Study on flexural behaviour of reinforce concrete beam with GGBS and steel fibre

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Abstract

The present day research is focussed on development of alternative materials are incorporated with raw materials of Cement, Fine aggregate and Coarse aggregate due to scarcity of materials and enhancing the strength property with the production of concrete. This thesis is proposed a method for experimental investigation of concrete structural elements. A trial mix has been tried for CC, Trial mix1, Trial mix2, Trial mix3 and we selected trial mix3 replacement materials of GGBS 40% by replacement of cement and Steel Fibre 1% by replacement of cement, high range water reducing admixture Conplast SP-430 is used for casting the specimens and research it with 7 and 28 curing days. Experimental results are planned to report including compression and flexural properties of concrete specimens. The sizes of the cube specimen are 150mmX150mmX150mm, cylinder specimen of size 150mmX300mm and Beam specimen of size 3200mmX125mmX250mm. The specimens are planned to test including the cubes, cylinders and beams under static incremental loading in flexural behaviour and compressive behaviour of respective specimens. The result obtained by the replacement materials for mechanical properties are compared with conventional concrete. The result will be computed experimentally and analyzed using Artificial Neural Network (ANN).

Keywords: ANN, flexural properties, GGBS, mechanical properties, Steel fibre.

I. INTRODUCTION

A concrete is a mix of coarse aggregate, fine aggregate, cement and water. In this project to reduce cement consumption by replacing it with Ground Granulated Blast Furnace Slag. In addition to that, steel fiber is added to increase tensile property .To make the concrete to reduce the problem of disposal of waste, by effectively utilizing the material GGBS. The widespread use of concrete in many roman structured has ensured that many survive to the present day. The development of eco friendly and sustainable construction materials has gained major attention by the construction field. Use of chemical admixtures reduces the water content, thereby reducing the porosity within the hydrated cement paste. Mineral admixtures, also called as cement replacement materials, act as pozzolanic materials as well as fine fillers, thereby the microstructure of hardened cement matrix becomes denser and stronger. Silica fume improves the properties by pozzolanic reaction and by reactive filler effect. In concrete, it is necessary to reduce the w/c ratio and which in general increases the cement content. To overcome these low workability problem, different kinds of mineral admixtures of industrial by-products like ground granulated blast furnace slag and steel fibre can be used. Also at the same time, chemical admixtures such as high range water reducers are needed to achieve the required workability, to ensure that the concrete is easy to transport, place and finish and to ensure that the concrete meets the specified performance. GGBS is used as a direct replacement for Portland cement, on a one-to-one basis by weight. Replacement levels for GGBS vary from 30% to up to 85%. Typically 40 to 50% is used in most instances. Blast furnace slag is a non-metallic by-product produced in the process of iron making (pig iron) in a blast furnace and 300kg of Blast furnace slag is generated when 1 ton of pig iron produced. In India, annual productions of pig iron is 70-80 million tons and corresponding blast furnace slag are about 21-24 million tons. Blast furnace slag is mildly alkaline and exhibits a pH in solution in the range of 8 to 10 and does not present a corrosion risk to steel in pilings or to steel embedded in concrete made with blast furnace slag cement or aggregates. The blast furnace slag could be used for the cement raw material, the roadbed material, the mineral admixture for concrete and aggregate for concrete, etc.

