

ANALYTICAL STUDY ON THE BEHAVIOUR OF REINFORCED BEAM COLUMN JOINT WITH PARTIAL REPLACEMENT OF GGBS SLAG SUBJECTED TO CYCLIC LOADING BY USING ANSYS CIVIL FEM

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Abstract: This paper reports the study on the behavior of reinforced beam-column joint subjected to cyclic loading with partial replacement of GGBS slag and theoretical investigation has been done along with beam-column joints with hysteretic response on the structures. A model is developed to represent the response of reinforced beam-column joints under cyclic loading by using ANSYS finite element software. Six experiments were conducted on beam-column joint with and without GGBS. Out of the six specimens, two control specimens were cast without GGBS and the other four specimens were cast with 40% GGBS. The specimens were tested under constant axial load and varying lateral load. The GGBS concrete specimens shows good seismic performance as it has good energy absorption capacity as that of control specimens. It increase with 7.6% when compared with the specimen without GGBS tested at 28days and also it increases with 20.73% when compared with the specimen without GGBS tested at 56 days. Thus 40% GGBS as replacement for cement can be used in RC specimens as it showed good strength, ductility and energy absorption capacity. The failure patterns are concentrated in the joints and this is similar to the failure patterns obtained in ANSYS CIVIL FEM.

Key words - Reinforced Beam-column joint, GGBS slag, Finite element modelling, hysteretic curve.

I. INTRODUCTION

Now a days concrete is widely used construction material due to excellent in compressive strength and durability point of view. Some of the recent studies in various parts of the world have revealed that Ground Granulated Blast furnace Slag (GGBS) concrete can protect the steel reinforcement more efficiently, so that it can resist corrosion, and thus the structure as a whole, If concrete is mixed with ground granulated blast furnace slag as a partial replacement for Portland cement, it would provide environmental and economic benefits and the required workability, durability and strength necessary for the design of the structures. From structural point of view, GGBS replacement enhances lower heat of hydration, higher durability and higher resistance to sulphate and chloride attack when compared with normal ordinary concrete. Typically, in modeling the reinforced concrete structures under earthquake loading, it is assumed that beam-column joint remains elastic. Hysteretic behavior of structures subjected to cyclic loads can be explained by the behavior of structures under earthquake load. If hysteretic loop is very narrow and very low strength loop, it will accompanied by limited energy dissipation and ductility. While the wide loop and high strength and high strength hysteretic loop represents the more ductility and energy dissipation..

The finite element modeling is used to find the effect of openings in reinforced concrete beams and to validate their experimental performance. The finite element software package ANSYS CIVILFEM is used to create the models of the tested specimens of beams. Using these models, the experimental behaviour of reinforced beam-column with partial replacement of GGBS slag subjected to cyclic loading compared with the experimental results.

II. Literature Review:

Elsewhere, Sharif et al (2010) have investigated the compressive strength properties when GGBFS is used to make concrete. The uniaxial compression tests have been conducted on these concrete specimens with and without GGBFS at the ages of 3, 7, 28, 56, 90, 150 and 180 days. Increasing strength in concrete with GGBFS up to 40% to 60% and decreased afterwards. Among GGBFS based concrete, at the age of 56 days, the concrete made with 40% replacement of cement by GGBFS attains higher compressive strength as compared to the 20% and 60% GGBFS based concrete. Garcia et al (2009) have investigated the compressive strength of the concrete containing ground granulated blast furnace slag of 230, 280 %, 50% and 70% of Portland cement. Siddique et al (2011) investigated the compressive strength of concrete. The normal strength concrete and high-performance concretes (HPC) are being used extensively in the construction of structures subjected to elevated temperatures. It deals with mechanical properties of concrete made with ground granulated blast furnace slag subjected to temperatures up to 350°C. The cement was replaced 0,20,40 &60% of GGBFS and the compressive strength was found out at 28days and 56days. Johari et al (2010) have investigated the compressive strength of high strength concrete (HSC). They have studied influence of supplementary cementitious materials (SCMs), namely silica fume, metakaolin, fly ash and ground granulated blast-furnace slag. Xue et al (2009) have investigated the porosity and corrosion resistance of high performance concrete. The concrete were containing 10% of ground granulated blast-furnace slag as Portland cement replacement. The experimental results show that the replacement of Portland cement by even such a low amount of ground granulated blast furnace slag as environment more friendly and valuable alternative binder in properties of hardened concrete mix. Bilim et al (2008) investigated the compressive strength of concrete. Data set of a laboratory work, in which a total of 45 concretes were produced was utilised in artificial neural networks. Oner et al (2007) had investigated the optimum level of GGBS on the compressive strength of concrete.

