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Behavior of Monotonic Loading for Glass Fibre based High Performance Concrete in External Beam-Column Joint using ANSYS. Analysis

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Abstract. Strength, ductility of structures differ primarily on appropriate detailing of. beam column joints need a vital role in the structural reliability of the structures given with appropriate stiffness and ultimate strength to maintain the loads transmitted from beam and column. Beam column joints defined as the reinforced concrete buildings, in which portion of columns and beams having their intersections. Although these forces greater than these are affected during earthquakes, joints are relentlessly damaged. As far as earthquake is affected, research on beam-column joint is essential. In HPC, these materials with admixtures are meticulously designated and proportioned to produce very high early, ultimate strengths and durability away from conventional concrete. The admixtures like flyash, silicafume, ground granulated blast furnace slag (GGBFS), which are combined with its strength and durability and boost its marketability as a natural friendly product. The most important purpose of the present study is to investigate the performance of high performance reinforced beam-column joints (replacement of cement with GGBFS). Ground granulated blast furnace GGBFS is employed as a partial replacement of cement with glass fibre and super plasticizer is applied to accomplish required workability. In this study, a evaluation of control specimen and specimen of beam column joint with 7.5% GGBFS and 0.3% glass fibre replacement intended as per IS 456:2000 and IS 13920:2016. Also, to ascertain the performance of beam-column joints subjected to monotonic loading for high performance concrete employing with Ground Granulated Blast Furnace Slag (GGBFS) and glass fibre.

1 Introduction

The importance of concrete structures with high ductility which have revealed again by earthquakes in various parts across the world. Ductility defined as the ability of reinforced concrete sections, elements and structures to enthrall the larger energy emitted during the tremors devoid of losing their strength below greater scale and reversible deformations. Strength, ductility of structures be contingent mostly on appropriate detailing of the reinforcement in beam column joints. Beam column joints provides a critical role in the structural consistency of the structures providing with sufficient intensity and strength to withstand the loads transferred from beam column.

Beam-column joints are critical zones for transferal of loads. When forces bigger than these are applied during earthquakes, joints are severally damaged. HPC is formed by make use of superplasticizer, micro fillers, and various types of fiber. The admixtures like fly ash, silica fume, GGBFS are enhanced both with strength, durability and improving the market ability as a global friendly material.

The quantities which essential components are mixed, admixtures used, comprises the major variation between the conventional concrete with HPC. The necessary lower water-cement ratio of 0.30 is required for a high range water reducing admixture.

GGBFS is a non-metal product, necessitating of silicates, alumino-silicates of the calcium and other sources, developed in a liquefied condition quickly with iron in a blast furnace. GGBFS replacement builds lower heat of hydration, greater stability and improved resistance to sulfate and chloride attack produced with conventional concrete, from a structural view. It lessens the use of cement all over the production of concrete, which fosters to environmental protection. The complement of GGBFS to concrete will alter in a minimal growth in elastic modulus for afforded compressive strength, even if the discrepancies are not huge enough to be importance in design.

2 Material properties and Investigations

Cement of grade 53 used for the investigation was assessed its properties corresponding to IS4031:1988 giving specific gravity of 3.15 and other physical properties are within the parameters indicated by the Indian Standard Code.

GGBFS is a hydraulically latent substance, with lime offered with cement, a resultant reaction pertaining to Calcium Alumino Silicate elements set in. As an significance, cementitious compounds which utilized and classified as ancillary CSH gel outcomes in growth of further CSH, as a primary binding material, stimulates to the strength and durability properties of the structure. The collaboration of GGBFS and Cement in incidence of water is illustrated with.

Hydration of OPC	OPC (C3S/C2S) + H2O ➔ C-S-H + CH
Hydration of GGBFS	C2AS/C2MS + H2O ➔ C-S-H + SiO2
Reaction of pozzolanic substantce	SiO2+ CH + H2O ➔ C-S-H

Cem-FIL AR glass fibers, an inimitable as a concrete reinforcement having the equivalent specific gravity as the aggregates which assures the fiber dispersion is easier to accomplish than with other fibers. According to ASTM Standards, specific gravity is 2.68 g/cm^3, filament diameter is 14 µm and Elastic Modulus as 72 GPa.

In the neighborhood, local sand is consumed as fine aggregate which passes through 4.75mm and retained on 0.075mm sieves. The river sand is related to Zone II as per IS 383-1970. Coarse aggregate is trampled granite angular aggregate passing through 20 mm then retained at 4.75mm sieve. The coarse aggregate corresponds to IS 383-1970 and is examined as per IS 2386-1963 for the physical properties. Its Specific gravity of 2.71, Bulk density as 1465 kg/m3 and Bulk density as 1519 kg/m3 in loose and compact state.

