# EXPERIMENTAL STUDY OF TERNARY BLEND IN HIGH STRENGTH CONCRETE

Venkat Ramana G[1], Jaya Raj P[2], Gnanamoorthy P[3]
[1,2,3]Assistant Professors, TKR engineering College, Hyderabad

**ABSTRACT**

**High Strength concrete may be defined as a concrete which having characteristic compressive strength more than 40Mpa. High-strength concrete can resist loads more than the normal-strength concrete. High strength concrete is produced by replacing cement by mineral admixtures. Mineral admixture is nothing but an industrial byproduct which are having the cementitious properties. The usage of mineral admixtures leads to the saving of cost, energy and resources conservation. In the present work HSC is prepared by using GGBFS and Silica fume. GGBFS is a byproduct of iron manufacturing factory. Silica fume is a byproduct of producing silicon metal. In this work high strength concrete is made up with partial replacing of GGBFS and silica fume. In total there were six different combinations of mixes were studied at three different ages of concrete namely 7, 28 and 56 days of concrete. The compressive and split tensile strength results were observe for 7, 28, and 56 days of concrete. The optimum mix is selected from the 28 days age compressive strengths of different mixes. The beams cast for control and obtained optimum mix were casted. The beams are tested to determine the Load – Deflection characteristics and peak load, first crack load were observed. The obtained results are compared with the control mix.From the results the inclusion of GGBFS and silica fume increased the strength properties of high strength concrete up to an optimum level**.

## INTRODUCTION

### 1.1 GENERAL

Concrete is the most used material for construction in the world. The quest for the development of high strength concrete has been increasing due to the demand prevailing in concrete industry. For high strength and high performance concrete mixes use of supplementary cementitious materials has become an integral art since high strength or high performance concrete using cement without any mineral admixtures require high paste volume which may lead to problems such as excessive shrinkage, large evolution of heat due to hydration Manageable utilization of supplementary materials and progressive advancements in superplasticizing admixtures has encouraged upgrades in the mechanical properties of concrete.

Cement is the main ingredient in the production of concrete. Unfortunately the production of cement emits greenhouse gases which are the main source of global warming. So the researchers try to find a material to replace cement or partially replace in the cement. We replace the cement by some materials which are having the cementitious properties which are called as mineral admixtures or supplementary cementitious materials.

The replacement of mineral admixture up to an optimum level leads to increase in strength and durability properties. These concrete are called as high strength or high performance concrete. The advent of high raised buildings increased the usage of high strength and high performance concrete

### 1.2 HIGH STRENGTH CONCRETE

High Strength concrete may be defined as a concrete which having characteristic compressive strength more than 40 MPa. High-strength concrete can resist loads that normal-strength concrete cannot. Manufacture of high-strength concrete involves making optimal use of the basic ingredients that constitute normal strength concrete. The high strength of concrete can be achieved by replacing partially cement with mineral admixtures like Metakaolin (Mk), Ground Granulated Blast Furnace Slag (GGBFS), Fly Ash (FA), etc. By using these mineral admixtures leads to lowering the global warming. The main applications of high strength concrete in situ concrete construction are in offshore structures, columns for tall buildings, long span bridges and highway structures.

## 1.3 MINERAL ADMIXTURES

Admixture is a material that is used as an ingredient of concrete and is added at the time of grinding. Producers use admixtures primarily to reduce the cost of concrete construction; to modify the properties of hardened concrete; to ensure the quality of concrete during mixing, transporting, placing, and curing; and to overcome certain emergencies during concrete operations. Successful use of admixtures depends on the use of appropriate methods of batching and concreting. Most admixtures are supplied in ready-to-use liquid form and are added to the concrete at the plant or at the jobsite. The effectiveness of an admixture depends on several factors including: type and amount of cement, water content, mixing time, slump, and temperatures of the concrete and air.