III. OBJECTIVES OF STUDY:

The Seismic performance of GGBS concrete beam column joint with a replacement percentage of 40% is to be studied in order to utilize it in the building construction. The beam-column joint is to be modelled and analyzed using ANSYS CIVIL FEM.. The reversed cyclic loads have to be established experimentally so that the beam-column experience substantial inelastic deformations in tension and compression in the presence of axial loads, similar to those during earthquake.

- To model and analyse the beam-column joint by using the ANSYS CIVIL FEM.
- To design the mix for M40 grade concrete with 40% of GGBS as replacement of cement.
- To study the seismic performance of the beam-column joint by subjecting it to reversed lateral loads.
- The experimental results should be manipulated and analyzed by ANSYS CIVIL FEM and validated

IV. FINITE ELEMENT MODELLING

A three dimensional non-linear finite element model is developed by using ANSYS. To model the characteristics of concrete, a eight node solid element, solid 65 is used. The solid element of eight nodes with three degrees of freedom at each nodal- translation at the nodal x, y and z directions. The element is capable of plastic deformation, stimulating the cracking and crushing of concrete. The William-varnk criterion is used for fracture modeling in concrete. The element is capable of accounting, for the cracking of concrete in tension and compression. Some of the important parameters to perform the failure envelope in the model for elastic modulus, uniaxial compressive strength, uniaxial tension strength and poissions ratio and shear transfer coefficients for open and closed cracks. A bi-linear stress strain curve is used to model the material in both compression and tension and in any direction of x, y and z. A multi-linear stress –strain curve is considered for the formation of stress-strain curve.

ELEMENTS TYPE USED IN THE MODEL

Concrete generally exhibits large number of micro cracks especially, at the interface between coarse aggregates and mortar even before it is subjected to any load. The elements used in ANSYS CIVILFEM to develop the model were LINK8, SOLID65 and

BEAM188. The SOLID65 is used to model the concrete and BEAM188 elements used to model the reinforcement. The LINK8 element is used to combine the both SOLID65 and BEAM188 elements.

SOLID65 ELEMENT

ANSYS CIVLFEEM provides a here-dimensional eight noded solid isoperimetric element, SOLID65 is used to model concrete. This element has eight nodes with three degrees of freedom of each node-translations in the nodal x, y and z direction. This element is capable of plastic deformation, cracking n three orthogonal directions and crushing. A schematic diagram of the element is shown n fig 4.1

