Experimental Investigation on Fibre Reinforced Beam Column Joint by Partial replacement of Cement with GGBS

S. V. D. Naveena, J. Durga Chaitanya Kumar

Abstract: The beam column joint is the Critical zone in a reinforced concrete moment resisting frame. Beam column joint is the media to transfer the forces to next floor. To resist the beam column joint from the huge loads in a structure, fibre reinforced concrete is used in this present study. To make more ductile at beam-column joint, 0.5 % of electrical/ chemical resistance (ECR) glass fibres are added to the volume of concrete and also, to reduce the greenhouse gases from the cement industry replacement of cement with Ground Granulated Blast Furnace Slag (GGBS) up to 40% (0, 30, & 40) are used. To know the optimum strength of concrete, the compressive strength of cubes, split tensile strength of cylinders, modulus of rupture of prisms and flexural behaviour of the beams with size of 750 x 150 x 150 mm have tested and assessed as pilot study. Further, the concrete durability (Chloride attack and Sulphite attacks) studies are also carried out. All the results are compared with normal concrete grade of M30.

Index Terms: : Beam Column Joint, Durability, ECR, Glass Fibre, GGBS,.

I. INTRODUCTION

Recent studies have stated that it is a challenging task to incorporate concrete in the joint sections of the framed structures. Shear failure in joints is considered as objectionable which results in the deterioration of strength and stiffness of the frame. Glass fiber reinforced concrete delineates the composition of cement; fine aggregate, coarse aggregate, ECR glass fibers. Generally, fibers having modulus of elasticity which is greater than the concrete tends to carry loads by developing the tensile strength in the concrete. These ECR glass fibers have high acid resistance to corrosion and do not allow water to pass through it. furthermore, ground granulated blast furnace slag (GGBS) cement is replaced to the concrete mortar which accomplishes inferior heat of hydration than Portland cement and increases the structures senility. The efficiency of these fiber reinforced concrete which is incorporated by GGBS is scrutinized experimentally by 3 specimens under cyclic loading. The test results of all joint specimens show that it is proficient to withstand the design criteria which satisfies the performance of the code requirements.

Studies stated that shear strength equation contributes to only few governing parameters which are simple in application. The evaluations of regulating the parameter on the joints are done which composes 492 experimental data of beam column joints. Different types of failure patterns were analyzed to define the irregularities between lab code provisions and lab observations [1].An experimental campaign on the shear failure of joints having different structural sizes is conducted to access the size effect on the joints with respect to nominal shear strength and concluded that joints having higher structural size are prone to have less nominal shear strength [2]. A model was stimulated which can prophery the shear response of beam column joints under seismic action by assuming the principal shear stress and strain directions coexist[3].Experiments carried out on both interior and exterior beam column joints which are subjected to seismic loads and are validated with FE analysis results stated that joints deteriorates when corrosion increases [4]. Experiments were also conducted by replacing 50% of cement with fly ash and are subjected to reverse lateral loading which exhibits high load carrying capacity than the conventional specimens [5]. A novel proficiency of strengthening beam column joints which are shear deficient and incorporates the joints which are embedded by carbon-fiber reinforced polymer with the help of epoxy where CFRP's exhibits more ductility, joint shear strength and stiffness when compared with conventional specimens[6].

II. RESEARCH SIGNIFICANCE

Research studies have been carrying out on the behavior of beam column joints. The objective of this study is to visualize the damage of glass fiber reinforced beam column joints and to identify the beam displacement, maximum load and strain under cyclic loading.

III. MATERIALS

Cement

Ordinary Portland cement of 53 Grade which is confined to Indian standard specifications of IS: 12269 -2013 was adopted in preparation of the concrete.

Fine Aggregate

Nominal size of 4.75mm natural sand was used as fine aggregate in concrete.

Coarse aggregate

The nominal size of aggregate is maintained as 20mm which is obtained by the Indian standard specifications of IS:383-2016.Table- 1 shows the properties of aggregates

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Table -1: Properties of Aggregates

S.No	Properties	Fine aggregate	Coarse aggregate
1	Specific gravity	2.68	2. 7
2	Density(kg/m³)	1500	1600
3	Fineness modulus	2.4	6.7

Water

Potable drinking water was used for casting and curing of concrete specimens.