These are finely divided siliceous materials which are added to concrete in the range 20 to 60 percent by mass of the total cementitious material. These are the waste by-products from various industries. These are of two types:

1. Chemically active mineral admixtures like MK, SF.

2. Micro Filler mineral admixtures like GGBFS, and FA.

## METAKAOLIN (MK)

It is a dehydroxylated form of the clay mineral kaolinite and obtained from calcination of kaolinite clay in the range of 740 – 840oC. The particle size of metakaolin is smaller than cement particles, but not as fine as silica fume. Replacing Portland cement with 8–20% (by weight) MK produces a concrete mix, which exhibits favorable engineering properties, including: the filler effect and the pozzolanic reaction. The filler effect is immediate, while the effect of pozzolanic reaction occurs between 3 to 14 days.

## SILICA FUME (SF)

Silica fume is a byproduct of silicon metal or ferrosion alloys. One of the most beneficial material to replace in cement due to its pozzalonic nature. Silica fume is 1/100 time smaller than the particle of cement. The replacement of silica fume increases the strength and durability of the concrete. Replacing Portland cement with 10–20% (by weight) SF produces a concrete mix, which exhibits favorable engineering properties, including: the filler effect and the pozzolanic reaction. The addition of silica fume provides early strength of concrete.

## GROUND GRANULATED BLAST FURNACE SLAG (GGBFS)

It is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. The addition of GGBFS makes concrete more durable, due to its lower setting time the heat of hydration is lowered. GGBFS contains silicates and alumino-silicates of calcium and is a by-product of iron manufactured in a blast furnace. The GGBFS can be replaced with cement up to 10-50%.

## 1.4 OBJECTIVES

- To prepare a high strength concrete by replacing cement by mineral admixtures( GGBFS and silica fume )
- To study the strength properties of admixture concrete.
- To arrive the optimum replacement of admixture from the compression test results.
- To study the load deflection characteristics of the control beam and optimum beam.

## 1.5 APPLICATIONS OF HIGH STRENGTH CONCRETE:

- High-strength concrete is needed in building ventures that have concrete segments that must oppose high compressive strengths. High-quality concrete is ordinarily utilized as a part of the erection of tall building structures. It has been utilized as a part of segments, for example, section. (particularly on lower floors where the loads will be most prominent), shear walls, and foundations.

- High strength concrete is occasionally utilized as a part of the development of highway bridges. High-quality concrete grants reinforced or pre-stressed concrete girders to span more noteworthy lengths than normal strength concrete supports. Additionally, the more prominent individual support limits may empower a lessening in the quantity of girders needed.
- In some cases, high strength concrete is also recommended for the construction of nuclear waste containment structures.

## 3.1 MATERIALS

### 3.1.1 CEMENT

OPC of 53 grade conforming to IS: 8122-1989 was used for the present experimental investigation.

### 3.1.2 FINE AGGREGATE

Natural river sand with fraction passing through 4.75 mm sieve and retained on 600µm sieve confirming to gradation zone –III was used as fine aggregate. The fineness modulus of sand used was 2.81 with a specific gravity of 2.65.

### 3.1.3 COARSE AGGREGATE

Crushed granite of maximum size of 20 mm was used and specific gravity was found to be 2.70.

**Table 1 chemical composition of ordinary Portland cement**

| Name of compound | %content |
|---|---|
| SiO2 | 21.46 |
| Al2O3 | 5.55 |
| CaO | 63.95 |
| Fe2O3 | 3.46 |
| MgO | 1.86 |
| SO3 | 1.42 |
| K2O | 0.84 |

**Table 2 physical properties of fine aggregate**

| Property | Result |
|---|---|
| Specific gravity | 2.65 |
| Fineness Modulus | 2.4 |
| Bulk density (kg/m3) | 1700 |
| Water Absorption | 1% |

**Table 3 physical properties of coarse aggregate**

| Property | Result |
|---|---|
| Specific gravity | 2.7 |
| Fineness Modulus | 6.48 |
| Bulk density (kg/m3) | 1650 |
| Water Absorption | 0.9% |

### 3.1.4 WATER

Potable tap water available in the laboratory was used for mixing of concrete and curing.

