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Analytical and Experimental Study of RC Beam Column Joint with Steel Slag Aggregate

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Abstract: The high demand for concrete using aggregate such as gravel and granite drastically reduced the natural stone deposits and this has damaged the environment thereby causing ecological imbalance. In this project, steel slag aggregate (SSA) is used as a substitute for natural aggregate. Slag is an industrial waste and also Slag is eco-friendly to the environment. The beam column joint is the crucial zone in a reinforced concrete moment resisting frame. Beam column joint specimens were casted and tested under reverse cyclic loading. In total, five specimens of beam column joint were casted with Steel slag fine aggregate concrete (SSFAC), Steel slag fine aggregate concrete with polypropylene, Steel slag coarse aggregate concrete (SSCAC), Steel slag coarse aggregate concrete with polypropylene and conventional concrete (CC). Experimental tests are done and compared with analytical results of these beam column joint specimens.

Keywords: Conventional Concrete, Steel slag, Steel slag fine aggregate concrete, steel slag coarse aggregate concrete.

I. INTRODUCTION

The high demand for concrete using aggregate is increasing day by day; there is a need for the replacement. Therefore, there is a need to explore and to find out suitable replacement material to substitute the natural aggregate. In this project, steel slag aggregate is used as a substitute for natural aggregate. Slag is an industrial waste and also Slag is eco-friendly to the environment. Beam column joint is the initial part to be damaged under seismic loading in a Reinforced Concrete structure. Hence it is important to test beam column joint under reverse cyclic loading so as to perform the seismic analysis.

The joint should have maximum strength to resist the internal forces. Steel slag aggregates were replaced by conventional aggregates in beam column joint specimens and reverse cyclic loading was applied. Steel slag aggregates were replaced fully in place of conventional aggregates in the joint specimens. Polypropylene fibers were used in the joint to enhance the strength of the beam column joint. Experimental results were done to find out the load carrying capacity when loading is applied. And then analytical results were analyzed using Midas software and the results were compared with convention concrete beam column joint specimens.

The demand on this finite size part is usually severe particularly underneath seismic loading. The beam column joint specimens were tested experimental as well as analytically under reverse cyclic loading. Hysteresis loops were formed plotted load versus deflection. Steel slag fine aggregate concrete (SSFAC) and Steel slag coarse aggregate concrete (SSCAC) were compared with conventional concrete (CC) beam column joint specimens.

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II. MATERIALS

A. Materials Used

Cement: Portland cement is the common type of cement used. In this, OPC is used for concrete.

Water: By the process of hydration, cementious material reacts with water and form a paste. This cement paste fills the voids and makes the aggregate together. Low water cement ratio makes a durable, strong concrete. High water cement ratio makes high slump concrete.

Chemical Accelerators: Chemical accelerators help in reducing the setting time and increasing the early age strength. The chemical accelerators used in this study are calcium nitrate and Triethanolamine.

Super plasticizer: To achieve the workability for concrete, super plasticizers are used. In this, polycarboxylic ether is used.

Polypropylene: Polypropylene fiber used is of 6mm length and short. It helps in reducing bleeding. Specific gravity is 0.9gm/cm².

Steel slag aggregate

Slag aggregates are used with fully replacement of conventional aggregate. Slag aggregate is an industrial waste obtained from steel industry. Also, Slag is eco-friendly to the environment.

Properties of steel slag aggregate

The Specific gravity and Water absorption results have been tested using pycnometer apparatus and the results are shown in Table 1.

Table 1 Steel slag aggregate Properties

S.no	Properties	Fine	Coarse
1	Specific Gravity	2.4	2.3
2	Water Absorption	2.8%	2.7%
3	Size	Passing through 4.75mm sieve	20mm

.Mixture Proportion

The mix proportioning for M30 grade concrete has been done as per IS10262. River sand is replaced by Bottom ash as fine aggregates and the water absorption is taken care in the calculation.

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Table 2 Quantities per cubic meter

MIXES	CC	SSFAC	SSCAC
CEMENT	350	350	350
FA	800.29	0	920
CA	1200.4	1220.45	0
SS as FA	0	654.8	0
SS as CA	0	0	1080.5
W/C	0.4	0.45	0.45

B. Curing Condition

Chemical curing has been adopted throughout the study. **CERA POLYCURE-R** is the chemical used for curing the concrete which prevents the evaporation of water from the capillaries of concrete to ensure proper hydration process.
Cera Polycure – R forms a seamless film and prevent the evaporation of water from the capillaries of concrete to ensure proper hydration process.