II. LITERATURE COLLECTION

Sagar Patel & Balakrishna (2014) reported that the replacement of GGBS upto 40% and found workability and mechanical properties and flexural characteristics of concrete. Also, the slump is improved as the GGBS content is increased with shear type of failure compared to the control mix. The results of the hardened concrete properties such as Compressive strength, split tensile strength and the flexural tensile strength of all the concrete mixes concluded that the mix having 40% GGBS (i.e. MIX- 2) was optimum and equal to the control mix for 28 days of curing period. The MIX- 2 was incorporated in beams to study the flexural behavior of singly reinforced RC beams. The flexural crack propagated from the tension fiber to the compression fiber with crushing of concrete at the top surface with no horizontal cracks at the level of the reinforcement, indicating no bonding failure. **Martin Blazejowski et al., (2012)** investigated that the flexural characteristics of concrete with steel fibre 2 % and found the mean value of the first crack load and peak load was 103.5 kN and 124.3 kN respectively, with standard deviations of 10.9 kN and 12.4 kN. The mean value of displacement at first crack load and displacement at peak load was 4.23 mm and 8.58 mm respectively, with standard deviations of 0.83 mm and 1.66 mm. Computed tomography scanning verified that the variation of fibre distribution in the SFRC segments ranged from 0% to 1.86 %, with the majority of fibres being located at the intrados of the segments. **Spadea et al (1998)** studied that the use of carbon fibre reinforced polymer (CFRP) Sheets, as externally bonded reinforcement, is a practically efficient and technically sound method of strengthening and upgrading structurally inadequate or otherwise damaged or deteriorating load bearing members. They tested four beams out of which there are treated as control and the remaining beam are strengthened with CFRP plates. One beam is externally bonded with CFRP plate. **Rakesh diggikar . et al (2013)** studied that they concluded that the strengthening of the beam opening by using CFRP and GFRP sheets both around and inside the opening increases the load carrying capacity in 50.50% where as in GFRP sheets percentage of increase in land carrying capacity in 37.41%.The overall study, it can be founded that the strengthening with CFRP around and inside the opening is more efficient and in considered as best strengthening scheme. **Toutanji, et al (2006)** concluded the externally bonding fibre reinforced polymer (FRP) sheets with an epoxy resin in an effective technique for strengthening and repairing reinforced concrete (RC) beams under the flexural loads. They tested eight RC beams was tested and analysed, one control beam and seven beams reinforced with three to six layers of CFRP laminates and found ductility of the FRP strengthened beam greatly reduced compared to the control to the control beam. **Habibur Rahmansobuz et al (2011)** studied that the flexural behaviour of reinforced concrete beams strengthened with CFRP laminates attached to the bottom of the beams by epoxy adhesive subjected to traverse loading. A total five beams having different CFRP laminates configurations were tested to failure in four point bending and the results had shown that the addition of CFRP sheets to the tension surface of the beams demonstrated significantly improvement in stiffness and ultimate capacity of beams. **Esfahari, et al (2007)** studied that the effect of reinforcing has ratio on the flexural strength of the strengthened beams is examined. Twelve concrete beams specimen with dimensions of 150mm width 200mm and 2000mm length were manufactured and tested. CFRP sheets in increasing the flexural strength of beams with small value (p max). **Adams Joe & Maria Rajesh (2014)** observed that the Optimum Compressive Strength of High Performance Concrete is obtained replacement of 40 % Cement by GGBS and the experimental results it is proved that, GGBS can be used as alternative material for the cement. Based on the results the compressive, split tensile, flexural and Pull out strengths are increased as the percentage of GGBS increased upto 40 % and above decrease. **Siddharth, et al., (2015)** used GGBS 40% and 1% SF with respect to conventional concrete. Compressive strength and Split tensile strength of concrete increased about 13% and 18.20% respectively. Flexure strength of prisms and beams increased about 15.16% and 15.32% respectively. The partial replacement of cement by GGBS, not only provides the economy in the construction but it also facilitates successful utilization of the GGBS which is generated in huge quantities from the steel industries.

III. EXPERIMENTAL INVESTIGATION

MATERIAL PROPERTIES

In the experimental study, generally a good quality of cement like 53 grade cement is preferred but it may vary according to the grade of concrete needed. Natural sands crushed and rounded sands and manufactured sands are suitable for concrete. River sand of specific gravity 2.657 and conforming to zone III of IS 383 was used for the present study. The shape and particle size distribution of the aggregate is very important as it affects the packing and voids content. The moisture content, water absorption, grading and variations in fines content of all aggregate should be closely and continuously monitored and must be taken into account in order to produce concrete of constant quality. Coarse aggregate used in this study had a maximum size of 10mm. Specific gravity of coarse aggregate used was 2.739 as per IS 383. Ordinary potable water was used. GGBS is a pozzolanic material used as a cementitious ingredient in both cement and concrete composites and it is governed by IS: 10289-1987 Table-2 shows the properties of GGBS. Hooked end type of steel fibre is used for this present study. Because this type of steel fibre are act as a low carbon steel bar. Its aspect ratio (l/d) is 50, Diameter = 0.5 And Length = 25. It was able to provide tensile strength up to 1000mpa. Hook ended steel fibre conforming to ASTM A820.

Mix Design & Mix proportion

As per the recommended procedure of Bureau of Indian Standards IS 10262–1982, mix ratio is designed with the test results of workability, specific gravity, water absorption for the materials. Design is stipulated for good degree of quality control and mild exposure. The mix proportions (Cement: fine aggregate: coarse aggregate) with a water cement ratio of 0.45. Using the designed mix, specimens are casted.

Table 1: Physical properties of materials

Sl.No.	Material	Specific Gravity	Fineness Modulus
1	Cement	3.080	–
2	Fine Aggregate	2.650	2.432 (III)
3	Coarse Aggregate	2.739	3.435
4	SP`	1.2	-

Test Details

In order to consider the effect of partial replacement of GGBS, the proportion of water cement content, method of curing are kept constant. The water cement ratio is kept constant at 0.45 throughout the investigation. 24 numbers of cubes 150mmx150mmx150mm cubes are cast for each mix, 12 cylinder dia 150mmx300mm height, 9 prisms of 100mmx100mmx500mm size are casted and cured in water at 28 days. The optimum percentage of replacement is found for every mix replacement. Further test procedure is carried out to determine the mechanical properties such as compression, tension, flexure test.