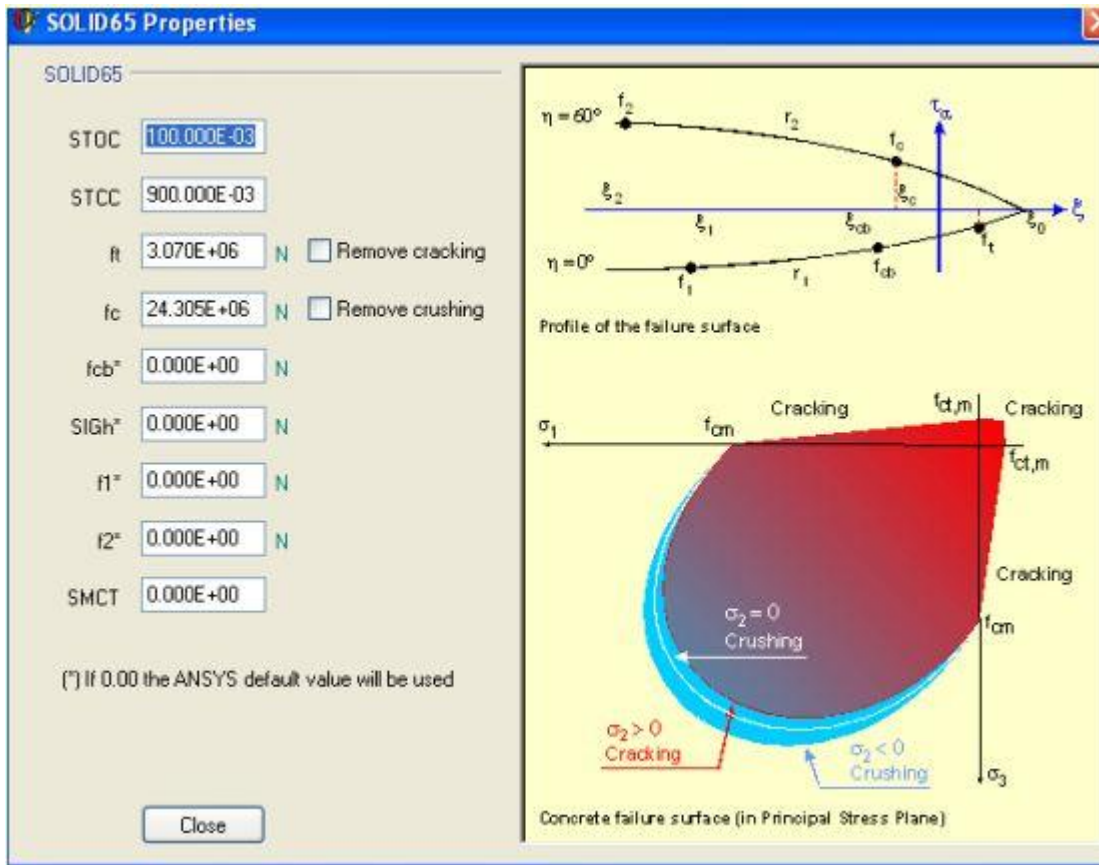


Fig 4.1 SOLID 65 PROPERTIES

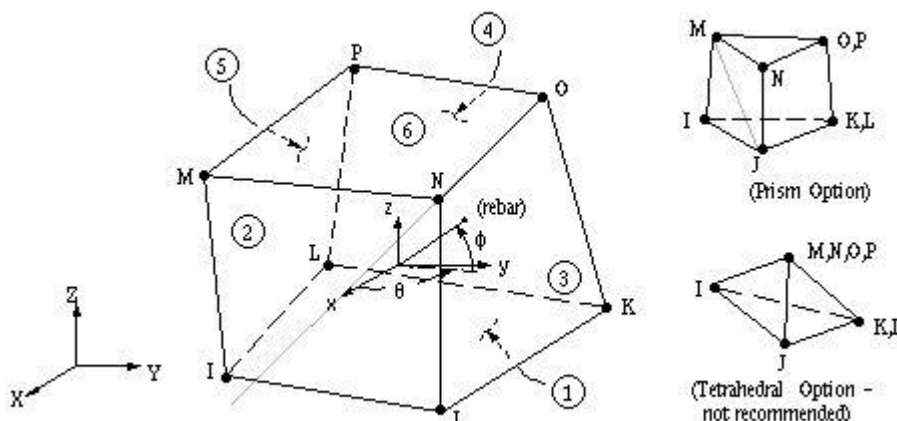


Fig 4.2. SOLID65 ELEMENT

BEAM188 ELEMENT

Fig 4.3 shows the details of BEAM188 is a linear (2-node) or a quadratic beam element in 3-D. This element has six degrees of freedom at each node, with the number of degrees of freedom depending on the value of KEYOPT(1), When KEYOPT (1) =0 (the default), six degrees of freedom occur at each node. These include translations in the x, y, and z directions and rotations about the x, y and z directions.