D. Test on Hardened Concrete

The compressive strength of the concrete test specimens were tested as per IS516-1959.

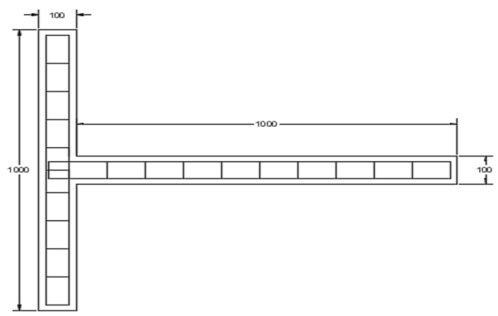
Table 3 compressive strength

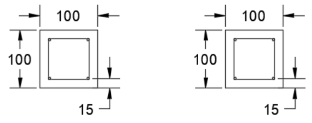
S.no	Specimen	28 days (N/mm²)
1	SSFAC	40.5
2	SSCAC	39.5
3	conventional	42

III. EXPERIMENTAL RESULTS

A. TEST STEUP

Beam column joint specimens were tested under reverse cyclic loading. Specimens dimension were: (a) beams with cross section 0.1 x 0.1 m, length 1 m; (b) columns with cross section 0.1 x 0.1 m, and length 1 m. The column was fixed at both the ends and loading was given at the edge of the beam. Deflection is measured at both the ends in free end as well as fixed end of the beam. Dial gauge was fixed at the end of the beam to measure the deflection when load is applied. Deflection is measured corresponding to the applied load. The maximum load is noted and is taken as peak load. Hysteresis curve will be formed when plotting load versus deflection. The Reinforcement details are shown in fig 1.





Beam section Column section

Fig1. Reinforcement details

Fig2. Test setup

B. Hysteresis loops

When a number of cycles of reverse cyclic loading were applied, the bond starts to deteriorate at the joint because of the yield penetration that moves towards the joint core. The below figure shows the relationship between the load and deflection in the reverse cyclic loading, Fig illustrates the hysteresis loops of Conventional concrete (CC), Steel slag fine aggregate concrete (SSFAC) and steel slag coarse aggregate concrete (SSCAC) beam column joints under reverse cyclic loading. The curves of hysteresis loops were very narrow in free end deflection of all the specimens. The hysteresis loop curves of CC and SSFAC joints are quite similar.
Loads were given at specific interval of time and deflection is noted at the free end for each load. Positive and negative loading were given alternatively and deflection is noted according to the given load. With positive and negative loading and its corresponding deflections, Hysteresis curves were plotted.

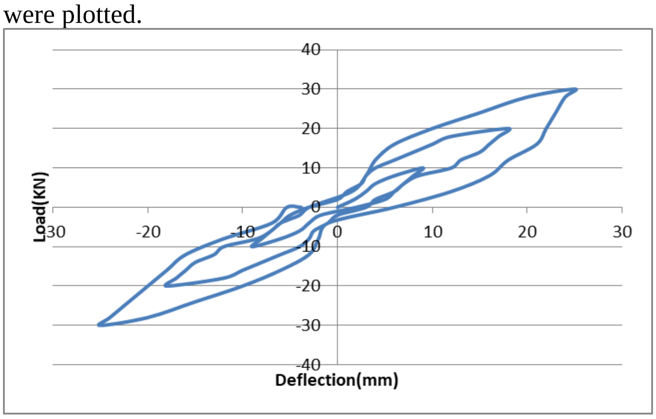


Fig 3 (a) SSFAC

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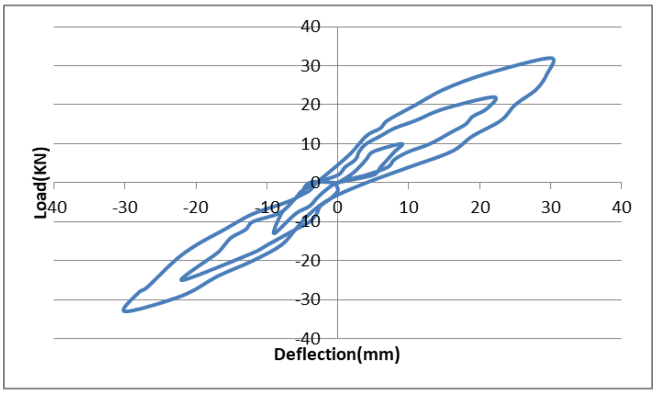