Mechanical Properties of concrete

a) Compression Test

Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristics properties of concrete are qualitatively related to its compressive strength. Compressive strengths were attained as a result of the compressive tests conducted on the cube specimens of size 150mm x 150mm x 150mm and cylinders of size 150mm in diameter and 300mm height. The specimens are subjected to compressive loads in compression testing machine as per IS: 516-1969 and the crushing load is noted. The compressive strength is the ratio of crushing load to the surface area of the specimens expressed in N/mm^2.

Figure 1 Test Setup for Cube Testing

b) Elastic Modulus for Concrete

The Elastic Modulus for Concrete test is the most common test conducted on hardened concrete, partly because it is an easy test to perform. Concrete is not really an elastic material, i.e., it does not fully recover its original dimensions upon unloading. Hence, the elastic constants are necessarily considered for conventional design of reinforced concrete structures. The young's modulus of elasticity is a constant defined as the ratio, within the linear elastic range, of axial stress to axial strain under uniaxial loading. In the case of concrete under uniaxial compression, it has some validity in the very initial; portion of stress- strain curve, which is particularly linear, i.e., when the loading is of low intensity and of very short duration. If the loading is sustained for very long

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duration, inelastic creep effects come into play, even at relatively low stress levels. This test is normally conducted by using the cylinder specimens of size 150mm x 300mm.

Figure 2 Test Setup for Cylinder Testing

FLEXURAL BEHAVIOUR OF RC BEAMS CASTING AND CURING

The test program consists of casting and testing four beams of size 125 mm wide, 250 mm deep and 3200 mm long. Two beams is for control beam and the remaining two beams Bagasse Ash replaced beams The grade of concrete used in this work is M30. The beams are designed as under reinforced section. The beam reinforcement grill is shown in Figure 3.3. High yield strength deformed (HYSD) bars of, two numbers of 12mm diameter are used as bottom longitudinal reinforcement two numbers of 10mm dia bar at top used as a hanger bar and 8 mm diameter mild steel two legged vertical stirrups are provided at 140 mm spacing as shear reinforcement in all the beams as shown in Figure 3.4 the casting of specimens and curing of specimen are shown in Figure. The reinforcement bars is properly kept in mold. The fresh concrete is placed in the twin mould and compacted using needle vibrator. After casting the specimens, they are kept in mould for one day. Then specimens are removed and kept in water for 28 days.

TEST SETUP

The test setup for flexural test is shown in Figure 3.9. The test specimen is mounted in a beam testing frame of 300 kN capacity. The beams are simply supported over a span of 3000 mm, and subjected to two concentrated loads placed symmetrically on the span. The distance between the load points is 1000 mm. The load is applied on two points each 500 mm away from the centre of the beam towards the support. Dial gauges of 0.001 mm least count is used for measuring the deflections under the load points and at mid span for measuring the deflection. The dial gauge readings are recorded at different loads. The strain in concrete is measured using a demec gauge. An automatic data acquisition unit is used to collect the data during test. The load is applied at intervals of 25 kN. The first crack loads are obtained by visual examination.

Figure 3 Testing of Beam under Two Point loading

IV. RESULTS AND DISCUSSION

Compressive Test Results

The results of compressive strength for M30 grade on concrete by the average of three cubes. The specimens are separated by three trial mixes with GGBS and steel fibre. The table 4.1 gives the variation of compressive strength at 7 and 28 days curing. Compressive strength

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test had been conducted for 28 days strength three cubes were cast for each one and the average was calculated. It shows the relative effect of GGBS on the compressive strength of the concrete mixes. The results were compared with the results of conventional concrete specimens. Concrete has higher compressive strength than the conventional concrete with increasing percentage varies from 5% to 10% for 0.42 water-cement ratios. When GGBS are added as additional admixtures there is a significant improvement in the strength of concrete.

Table 2 Comparison of Compression Results

Mix	**Average Compressive strength (Mpa)**	
	7 days	**28 days**
CC	22.08	40.88
TM1	22.81	40.48