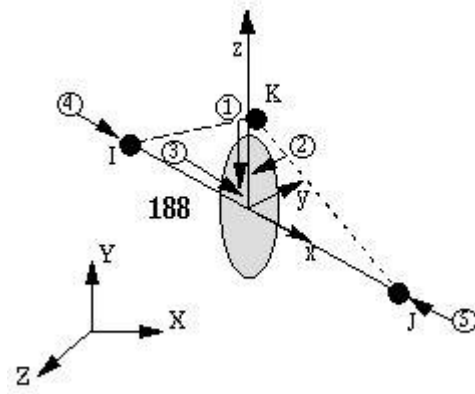


Fig.4.3. BEAM188 Geometry

V. ANSYS CIVILFEM MODELLING

Fig.5.1 and Fig.5.2 are the details of provided reinforcement of beam-column joint and beam cross-section is 200mmX150mm and column cross-section is 150mmX150mm.

Whereas,

The bars used for providing reinforcement of beam column details are:

Main reinforcement provided for beam = 12mm and 10mm diameter bars

Main bars provided for column = 12mm diameter bars

Stirrups reinforcement provided for beam-column joint = 8mm diameter bars.

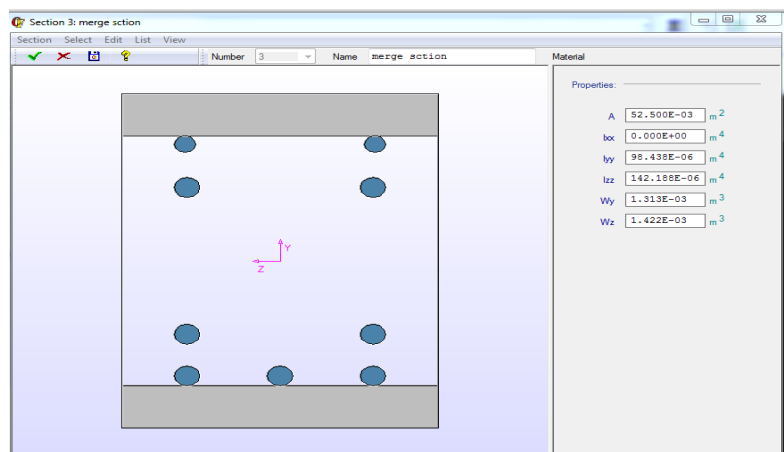


Figure 5.1 : Details providing merge of reinforcement of beam-column joint model

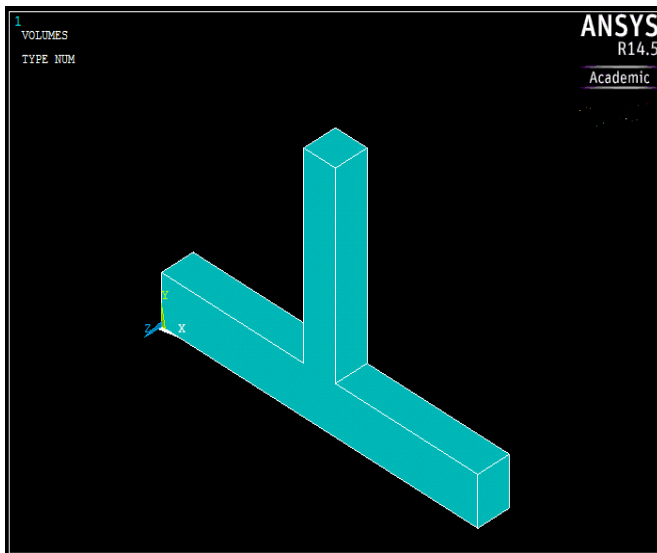


Figure 5.4 : Beam-column joint modelled in ANSYS.