Super plasticizer CONPLAST SP430, formed on Sulfhanated naphthalene polymers, conforms with IS 9103 1999 and ASTM C 494 used as water reducing admixture for this study. Designed for the proportion of Mix M75 by weight basis conforming ACI 211.4R-93 ACI Mix Design is implemented. Mix proportioning aspects are formulated with this Table 1:

Table 1: Mix proportioning of M75 Grade

Cement (kg/m³)	F.A (kg/m³)	C.A (kg/m³)	WC Ratio
589.45	606.21	1169.06	588.401
1	1.04	1.99	0.27

Table 2: percentage of GGBFS and Glass Fibre

Mix	**GGBFS (%)**	**Glass fibre (%)**	**Ratio**
M0	0	0	1:1.04:1.99:0.27
M5	5.0	0.30	1:1.04:1.99:0.27
M7.5	7.50	0.30	1:1.04:1.99:0.27
M10	10.0	0.30	1:1.04:1.99:0.27

Table 3: Percentage of GGBFS and Glass Fibre

Mix	GGBFS (%)	Glass Fibre (%)	M75 Grade Concrete Slump (mm)
M0	0	0	63
M5	5.0	0.30	57
M7.5	7.50	0.30	60
M10	10.0	0.30	65

After the outcomes of compressive strength, split tensile strength and flexural test, the optimum result was exhibited by 7.5% replacement of GGBFS.

Mix	GGBFS (%)	GF (%)	Compressive Strength	Split Tensile Strength	Flexural Strength
			28 Days/MPa)		
M0	0	0	75.02	6.5	6.40
M5	5.0	0.30	75.59	6.4	6.54
M7.5	**7.50**	**0.30**	**79.96**	**6.52**	**6.64**
M10	10.0	0.30	79.12	6.46	6.62

3 Numeric Analysis using ANSYS

ANSYS accords with engineering simulation solution accompanies in engineering simulation which design process necessitates. Specimens examined in a loading frame of 1000 kN capacity with relentless 150 kN load, about 20 % of the axial capacity of the column employed to the column for maintaining the specimens in position. A hydraulic jack capacity 500 kN was applied to operate load at the beam and 50 kN load cell capacity to calculate the operated load accurately with a continuing increase of load employed at the end of the beam. By employing the LVDTs, distortion of the beam is measured.

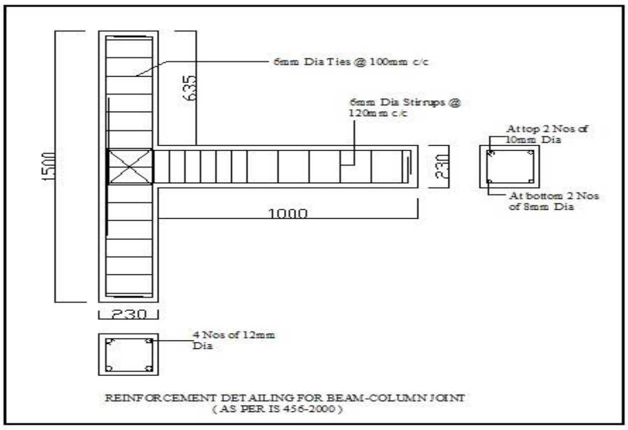

Fig 1. Reinforcement Detailing as per IS 456 : 2000

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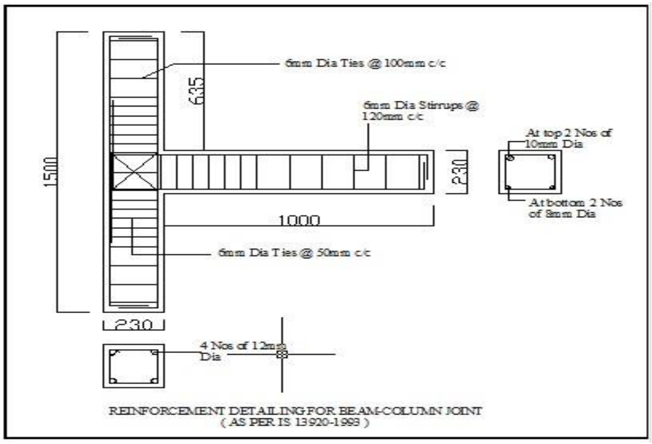

Fig 2. Reinforcement Detailing as per IS 13920: 1993

Displacement boundary controls required to control the standard to create a distinct result for attaining the translations at the nodes like U_X, U_Y and U_Z are delivered with constant values of zero. The external beam column joint is examined for employing loads. The support conditions are specified on key points and the loads in nodes. The column is attached at the bottom and continual load is utilized at top of the column and at the free end of the beam the static loading is provided at the bottom.