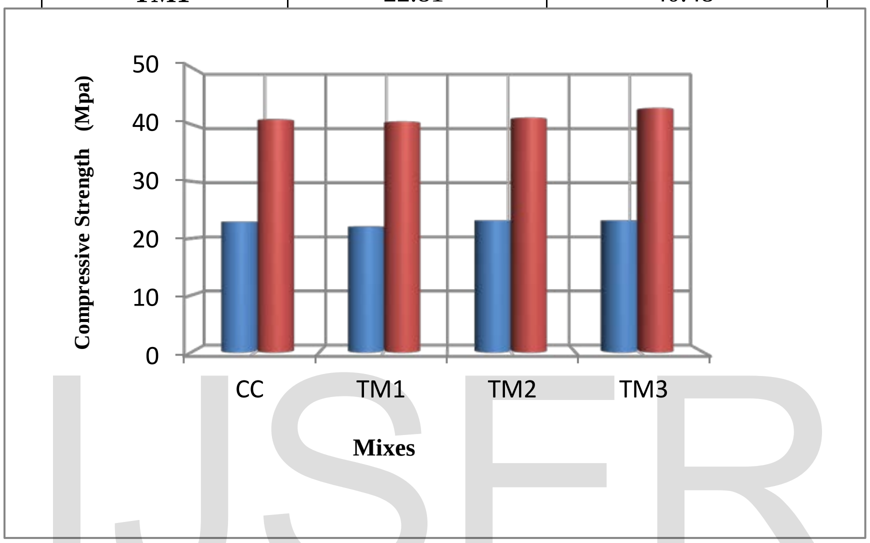


Figure 4 Comparison of compression test at 7 and 28 days

Elastic Modulus of Concrete Results:

The results of Elastic Modulus of Concrete for M30 grade on concrete on cylinder. The specimens are separated by three trial mixes with GGBS and Steel fibre. The table 4.2 gives the variation of flexure strength at 28 days curing.

E_c = 5000 $\sqrt{fck}$

E_c = Modulus of Elasticity of Concrete

fck = Characteristic Compressive Strength of Concrete

Table 3 Variation of at Elastic Modulus of Concrete results

Mix	**Elastic Modulus of Concrete (Gpa) = 5000 $\sqrt{f_{ck}}$**	
	Experimental Value	**Theoretical Value**
CC	33.87	31.96
TM1	34.96	31.81
TM2	35.64	32.07