Fig 3 (b) SSFAC with polypropylene

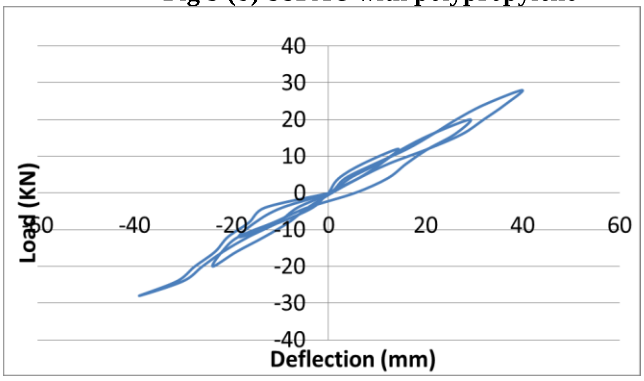

Fig 3 (c) SSCAC

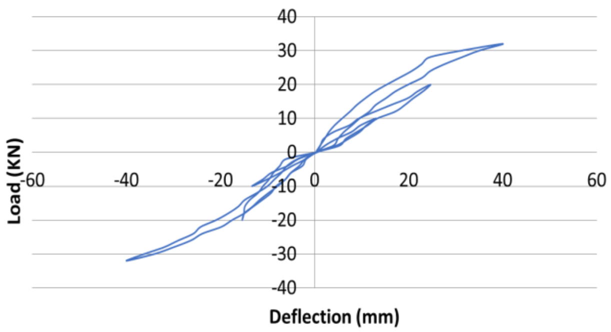

Fig 3 (d) SSCAC with polypropylene

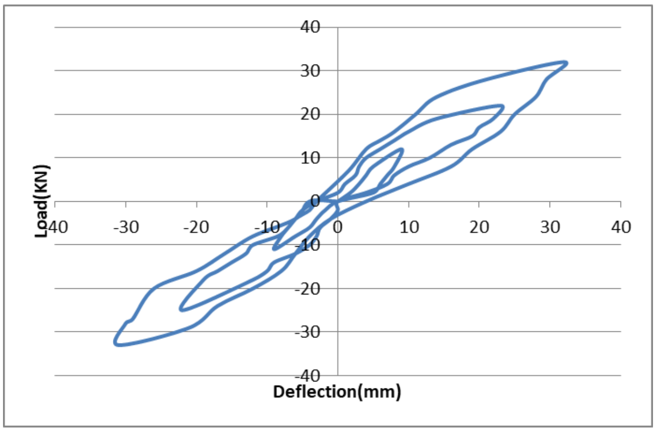

Fig 3 (e) Conventional concrete

Fig 3 Hysteresis curves

B. **Envelop curves**

Fig 4 shows the envelop curves of different specimens. Three points were chosen from the envelop curves under positive and negative loading to find out the deformation capacity. Point 1 show the crack load when the first crack occurred in the core. Point 2 corresponded to the peak load and point 3 locates the failure load.

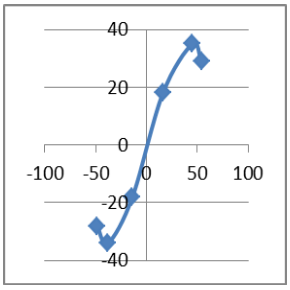

Fig 4(a) SSFAC

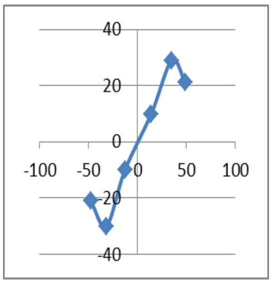

Fig 4 (b) SSFAC with PP

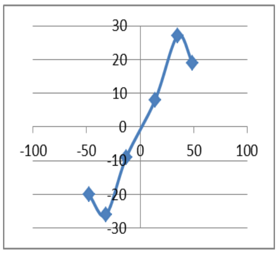

Fig 4(c) SSCAC

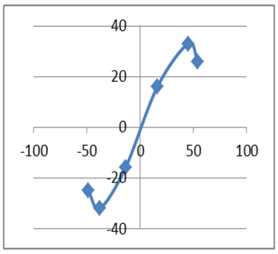

Fig 4(d) SSCAC with PP

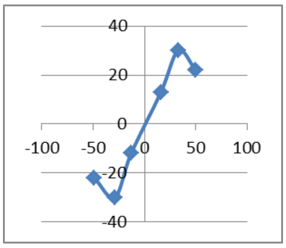

Fig 4(e) Conventional

Fig 4 Envelop curves

C. **Load carrying capacity**

Table 4 shows the maximum amount of load each specimen can withstand. Steel slag fine aggregate concrete (SSFAC) has high load carrying capability when compared to all the other specimens.