GGBS

Ground granulated blast furnace slag (GGBS) which is confined to Indian standard specifications of IS: 12089 - 1987 was used by replacing cement in different proportions.

Glass fibre

An electro chemical resistant glass fiber of constant % is used to improve the corrosion resistance, serviceability durability characteristics and tensile strength of the concrete by varying with different GGBS percentages.

Fig.1: Glass fibre

Super plasticizer

MYK remicrete, a carboxylic ether polymer is used to improve the durability and tensile characteristics of the concrete. Properties of super plasticizer show in table-II

Table-II: Properties of Super Plasticizer

Properties	values
Appearance	brown
Specific gravity	1.1
pH	6

IV. EXPERIMENTAL PROGRAM

Primarily, a conventional concrete mix of 0.45 w/c whose fluid consistency is about 100-150mm is casted and later fiber reinforced concrete with the same w/c and fluid consistency were casted by replacing the cement with 0-40% of GGBS to the concrete. A carboxylic either polymer based super plasticizer is added at a dosage of 0.6% to the weight of the concrete to attain their desired workability. Table-III represents the mix design of all proportions. The curing of these specimens was carried at an open-air temperature of 28degrees to attain a field conditions.

Table-III: Mix Proportions of Concrete

Mix Proportions	M0	M1-0%	M230%-	M3-40%
Water	177.4	177.44	177.44	177.44
Cement	348.7	348.75	266.166	310.527
GGBS	-------	-------	177.44	133.083
Fine Aggregate	655.39	655.39	650.71	651.8822
Coarse aggregate	1191.2	1191.234	1182.71	1184.847
Super plasticizer	2.66	2.66	2.66	2.66
Glass fibre	-------	5.44	5.44	5.44

A. Flexural behavior of beams

Rectangular cross section beams of size 150 mm width and 150 mm depth having a nominal length of 750mm whose effective span is 700mm is designed according to IS 456-2000. The longitudinal reinforcement is provided with 8mm diameter steel bars having yield stress of 550N/mm² and lateral reinforcement is provided with 6mm diameter bars at c/c spacing of 85mm with a nominal clear cover of 25mm on all sides of the beam. These beams were tested under two-point loading with a 25 tones capacity compression testing machine. Fig.2 shows the reinforcement details of beam.

Table-IV: Dimensions of beam

Length	Width	Depth
750	150	150

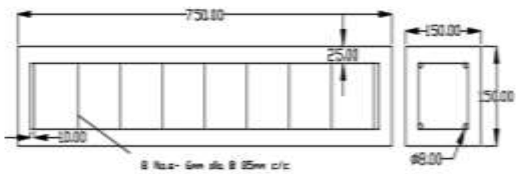

Fig. 2: Reinforcement details of beam

B. Beam column joint

Experimental program was carried out by preparing three exterior beam column joints whose dimensions are shown in table-V by maintaining % of glass fibre & longitudinal and transverse reinforcement monotonously by varying % of GGBS to 40%. Mix design calculations of M30 grade concrete was made as per IS 10262-2009. Under cyclic loading, the main factors that are influence the beam column joints which maintained consistent are a} spacing and size of bar, b) anchorage length. Reinforcement details of joints are shown in fig.3

Table-V: Dimensions of beam column joints

Beam dimensions			Column dimensions		
length	**width**	**depth**	**length**	**width**	**depth**
850	170	210	1000	170	210

Reinforcement details:

The specifications of reinforcement for all specimens was done according to IS 456-2000 and Transverse and longitudinal reinforcement details are shown in table –VI and table-VII.

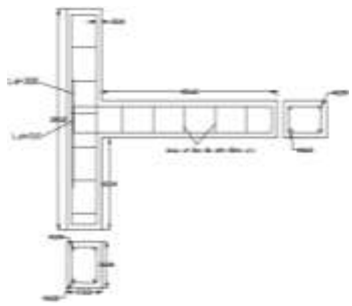

Fig.3: Reinforcement details of beam column joint

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Table-VI: Reinforcement details of Beam

beam	Longitudinal reinforcement			Transverse reinforcement		
S. No	No. of bars	A_{st}	ρ_t (%)	No. of bars	A_{st}	ρ_t (%)
A	Top r /f 2-12mm	226.08	0.006	6-8mm	301.44	0.0084
B						
C	Bottom r/f 2-16	401.92	0.0011			