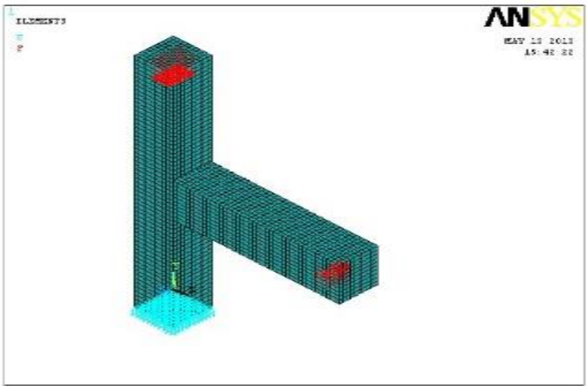

Fig 3. ANSYS modelling of Beam-Column Joint

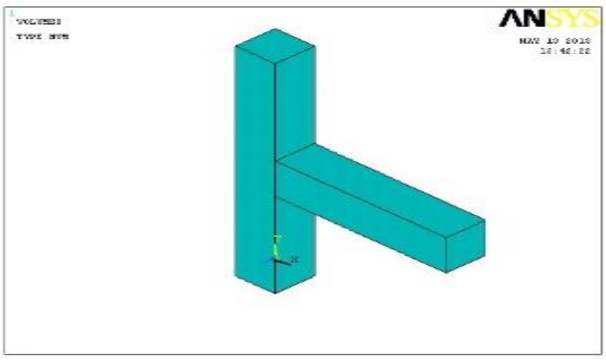

Fig 4. Displacement boundary conditions

In this study incorporating all these parameters, the HPC with GGBFS blended cement and fibre, when beam- column joint is imperiled to monotonic loading, in which four specimens are casted and tested for Ultimate load vs deflection at ultimate crack criteria tabulated in Table 4.

Table 4: Percentage of GGBFS & Glass Fibre

Specimen	Load on Initial Crack (kN)	Deflection on Initial Crack (mm)	Load under Ultimate point (kN)	Deflection under Ultimate Crack (mm)
S0	15	12.34	24	31.96
S1	18	14.12	27	29.67
S2	16	14.98	26	28.12
S3	20	12.32	29	27.96

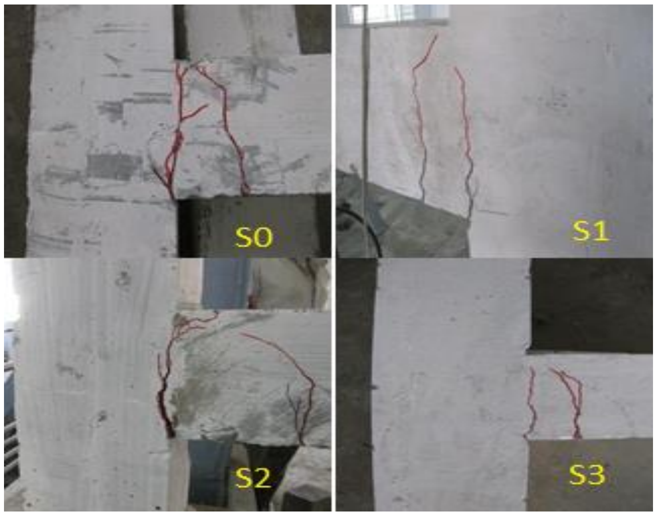

Fig 5. Crack patterns subjected to cyclic loading

Stiffness rigidity of an object, the amount to which it resist the deformation in the response to a force applied to it. Structural stiffness operates natural period and the seismic forces. It is load necessary to affect unit deflection on beam column joint where S1 increasing from S0 and starts lowered down to S2 as given in fig.6.