Table 4 Load carrying capacity

Specimen	First crack point (KN)	Ultimate point (KN)	Failure point (KN)
SSFAC	10	29	21
SSFAC with PP	18	35	29
SSCAC	8	28	19
SSCAC with PP	16	32	26
Conventional	13	30	22

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IV. ANALYTICAL RESULTS

A. Model in Midas

Beam column joint of various specimens have been analysed using Finite element method (FEM) software. Analytical results were done in Midas which is finite element software.

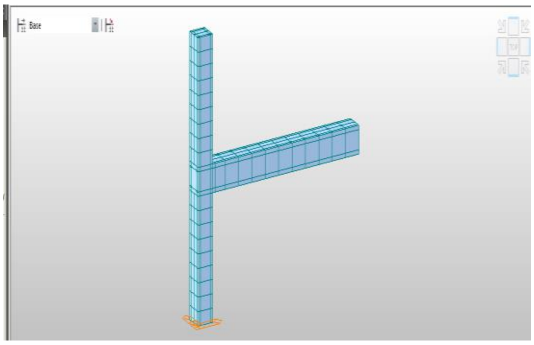

Fig 5.Model of a meshed beam column joint

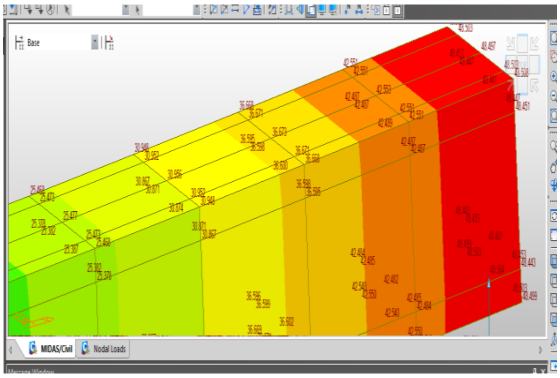

Fig 6(a) Positive loading

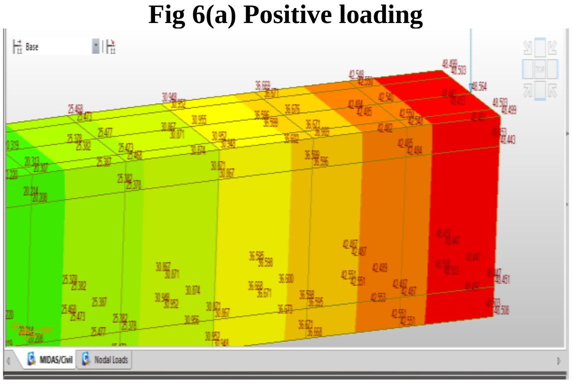

Fig 6(b) Negative loading

Fig 6 Deflection of SSFAC specimen

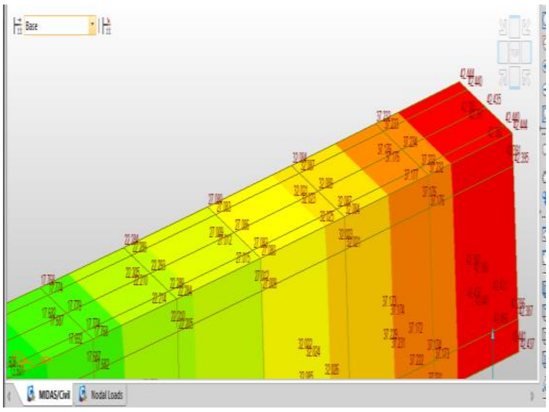

Fig 7(a) Positive loading

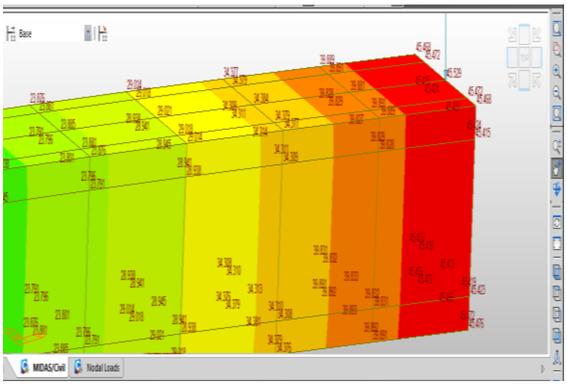

Fig 7(b) Negative loading

Fig 7 Deflection of SSCAC specimen

B. Hysteresis Loops

Hysteresis curve gives the relation between the load and deflection. Fig 8 shows the hysteresis curves of conventional concrete (CC) and steel slag fine aggregate concrete (SSFAC) and steel slag coarse aggregate concrete (SSCAC) joint specimens under reverse cyclic loading done in