Table-VII: Reinforcement details of Column

column	Longitudinal reinforcement			Transverse reinforcement		
S. No	No. of bars	A_{st}	ρ_t (%)	No. of bars	A_{st}	ρ_t (%)
A	Top r /f 2-12mm	226.08	0.006	7-8mm	351.68	0.0084
B						
C	Bottom r/f 2-16	401.92	0.0011			

Test setup:

The schematic view of the loading frame with external beam column joint is shown in fig-4. The specimens are white washed to facilitate the perceptibility of the crack formation clearly. These are subjected to axial load and cyclic loading with a capacity of 200 tones hydraulic jack. The boundary conditions of the column are maintained as fixed on top and bottom interface where an adjustable fin plates are assembled depending upon the depth of column. The girder is anchored with a plate where hydraulic jack is to be placed for applying axial load on column. The application of the cyclic load was at 150mm from the free end of the beam, a constant axial load on the column is applied with the help of a hydraulic jack which is fixed vertically to the loading frame for simulating the gravity load on the column. Failure of the specimen is noted by increasing the cyclic load gradually. By employing linear differential transducers (LVDTs), the deflection at the bottom end of the beam is measured at the time of application of load. A data logger transcript the data which is connected to a computer.

Fig:4: Beam Column Joint setup

V. EXPERIMENTAL PROGRAM & RESULTS

A. Compressive Strength

Compressive testing of the cubic specimens of 150×150×150mm size were carried out under universal testing machine confined to Indian standard specifications of IS:516-1959, where the load is applied manually for three cubic specimens of each mix proportion at a age of 7 and 28 days respectively.

B. Split Tensile Strength

The specimens are placed in compressive testing machine which is having a capacity of 100 tones and the load is applied without shock and increased continuously at a nominal rate of range 1.2 N/(mm²/min) to 2.4 N/(mm²/min). Fig.5 represents the Compressive and Split Tensile test of the specimens

Fig.5: Compressive and split tensile strength of specimens

Table-VIII: Compressive and Split Tensile Strengths of specimens

S. No	Compressive strength(N/mm²)		Split tensile strength(N/mm²)	
	7days	28days	7days	28 days
M0	29.8	39.5	3.82	4.3
M1	31.1	44.5	3.9	4.88
M2	34	48.8	4.08	4.42
M3	39.1	43.5	4.37	4.6

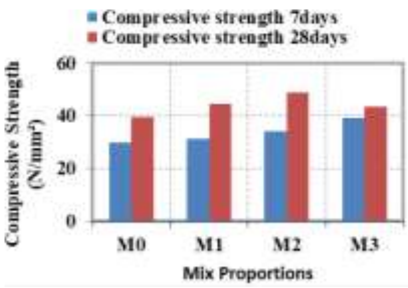

Fig.6: Compressive Strength of Mix Proportions

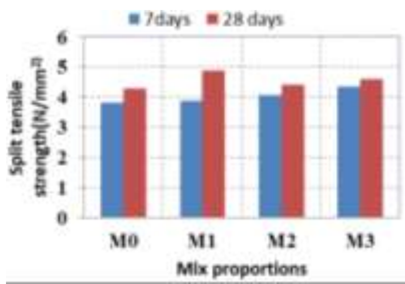

Fig. 7: Split Tensile Strength of Specimen

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C. Modulus of Rupture

This test is carried out on three prismatic specimens of each proportion with dimensions of $500mm \times 100mm \times 100mm$ at an age of 28 days where the average results are obtained as given below.

Fig.8: Testing of Prismatic specimens

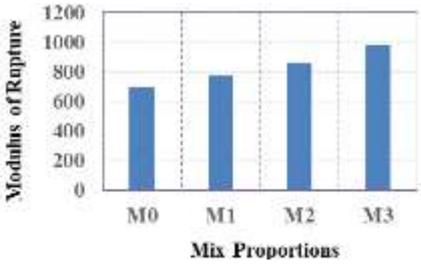

Fig.9: Modulus of Rupture

D. Modulus of Elasticity

The modulus of elasticity of concrete is obtained by testing the cylinders of length 300mm and diameter of 150mm under compression testing machine which is having a capacity of 200 tones as per the design procedure of IS :516-1959. A dial gauge is fixed to one side of the cylinder to obtain deflection at the controlled rate of loading. For each proportion of mix, 3 cylinders were cast and the average of each mix proportion is considered into account.