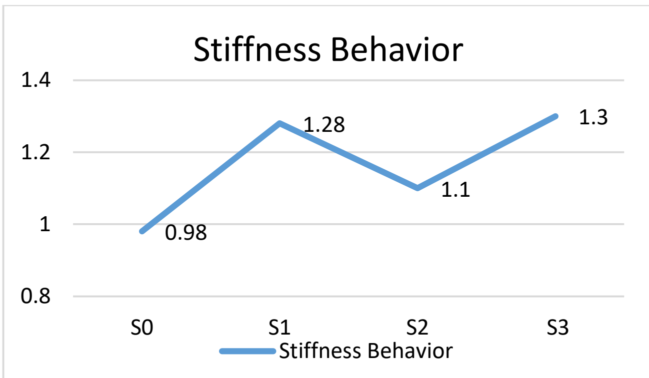

Fig 6. Stiffness behavior of controlled specimens

Displacement ductility is a rate of the enacted post-elastic deformation on a member is vital that an earthquake resistant structure is effective of twisting in a ductile manner imperiled to adjacent loads in several cycles in the elastic range. In this study ductility factor is well-described as the ratio of maximum deflection to the yield deflection. Similarly beam-column joint where S1 increasing from S0 and starts lowered down to S2 and increased in S3 as given in Fig.7.

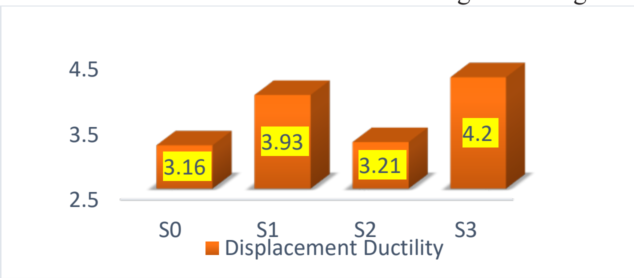

Fig 7. Displacement ductility of controlled specimens

3. Discussions

The deflection standards in the testing of controlled specimens in ANSYS were noted at free end of beam. The load Vs deflection behaviour for specimens S0, S1, S2 and S3 shows uniform variation between the ANSYS and experimental values from initial crack load to ultimate load and the variation in percentage fall ranges of 5-10% as shown in Table 5.

Table 5: Load vs Deflection under cyclic loading

Load (kN)	Deflection (mm)			
	S0	**S1**	**S2**	**S3**
0	0.0	0.0	0.0	0.0
5	6.02	4.52	6.12	5.22
10	8.96	7.86	9.78	7.12
15	12.34	12.17	13.02	9.57
20	17.12	14.12	14.98	12.32
25	23.27	16.34	16.65	17.56
30	31.96	20.02	20.69	22.16
-	-	25.12	26.81	27.96
-	-	29.67	28.12	-

Assessment between the load vs deflection findings retrieved from ANSYS analysis and from the experimental analysis displays that the ANSYS analysis results are merely some stiff than the experimental results. In ANSYS analysis at 15 kN is 10% decrease to the first crack load of 15 kN found in the experimental analysis, the initial crack load achieved. The ultimate load contracted in ANSYS is 30 kN which is 18.88% lower than the ultimate load achieved in the experimental analysis as shown in Table 5.

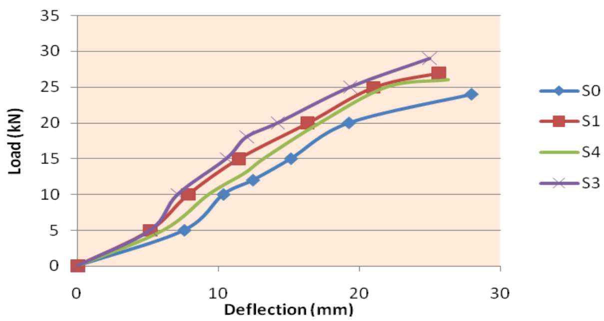

Fig 8. Load vs Deflection on S0, S1,S2 & S3 specimens

Table 6: Ult. load vs Experimental & ANSYS deflection

Mix (%)	Ultimate Load (KN)	Experimental Deflection (mm)	ANSYS Deflection (mm)
S0	30.46	31.96	27.41
S1	33.25	29.67	24.31
S2	31.19	28.12	22.67
S3	35.28	27.96	21.12