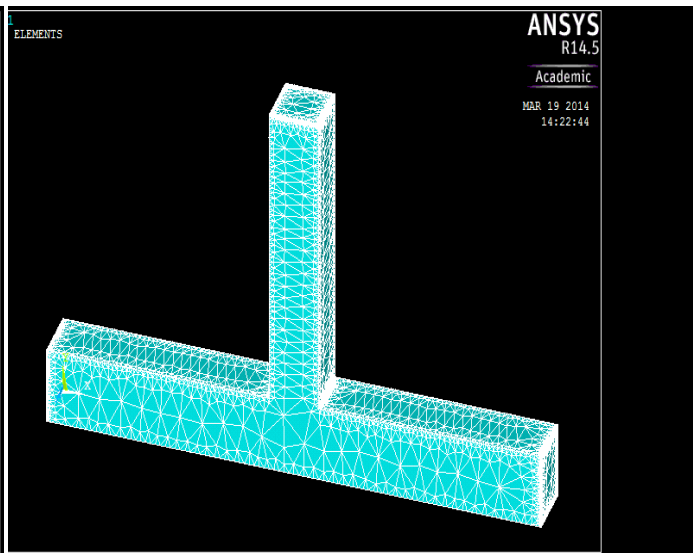


Figure 5.5 : Details of mesh model of beam-column joint.

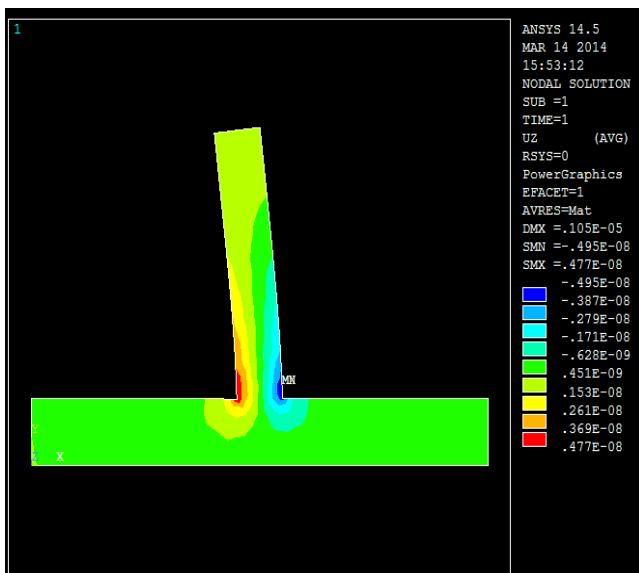


Figure 5.6

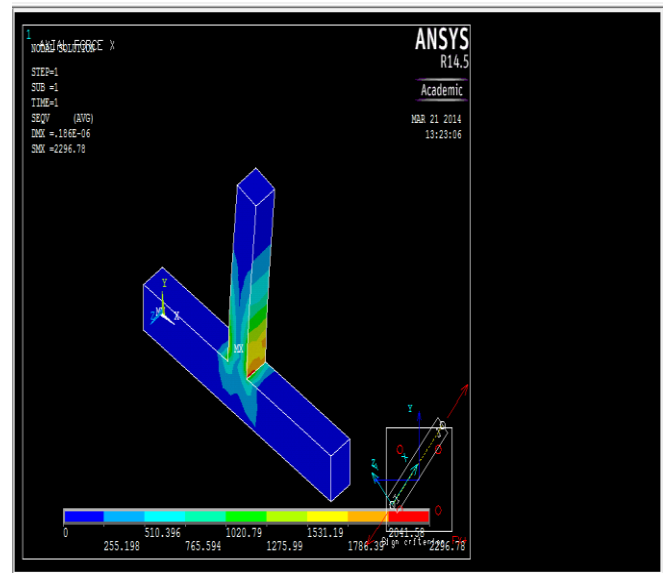


Figure- 5.7

VI. MATERIALS USED IN INVESTIGATION:

The different materials used in this investigation are

- Cement (OPC 53 Grade)
- Ground granulated blast furnace slag
- Fine Aggregates
- Coarse Aggregates (12.5 mm And 20 mm)
- Water
- Super plasticizer

Cement:

Cement used in the investigation was 53 Grade Ordinary Portland cement confirming to IS: 12269^[19]. The specific gravity of cement was 3.14 and specific surface area of 225 m²/g having initial and final setting time of 40 min and 560 min respectively.

Fine Aggregate:

The fine aggregate that falls in zone-II conforming to IS 383-1970 was used. It has fineness modulus and specific gravity of 3.07 and 2.65.