### 3.1.5 SUPER PLASTICIZER

Conplast SP430 was used as a high range water reducing agent complies with IS:9103-1999 having a specific gravity of 1.18.

### 3.1.6 GGBFS

GGBFS was obtained from ASTRRA chemicals, Chennai. The specific gravity of the GGBFS is 2.85

**Figure 1 Physical appearance of GGBFS**

**Figure 2 physical appearance of silica fume**

**Table 4 physical properties of GGBFS**

| | |
|---|---|
| Colour | Off white |
| Bulk density | 1.1-1.3 tones/m3 |
| Specific gravity | 2.85 |

**Table 5 chemical composition of GGBFS**

| Compounds | Amount present (%) |
|---|---|
| Cao | 40 |
| Sio2 | 35 |
| Al2o3 | 10 |
| Mgo | 8 |

### 3.1.7 Silica fume

Silica fume was obtained from ASTRRA chemicals, Chennai. The specific gravity of the silica fume is 2.22

**Table 6 Physical properties of silica fume**

| | |
|---|---|
| Colour | White |
| Bulk density | 1.1-1.2 tones/m3 |
| Specific gravity | 2.22 |

**Table 7 Chemical composition of silica fume**

| Compound | Amount present (%) |
|---|---|
| Cao | 1 |
| Sio2 | 85-97 |
| Al2o3 | - |
| Mgo | - |

## 3.2 AGGREGATE PROPERTIES

Water absorption and specific gravity were basic measure of properties of aggregates

- The pycnometer is cleaned and dried and it its empty weight is measured (W1).
- Then the bottle is fully filled with water and weighed (W2).
- Then water is removed from the bottle and then cleaned.
- The sand is poured into the bottle with care.
- The bottle is filled up to the half and then weighed (W3).
- Then, water is filled in the bottle already half filled with sand and it is weighed (W4).

Water absorption and Specific gravity was determined using the formula

i.) Water Absorption = x 100%

ii.) Specific Gravity =

## 3.3 MIX PROPORTIONING

The concrete used is of grade M50 and was designed as per the guidelines of IS 10262:2009. The designed mix proportion by weight is 1:0.72:2.23 and the water/cement ratio is 0.33.

**Table 8 mix composition**

| Mix | Cement (%) | GGBFS (%) | SF (%) |
|---|---|---|---|
| M1 | 100 | 0 | 0 |
| M2 | 85 | 15 | 0 |
| M3 | 80 | 15 | 5 |
| M4 | 75 | 15 | 10 |
| M5 | 70 | 15 | 15 |
| M6 | 65 | 15 | 20 |

## 3.4 SPECIMEN CASTING AND CURING

To examine the consequence of replacement of NA with untreated, treated RCA and additional usage partial replacement of cement with GGBFS, 100x100x100mm cubes, (100φx200mm) cylinder and 1200x100x150mm beam were casted. Chemical admixture is added in all the mixes as it gives better results and good workability. Concrete were placed in the well lubricated mould and compacted and the specimens were left at room temperature for 24hrs and after that specimens were placed in curing tank till their testing ages.

### 3.5 TESTING OF SPECIMENS

### 3.5.1 COMPRESSIVE STRENGTH TEST

The compressive strength test is the most common test conducted because most of the desirable characteristic properties of concrete and the structural design purpose are qualitatively related to compressive strength. The test setup is shown below in Figure 3. The test was conducted in compression testing machine of 3000kN capacity for different ages of concrete viz.7, 28 and 56 days as per the specifications given in IS 516: 1959 under normal room temperature.