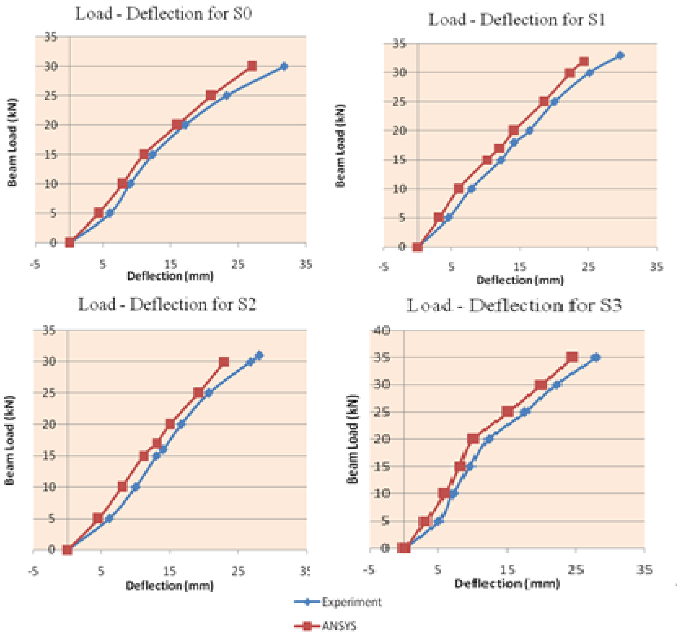

Fig 9. Load-Deflection for controlled and GGBFS specimens

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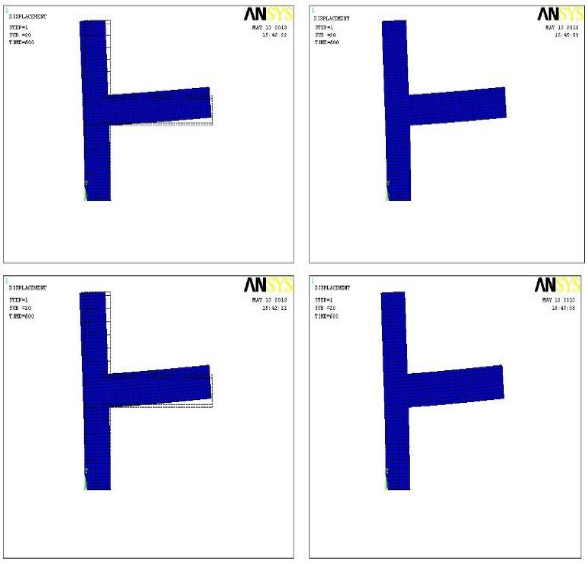

Fig 10. ANSYS Deflection on S0, S1,S2 & S3 specimens

4 Conclusion

In this present study, the concrete mix of M75 has been designed as 1:1.04:1.99:0.27. The concrete with various percentage replacement levels of GGBFS in cement mix quantities have been arrived and the tests have been conducted. In the investigational studies the subsequent conclusions were made:

1. The primary crack load of these specimen S3 is 34% in excess of the control specimen S3. This is due to the presence of GGBFS and Glass fibre and the ductile detailing given in the column as per IS13920.From the experimental outcomes, it can be determined that the improved strength characteristics is showed by 7.5% replacement of GGBFS and 0.3% replacement of glass fibre.
2. The High Performance Concrete joints by means of GGBFS and glass fibre endure huge displacements without evolving broader cracks compared to the HPC joints specifies that expose excessive ductility to the HPC joints having the vital properties on beam-column joints.
3. As per IS 13920:1993, Ultimate load carrying capacity is high for S3 related to control specimen S0 owing to the presence of GGBFS and Glass fibre and the ductile detailing specified in the column.
4. Ultimate load capacity is very high for S3 compared to control specimen whereas ultimate load bearing capacity of the joints also improved in specimen with GGBFS with glass fibre when associated to controlled specimen.
5. Fibres are intercepting the cracks to preclude them from transmitting in identical direction, when the micro-cracks developed in the matrix. Later, the cracks taken a diverged path, which necessitates additional power for more dissemination causing in greater load carrying capacity.
6. Ductile detailing gives better strength and the load vs deflection results achieved for the controlled and GGBFS specimens shows that the yield and ultimate load has substantially improved for the specimen S3. The yield load for the specimen S3 is identified at 35kN signifies a rise up of 18.63% from the yield load value of 30 kN for the control specimen comparing IS 456:2000 and IS 13920:1993 specimen.
7. Evaluation of results between the load vs deflection, acquired from ANSYS and investigational research substantiates the ANSYS results has smaller stiff than the experimental results.
8. After the investigational study and load vs deflection results attained from ANSYS analysis for the control and GGBFS beam specimens displays that the yield and ultimate load has significantly augmented for the IS 13920: 1993 GGBFS specimen, where first crack load, yield load and ultimate load originate in ANSYS analysis are inferior than the values attained.

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