Coarse Aggregate:

Crushed granite was used as coarse aggregate. The coarse aggregate was obtained from a local crushing unit having 20mm nominal size, well graded aggregate according to IS: 383^[20]. The specific gravity was 2.8, while the bulk density was 1487 kg/m³.

Mineral admixtures:**GGBS****Chemical composition**

Ecocem GGBS comprises mainly of Cao, SIO₂, Al₂O₃, Mgo, it contains less than 1% crystalline silica, and contains less than 1 ppm water soluble chromium IV. It has the same main chemical constituents as ordinary Portland cement, but in different proportions:

in Table 6.1.

Table 6.1 chemical composition of GGBS

Chemical constituent	Portland cement	GGBS
Cao	65%	40%
Sio ₂	20%	35%
Al ₂ O ₃	5%	10%
Mgo	2%	8%

Table 6.2 Physical Properties of GGBS

Particulars	Property	Particulars
Colour	Off white powder	Colour
Bulk density loose	1.0-1.1 tonnes/m ³	Bulk density loose
Bulk density vibrated	1.2-1.3 tonnes/m ³	Bulk density vibrated

Chemical admixtures:**Super Plasticizer:**

In the present investigation, GLENIUM B1-233 (BASF) Super plasticizer was used .It is used for commercial type high range water reducing agent suitable for fly ash concrete. GLENIUM B1-233 is free of chloride & low alkali. It is compatible with all types of cements as shown in

MIX DESIGN

This chapter deals with the mix design of concrete with and without GGBS.

Table 6.3 Mix design details of concrete with 40% GGBS

Particulars	Values
Cement	249.98 kg/m ³
GGBS	166.656 kg/m ³
Fine aggregate	677.066 kg/m ³
Coarse aggregate	1221.44 kg/m ³
Water	166.656 kg/m ³
Super plasticizer	2.67kg/m ³
Water-binder ratio	0.40
Mix Proportion	1:1.62:2.93

VII. RESULTS AND DISCUSSIONS

In the specimens without GGBS, failure was due to concrete crushing at the beam-column junction and minor cracks were noticed along the height of the column. In the specimen with GGBS also failure was due to concrete crushing at the beam-column junction and minor cracks were noticed along the height of the column. The following Figure shows the failure pattern of beam-column joint with and without GGBS.



Fig- 7.1- Specimen without GGBS



Fig- 7.2. Specimen with 40% of GGBS

LATERAL LOAD VERSUS LATERAL DISPLACEMENT CURVE

The Hysteresis Curves are plotted for the variation of lateral displacement with that of the lateral load for all the specimens as shown in Figure 7.1 & 7.2.

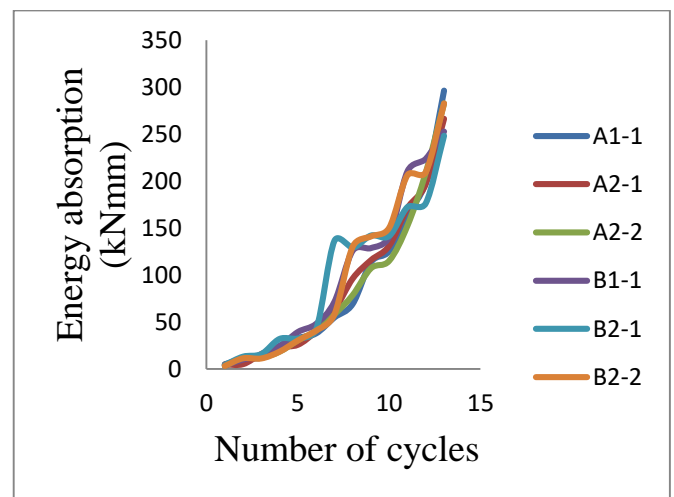
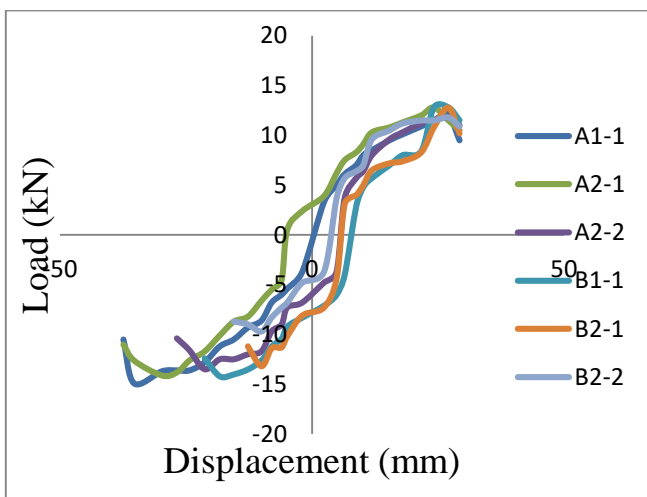