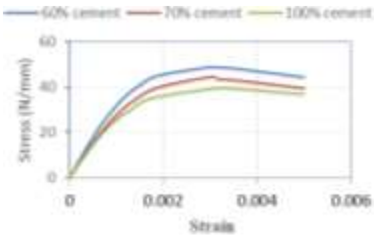

Fig.10: Stress-Strain curves of fibre concrete

E. Durability

Durability studies of 0.5% glass fiber reinforced concrete with varying GGBS percentages were studied which are effected with 5% H_2SO_4 and 3.5% NaCl

Fig.11: Compressive Strength of Acid attack specimen

VI. CONCLUSIONS

Table-IX: Compressive strengths

S. No	% of GGBS	28 Days(H_2SO_4)	28 Days (NaCl)
M1	0	17.3	27.5
M2	30	29	42
M3	40	25.3	39.5

Table-X: % Loss of Compressive Strengths due to Acid and Chloride attack

S. No	Compressive strength by conventional curing	% of loss in compressive strength(H_2SO_4)	% of loss in compressive strength (NaCl)
M1	48.8	64	43
M2	49	20.4	14.2
M3	43.5	41.8	9

F. Crack Pattern for beams and Beam Column Joints

Tensile cracks are formed on the interface of the beam where replacement of cement up to 30% shows more ductility nature and fig. 12 represents the high load carrying capacity of glass fibre concrete whose replacement is up to 40%. Fig.13 and fig.15 shows the crack pattern for beams and beam column joints.

Fig.12: Flexure testing of Beam under UTM

Fig. 13 Failure of Beam

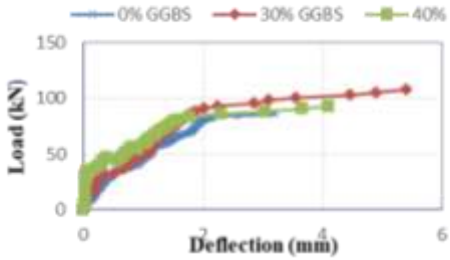

Fig.14: Load vs. Deflection of beams with different GGBS percentages.

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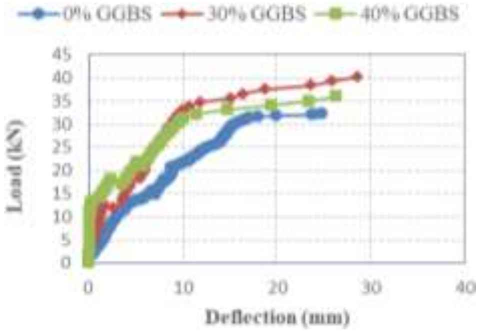

Fig.15: Load vs. Deflection

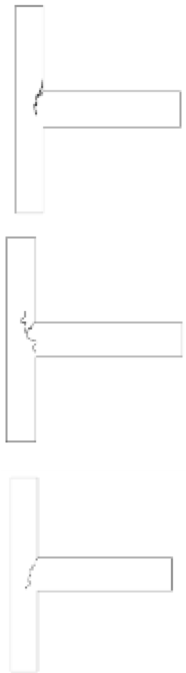

Fig.15: Crack pattern of beam column joints

VII. CONCLUSIONS

1. When the cylinders are compressed, the specimen failure is not sudden due to the bond between fibres and concrete.
2. Compressive Strength Studies of concrete in fig.6 shows increase in maximum load carrying capacity at an optimum of 30% replacement of cement with GGBS
3. Durability studies from table-IX and table-X shows the loss of weight of cubes observed after 28 days of curing in normal water and then in sulphuric acid and sodium chloride solution where the maximum weight loss occurred in acid curing. The corrosion resistance of the fiber concrete increases with 30% of GGBS where by increasing in GGBS content, the compressive strengths decreases to 40% in acid attack.
4. During testing of beams, at initial stage of loading no any cracks are observed. But after increasing the load gradually, crack formation is started. When the load is reached to its maximum level, flexural cracks are observed due to the yielding of steel in all specimens.
5. Load deflection curves for the joints which are made with constant fibre proportions by replacing cement with GGBS up to 40% shows load carrying capacity than conventional concrete.Fig..13. Shows that 30% of GGBS low deformation when compared with other specimens.

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