TM3	38.72	32.72

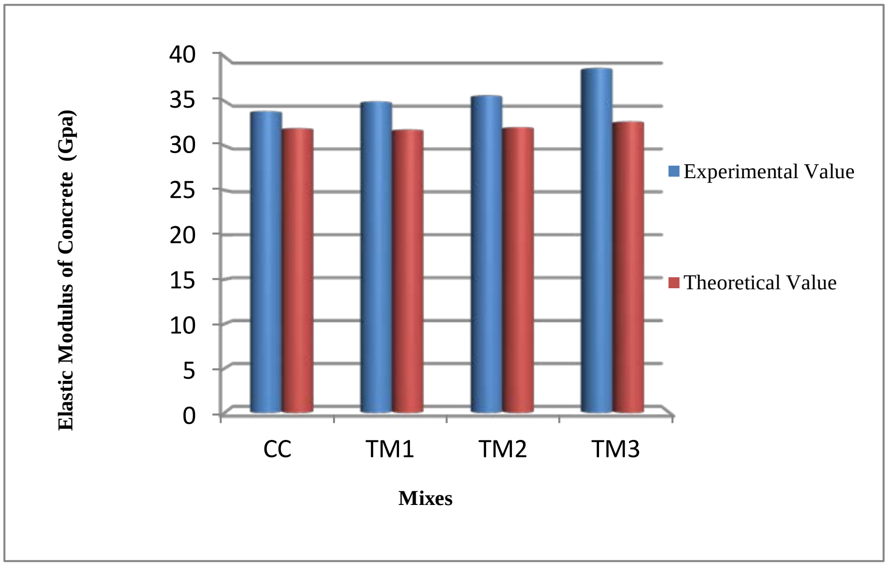


Figure 5 Comparison of Elastic Modulus of Concrete at 28 days

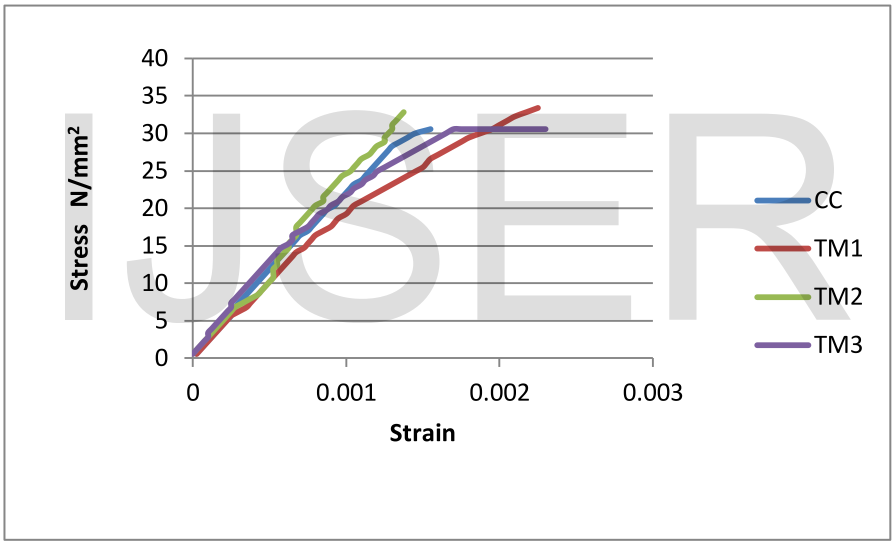


Figure 6 Stress- Strain Curve for Various Mixes

The test results are presented and discussed categorically with reference to variation of HPC beams with different combination of industrial by-products. The deflection at the centre of mid-span and loading points were recorded at every 5 Kn load increments and graphed. The load versus deflection diagrams indicated that, the HPC beams enhances not only the moment carrying capacity of beams but also controls the deflection. The beam's deflection until the initiation of cracks increased linearly and was proportional to load. After the initial cracking, deflection increased non-linearly until the maximum load was reached. The Details of Load Deflection Curve for Control Beam are shown in fig.

The results of beam tested for flexure two control beams and two control modified concrete beams. The first crack load observed in control beams are 15Kn and the same observed in Control Modified concrete beams are 25 Kn. The yield load of control beams is 30Kn and the beam in control modified concrete beams is 50 Kn control modified concrete beam shows 40% increase in yield load capacity. The ultimate load carrying capacity of control beam is 52.5Kn and the same in control modified concrete beam is 75 Kn the retrofitted beam shows40% increase in ultimate load carrying capacity when compared to control beams. The comparisons of control and control modified concrete beam at all stages shown in Figure 4.7.