Midas software. Load is given and corresponding deflection is measured at the free end. Same as experimental method, with each load and deflection of the specimens, hysteresis curves were plotted.

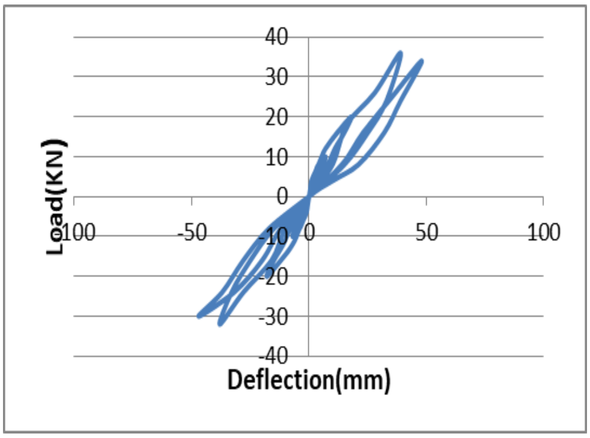

Fig 8 (a) SSFAC

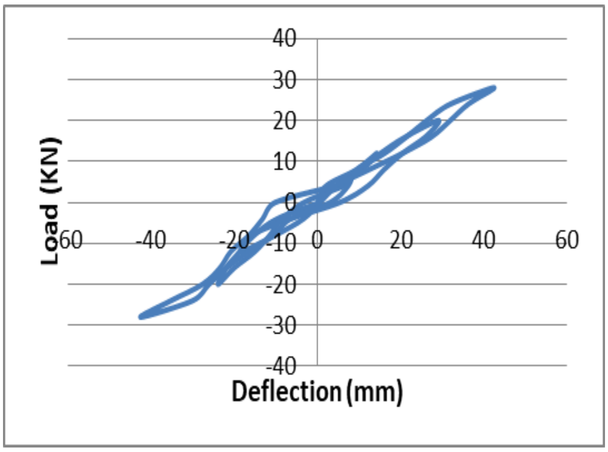

Fig 8 (b) SSCAC

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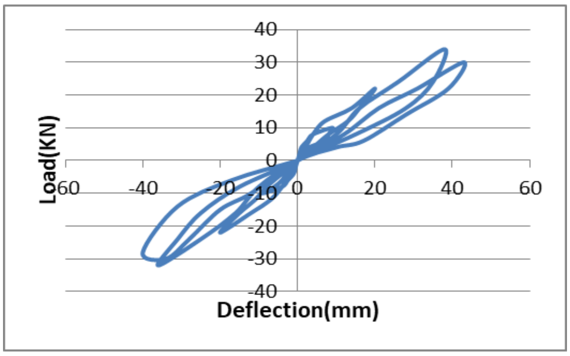

Fig 8 (c) Conventional concrete

Fig 8 Hysteresis curves and feature points of specimens.

V. CONCLUSION

The key conclusions can be drawn as follows.

- SSFAC specimen behaves well when compared to SSCAC and conventional specimens.
- Deflection at fixed end is almost same for all specimens when cyclic loading is applied.
- SSFAC beam column joint have almost equal load carrying capacity as compared to conventional concrete.
- On cyclic loading, large number of cracks is formed particularly in SSCAC beam column joint specimen.
- In case of joint failure, SSFAC with polypropylene specimen behaves well in experimental methods.
- On cyclic loading, deflection at free end for all specimens is very similar in analytical investigations.

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