**Figure 3 Test setup for compressive strength**

### 3.5.2 SPLIT TENSILE STRENGTH TEST

This is an indirect test to determine the tensile strength of cylindrical specimens. Splitting tensile strength tests were carried out at the age of 7 and 28 days for the concrete cylinder specimens of size 100 mm diameter and 200 mm length, using compression testing machine of 3000 kN capacity as per IS:516-1959. The test setup is shown in Figure 4. The load was applied gradually till the specimen splits and readings were noted. The splitting tensile strength was estimated using the relationship

$ft = 2P/\pi DL$

Where

ft = splitting tensile strength of concrete in MPa

P = load at failure in Newton

D = diameter of cylinder

L = length of cylinder

**Figure 4 Test setup for split tensile strength**

### 3.5.3 Flexural behavior test

For finding flexural behavior, tests were carried on 100 mm x 150 mm x 1200 mm beam prototypes at the age of 28 days using 1000kN capacity flexural strength testing machine. The test setup includes two point loading using a single point loading system by which the loads are transferred equally to the two points using a spreader beam and two rollers. Dial gauges are placed in the bottom of the beam at the mid-point to find the deflection. Demacs are placed on the surface of the beam to find the surface strain which are placed at a distance of 100mm from one another. The strains at these points are found using a mechanical strain gauge. The crack patterns are noted on both sides of the beams at particular intervals. The gauge length between the loading points are 333.33 mm and 100 mm are left on both sides of the beam at the supports. All the specimens were capped for uniform loading prior testing. The control of load over the test was 10 KN/min. Automatic data acquisition system was used to record the load, strain and axial displacement which in turn connected to the computer. Test setup is shown in Figure 3.4

**CONCRETE MIX DESIGN**

**4.1 GENERAL**

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative quantities with the object of producing as economically as possible concrete minimum properties notable consistent strength and durability. Mix design is done based on the guidelines of IS: 10262-2009.

**4.2 DESIGN STIPULATIONS OF M50 GRADE**

| | |
|---|---|
| Grade designation : | M50 |
| Type of cement : | OPC 43 grade conforming to IS 8112 |
| Maximum nominal size of aggregate : | 20mm |
| Minimum cement content : | 400 kg/m3 |
| Maximum water-cement ratio : | 0.45 |
| Exposure condition : | Severe |
| Maximum cement content : | 450/rn |

□□□

TARGET STRENGTH FOR MIX PROPORTIONING

f′ck = fck + 1.65(s)

Where

f′ck = target average compressive strength at 28 days,

fck = characteristic compressive strength at 28 days, and

s = standard deviation

For grade of concrete M50 assumed standard deviation (s) was 6.4N/mm2.

Therefore, target strength= 50+1.65 x 6.4= 60.56 N/mm2

SELECTION OF WATER-CEMENT RATIO

Maximum water-cement ratio = 0.35. As per IS 456

Based on experience, adopt water-cement ratio as 0.32. 0.32 < 0.35, hence O.K.

**BEAM DESIGN**

**5.1 DESIGN DETAILS**

Ast provided = 157 mm2

fck = 50 MPa

fy = 415 MPa

Ultimate moment = 6.34 kN-m

Calculated load carrying capacity = 38.kN

Reinforcement details:

Beam type: Doubly reinforced beam

- Longitudinal reinforcement (tension zone) = 2 nos. of 10mm dia.
- Longitudinal reinforcement (compression zone) = 2nos. of 8mm dia.
- Transverse reinforcement = 8mm dia. @ 100mm spacing at supports and increasing towards centre.