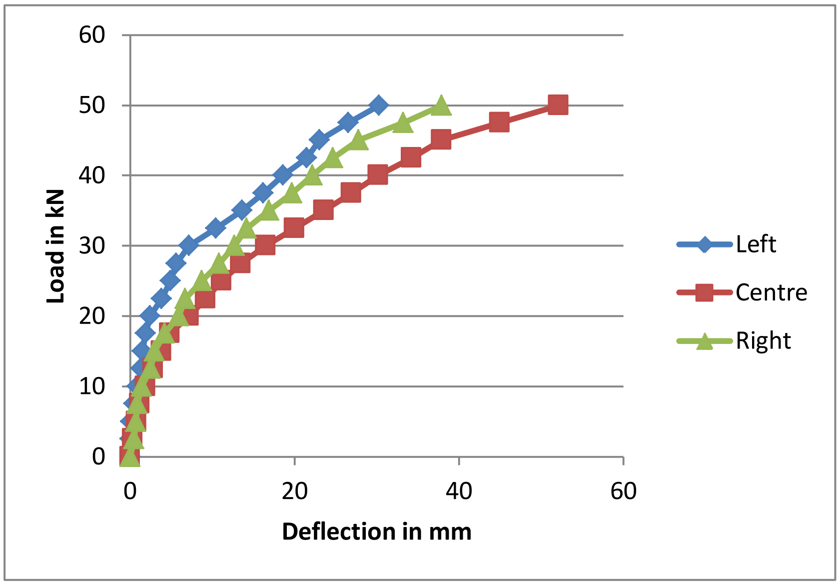


Figure 7 Load – Deflection curve for CB-1

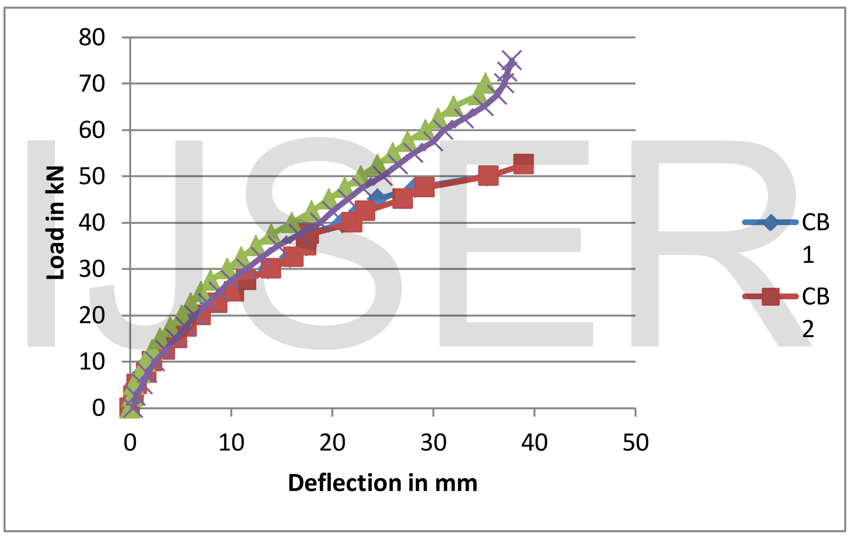


Figure 8 The load deflection curve for all Beams

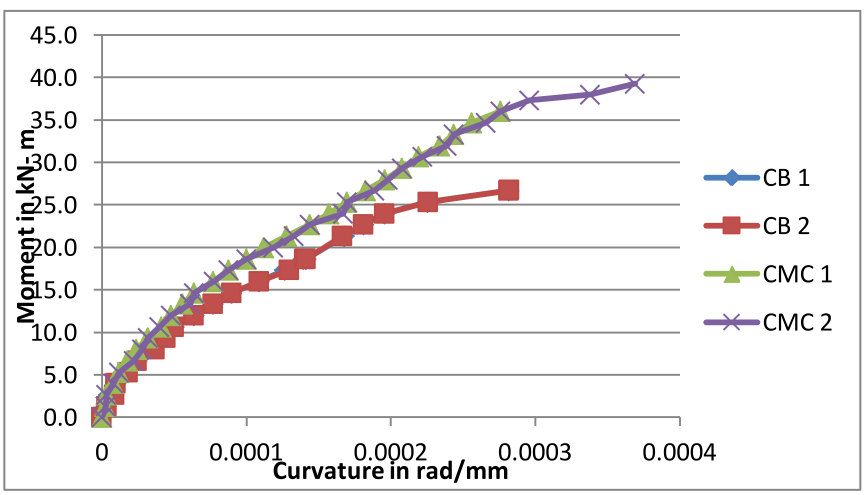
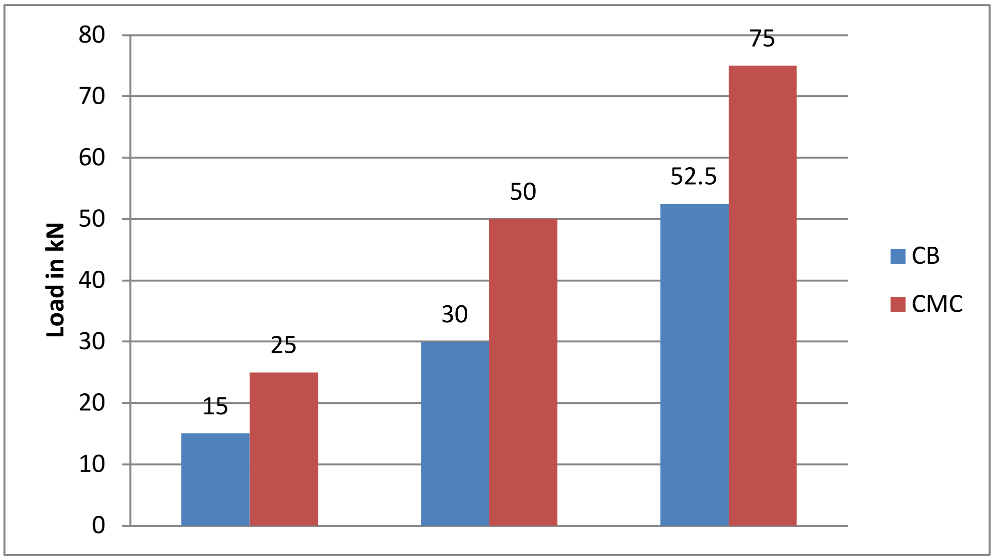


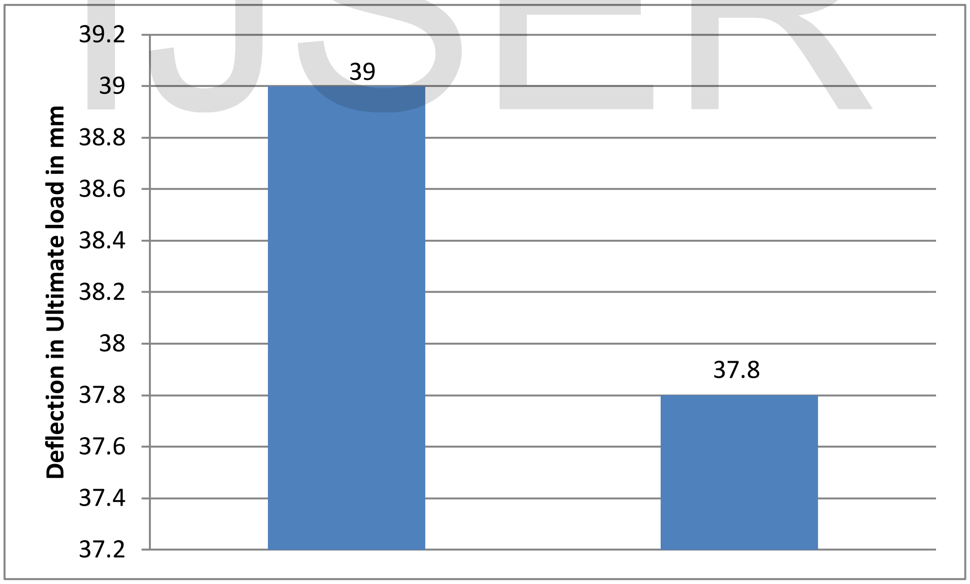
Figure 9 The Moment – Curvature curve for all Beams