Fig. 7.3 Comparison of Peak lateral loads-lateral displacement Fig. 7.4 average energy absorption capacity for specimens

From the Figure 7.4, it is observed that the peak energy absorbed by the specimen with GGBS and tested at 56days is maximum compared to all the specimens and is 23% is more when compared to the specimen series respectively.

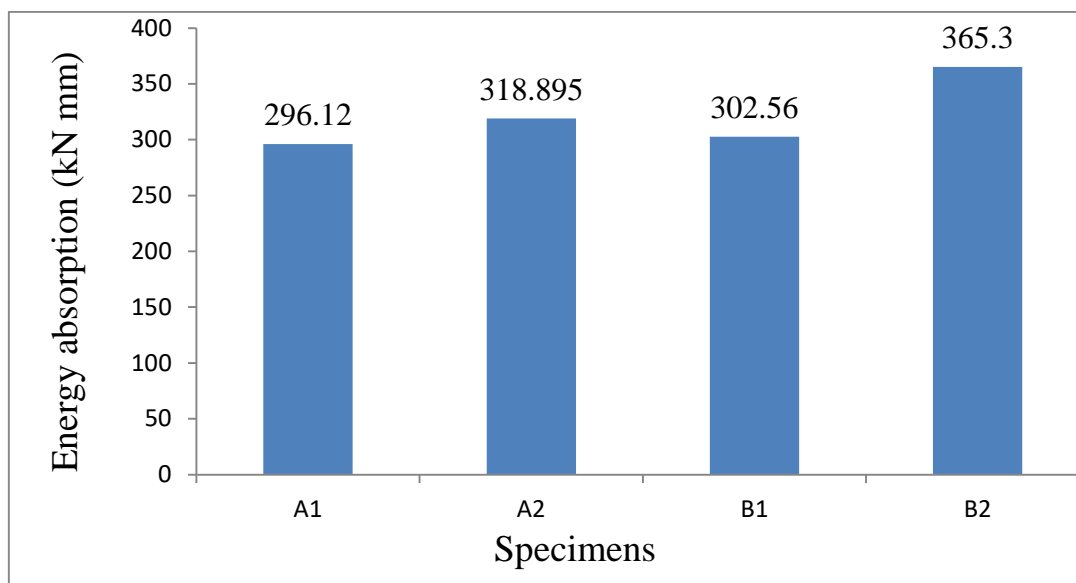


Fig. 7.5 Comparison of total energy absorption Capacity of specimen

VIII. CONCLUSIONS

- Thus 40% GGBS as replacement for cement can be used in RC specimens as it showed good strength, ductility and energy absorption capacity. The failure patterns are concentrated in the joints and this is similar to the failure patterns obtained in ANSYS CIVIL FEM.
- The load carrying capacity of the specimens with GGBS and tested at 28 days increases by 6.6% when compared with specimens without GGBS and increases by 3.5% when compared with specimen without GGBS at 56 days tested.
- The specimens with 50% GGBS shows adequate ductility when tested at 28 days and 56 days.
- The GGBS concrete specimens shows good seismic performance as it has good energy absorption capacity as that of control specimens. It increase with 7.6% when compared with the specimen without GGBS tested at 28days and also it increases with 20.73% when compared with the specimen without GGBS tested at 56 days.

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