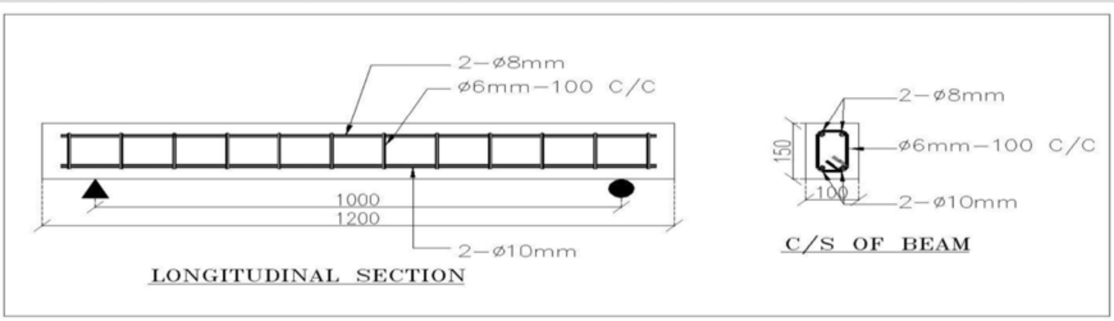


**Figure 6 reinforcement detailing**

## RESULTS AND DISCUSSION

### 6.1 COMPRESSION STRENGTH TEST RESULTS

The compressive strength value of the concrete was found at the age of 7, 28 and 56 days of curing. The mean value of three specimens were taken. The compressive strength value for six concrete mixes were represented in table 9

| Mix | 7days (MPa) | 28days (MPa) | 56days (MPa) |
|---|---|---|---|
| M1 | 31.5 | 48.4 | 49.8 |
| M2 | 30.9 | 46.3 | 48.2 |
| M3 | 32.2 | 43.7 | 45.6 |
| M4 | 33.1 | 44.6 | 46.4 |
| M5 | 32.9 | 49.9 | 51.3 |
| M6 | 28.4 | 39.4 | 41.9 |

**Table 9 compression strength test results**

The M5 mix shows higher strength than the control concrete at the age of 28 days curing. The optimum mix increased 3-4% more than the control mix at the age of 28 and 56 days curing. The increment in the strength is due to the pore filling property of the mineral admixtures.

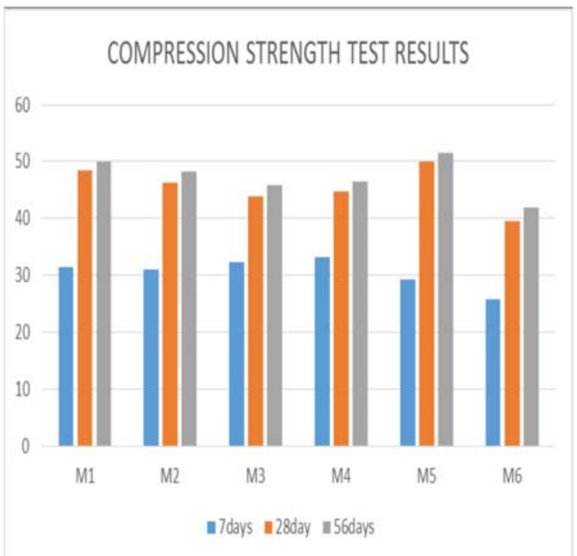


**Figure 7 compression strength test results**

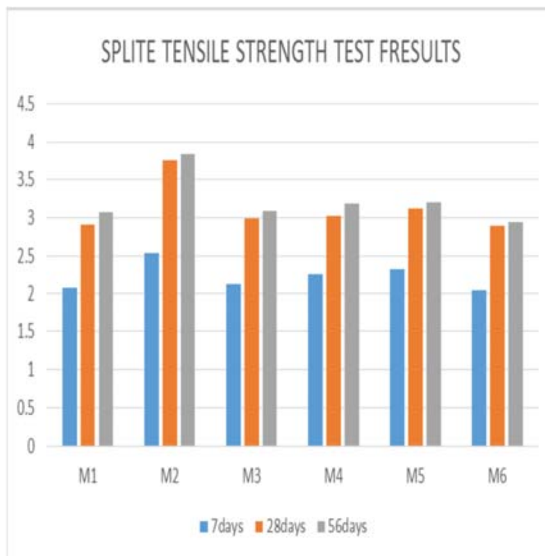


**Figure 8 split tensile strength test results**

### 6.2 SPLIT-TENSILE STRENGTH RESULTS

The split tensile strength test performed for six concrete mixes at the age of 7, 28 and 56 days of curing. The mean value of the three specimens were taken. The split tensile strength values are shown in table 10