First Crack **Yield** **Ultimate**

Figure 10 Comparisons of Beams at Different Stages of Loading

The Deflection of Control Modified Concrete is reduced when compared to Control Beams. The Maximum deflection observed in Control beam is 39 mm and the same is reduced to 37.8mm in and it is shown in fig 4.8



CB **CMC**

Figure 11 Comparison of Maximum Deflection of Beams

Bending moment-curvature relationship

Two approaches were used to calculate the curvature. In one approach, the strain gauges were used to create a strain profile for the height of the beam. The planer sections were assumed to remain planar. Therefore, the strain profile results could be used to determine the curvature. Individual gauges were used until their readings became unreliable due to cracking in the underlying concrete. The curvature of the cross section could be computed from these results. For the other approach, curvature was derived from deflection measurements by considering the geometry and static structural system. The moment-curvature curves are non-linear beyond this curvature. In the non-linear region, the curvature developed less rapidly for the beams with more rebar. This result may be attributed to the orientation of industrial by-products, which is also shown by load-deflection curves.

V. ANALYTICAL RESULT

An artificial neural network is an artificial intelligence technique. It is a simulation of human brain- like architecture. An artificial neural network is a massively distributed processor made up of interconnection of simple processing elements i.e. neurons outputs are connected, through weights, to all other neurons including themselves, It resembles brain in mainly in the aspects of. The factors that determine, the behaviour of a given neural network are weights of the connections. In a large network the contribution of a single weight is often slight; it is the effect of combination of connection weights that determines the output. The process of training a network is that of finding a set of values for the weights that make the network do what you want it to do. Mathematicians are still working on this, but is appears that given enough hidden units and connections there is little that a net is unable to do. Then the problem is in finding the right box to train generalized regression neural networks to solve specific problems. There is no way to determine a good network topology just from the number of inputs and outputs. It depends critically on the number of training examples and the complexity of the classification is trying to learn. There are problems with one input and one output that require only one hidden unit or none at all. In most situations, there is no way to determine the best number of hidden units without training several networks and estimating the generalization error of each if you have too few hidden units, you will get high training error and high statistical bias, if you have too many hidden units, you may get low training error but still have high generalization error due to over fitting and high variance.

Comparison of Results Using ANN

Table 4 Variation of compression test at 28 days

Description	Mix	Experimental Results	Predicted strength	Error
Compression Strength @ 28 days	CC	41.86	41.324	1.297
		39.91		-3.54
		40.88		-1.086
	TM1	41.60	40.234	3.39
		39.37		-2.19
		40.48		0.611
	TM2	42.80	41.543	3.02
		39.51		-5.145
		41.15		-0.955
	TM3	42.17	43.594	-3.376
		43.51		-0.193
		42.84		-1.76

