade concrete.
- There is an 23.53% increase in Flexural strength with 25% of replacement of cement with fly ash in M30 grade concrete.
- There is an 8.9% increase in split tensile strength with 25% of replacement of cement with fly ash in M60 grade concrete.
- 20% increase in flexural strength with 25% of replacement of cement with fly ash in M60 grade concrete was observed.
- By proper mix design with water cement ratio 0.29 high strength concrete with compressive strength 68.1 Mpa can be prepared even with replacement of cement by 25% of fly ash.
- The load at first crack was found to be almost same with the 25% of Fly ash replacement with cement.
- The Ultimate moment was found to be almost same with the 25% of Fly ash replacement with cement.
- Bar chart for the comparison of compressive strength, split tensile strength, flexural strength of concrete for various % of fly ash replacement is presented in this thesis.

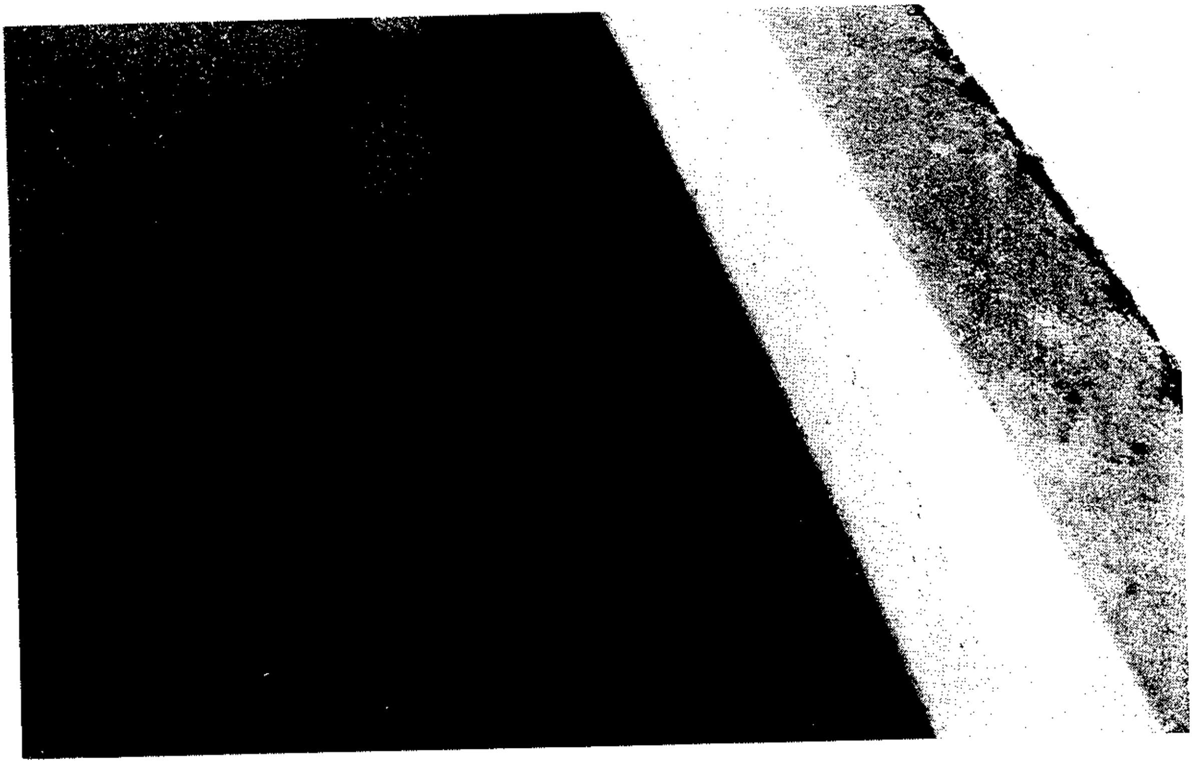
PHOTOGRAPHY

PHOTOGRAPHY

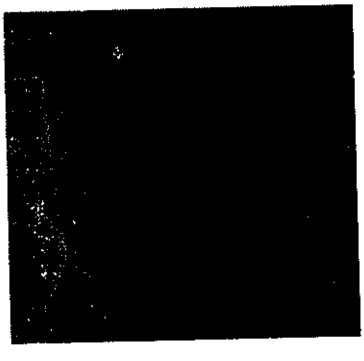
CASTING

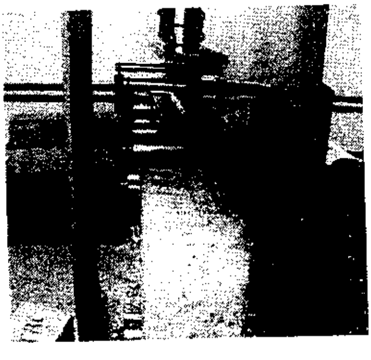


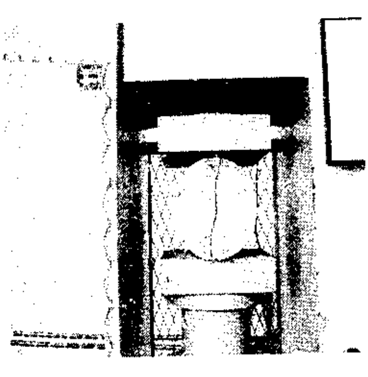
CURING

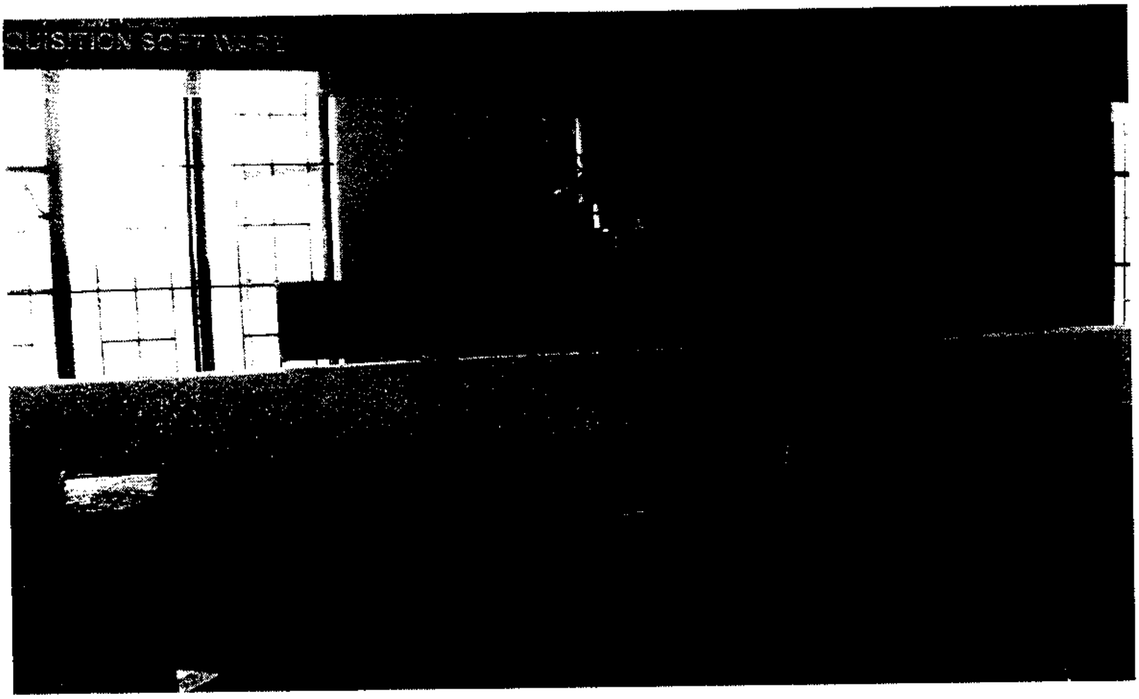


TESTING OF SPECIMEN

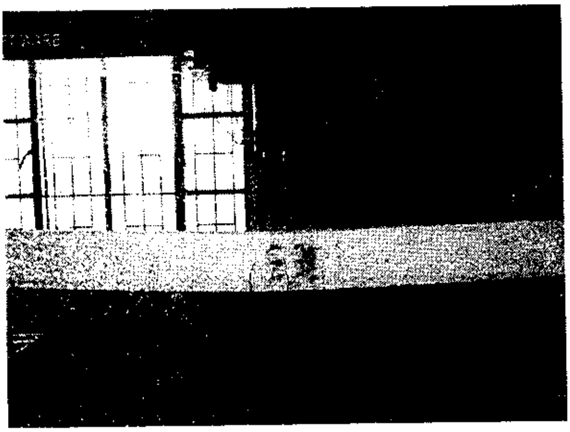


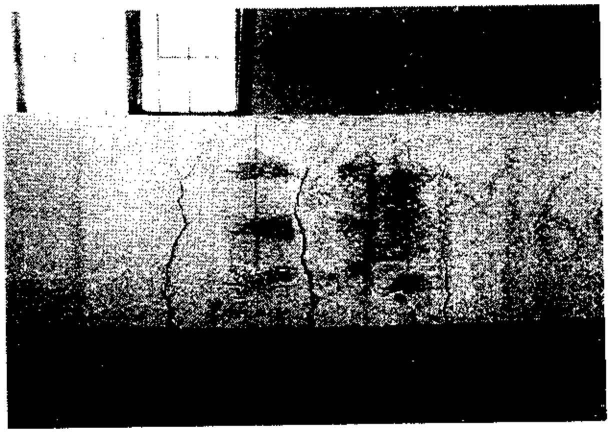






CRACKING PATTERN





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