| Mix | 7days (MPa) | 28days (MPa) | 56days (MPa) |
|---|---|---|---|
| M1 | 2.07 | 2.91 | 3.07 |
| M2 | 2.53 | 3.75 | 3.84 |
| M3 | 2.11 | 2.99 | 3.09 |
| M4 | 2.24 | 3.03 | 3.18 |
| M5 | 2.33 | 3.12 | 3.20 |
| M6 | 2.04 | 2.90 | 2.95 |

**Table 10 split tensile strength test results**

The M5 mix shows the highest strength value than the control specimen. After 56 days of curing the M4 and M5 mixes show the same strength. The M5 mix increased 7% and 4% than the control specimen at the age of 28 and 56 days of curing.

## 6.4 FLEXURAL BEHAVIOR

### 6.4.1 First crack load

The control and optimum concrete mix beams were tested to determine the flexural behavior. The first crack load for beams of control mix and optimum mix are given in Table 11. It can be seen that optimum mix i.e. M5 (C70+GGBFS15+SF15) exhibits higher first crack load than the Control mix of concrete. From this, it is evident that the inclusion of GGBFS and SF in concrete improved the flexural strength of the beams as it delays the first crack. There is an increase in first crack load by 25% than M50 control beam respectively.

### 6.4.2 Ultimate load:

The ultimate load for beams of control mix and optimum mix are given in Table 11. It can be seen that ultimate load of 50.2kN has been achieved for mix M5 which is 14% higher than M50 control beams respectively. It was observed that the beams cast with GGBFS and SF showed higher load carrying capacities coMPared to control beam.

**Table 11 Flexural behavior Results**

| Mix | Ultimate load (kN) | First crack load (kN) | Max Deflection (mm) |
|---|---|---|---|
| Control mix | 44 | 13.5 | 10.3 |
| Optimum mix | 50.2 | 16.4 | 11.93 |

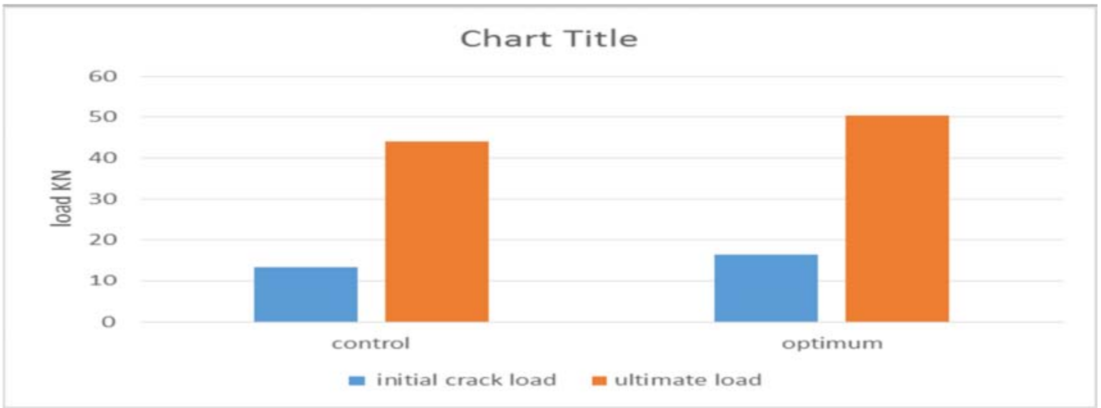


**Figure 9 load carrying capacity of beams**

### 6.4.3 Load –deflection behavior:

At every load increment, it was noted that the beam with optimum mix has higher deflection values in comparison to that of control beam. This shows that the replacement of cement by GGBFS and SF leads to ductile behavior. Greater deflection was observed under loads in beams cast with admixtures than the control specimen. There is an increase in deflection for mix M5 by 7.5% than M50 control beam respectively. Figure 9 gives the load deflection curve for control and optimum mix beams for M50 grade.