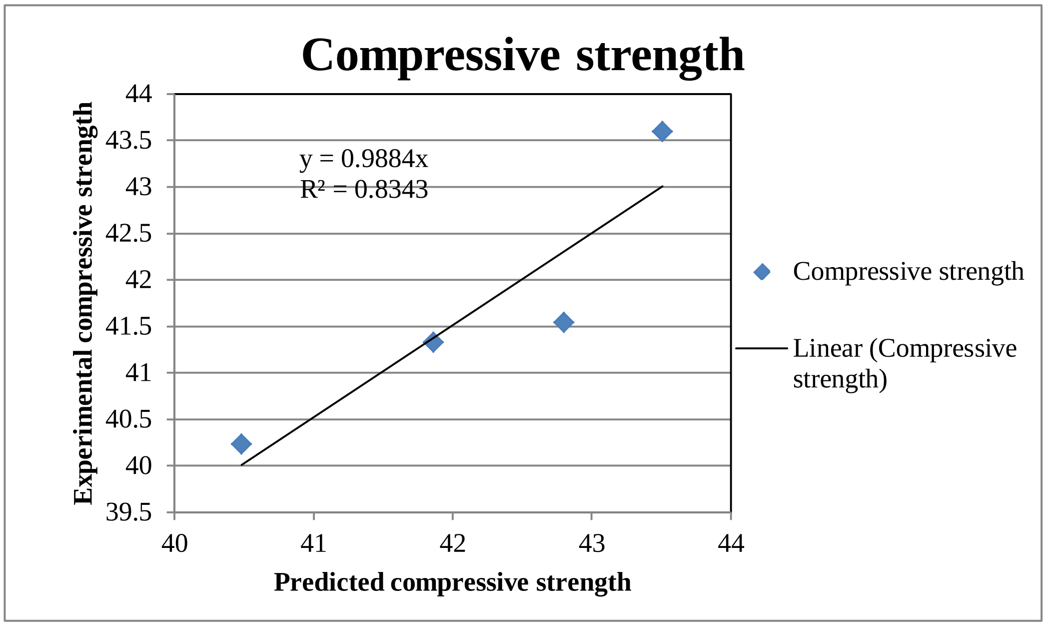


Figure 12 Comparison graph between experimental & predicted strength

Table 5 Variation of Elastic Modulus of Concrete

Description	Mix	Experimental Results	Predicted strength	Error
Elastic Modulus of Concrete Results	CC	33.87	32.789	3.29
		32.18		-1.892
		33.02		0.704
	TM1	33.19	33.958	-2.31
		34.96		0.005
		34.07		0.329
	TM2	34.95	35.236	-0.818
		35.29		0.153
		35.64		1.146
	TM3	37.62	37.135	1.306
		38.72		4.268
		38.17		2.787

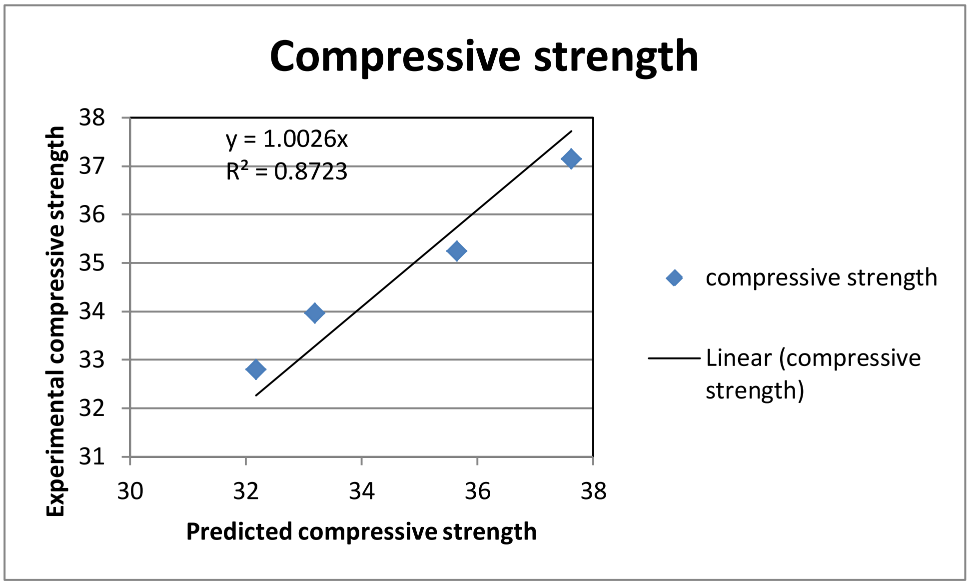


Figure 13 Comparison graph between experimental & predicted strength

VI. CONCLUSION

Concrete was designed with various replacements of constituent material of GGBS and addition of steel fibre and chemical admixture was casted. Concrete mixture were designed having a constant W/C ratio is 0.40. Based on the results of the experimental investigation of specimens, the following conclusions are arrived.

- ✓ With the addition of GGBS and steel fibre in concrete is optimized and pore size distribution is more reasonable, compressive strength of concrete increases gradually and mechanical aspects are enhanced.
- ✓ The improving effect is in the sequence compound of GGBS and steel fibre. In conventional Portland cement technology it is evident that the durability of concrete is strongly associated with the w/c ratio of the mix. Although this was found to be true in GGBS concrete, it has also been shown that the amount of calcium hydroxides present in the concrete needs to be considered.
- ✓ Under current design procedures, some potentially suitable applications for GGBS concrete include aggressive environments and unreinforced concrete applications.
- ✓ Marginal increase is observed in the workability, when adding GGBS and steel fibre in ordinary concrete. The results of fresh concrete revealed that average of workability and slump flow and percentage of segregation resistance reduced while increasing the replacement level of GGBS but the slump flow time increased because of GGBS has absorbed the mixture water contents.
- ✓ The mechanical properties result of conventional concrete is less than the other three mixes of TM1 to TM3 for both compressive strength and young's modulus while adding GGBS material.
- ✓ The Control modified concrete beams shows increase of 40% in ultimate load carrying capacity when compared to control beam. The Control modified concrete beams shows and decrease of 3% in deflection at ultimate level when compared to control beam. Both the beams were failed by yielding of steel followed by the crushing of concrete. It shows that, the beams were failed by flexure mode only.
- ✓ Partially replacing cement with GGBS, the consumption of cement from cement production reduces significantly. In addition to cement economizing, possibility of environmental pollution with GGBS is prevented and effective application for GGBS is found.
- ✓ The results obtained through Artificial Neural Network modelling shows good convergence with experimental results.

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