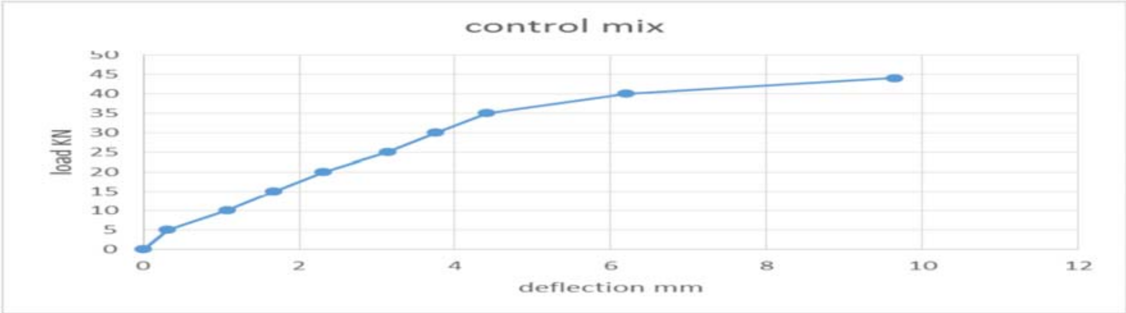


**Figure 10 load deflection curve for control beam**

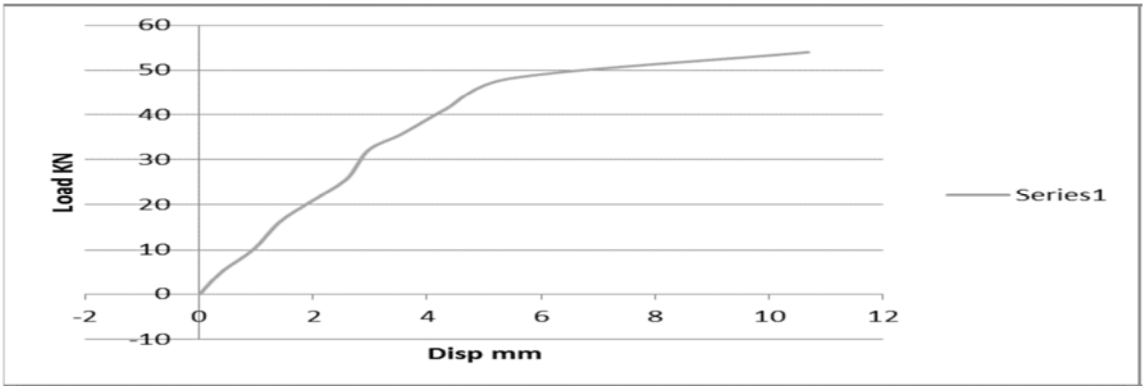


**Figure 11 Load deflection curve for optimum mix**

## CONCLUSION

From the experimental results present in the study, the following conclusion can be drawn

1) From the above results, the optimum replacement of ternary combination is arrived (cement70%+GGBFS15%+SF15%)

2) The compressive strength of the M5 mix shows higher strength than the control concrete. The strength increases 3 – 4% more than the control mix at the age of 28 and 56 days of curing.

3) The split tensile strength also increase than the control specimen at 28 and 56 days of curing. The compression and split tensile strength increases due to the pore filling effect of the mineral admixtures.

4) The load carrying capacity of the optimum beam increased 13% more than the control beam.

5) From the above results it is clear that GGBFS and silica fume are suitable materials to replace in cement.

6) By replacing the industrial byproducts in the cement it leads to environmental friendly and reduction in the cost of construction

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