International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

Joint Behavior of Self Compacting Concrete using Recycled Concrete Aggregate and Hybrid Steel Fibers

Frank Stephen S., Chockalingam M. P., Nalanth N.

Abstract: ***The beam column joint failure normally occurs due to the natural disaster like a strong earthquake, which leads to the collapse of buildings. A huge number of experimental studies have been conducted on beam-column joints made up of SCC using Natural aggregates. Only a few numbers of studies have been done on SCC (Self Compacting Concrete) made up of Recycled Concrete Aggregate (RCA). So, there is a necessity arises to conduct the experiments on beam-column joints produced with SCC using Recycled Concrete Aggregate (RCA). This paper presents behaviour of beam-column joint made up of SCC with RCA. A series of ten beam-column joints with three interior joints and two exterior joints were subjected to loading test, and the results were obtained in terms of load carrying capacity, ultimate load at failure and deformation curves. The obtained results gave experimental evidence of the applicability of RCA in SCC beam-column joints.***

Index Terms: ***Self-Compacting Concrete, Recycled Concrete Aggregate, beam-column joint, load carrying capacity***

I. INTRODUCTION

In the 21st century, the construction technologies concerning two aspects such as environmental impacts and economic costs [1]. These aspects mainly focus on the environmental impacts like non-renewable resources saving, reuse and recycling optimization and health issues. Natural aggregates are extracted from quarries, which lead to the exploitation of natural resources. So, the recent concrete technologies directed towards the alternates for coarse aggregates. The recycled concrete aggregate has taken from the demolished concrete buildings and mixed with the natural aggregates to produce SCC mixture. The mechanical behaviour of the SCC depends on the ability to adhere to mortar to its surface[2]. Previous studies suggested that the usage of RCA in concrete can be adequate for the structural applications in construction industry [3]. In this work, the mechanical behaviour of RCA was characterized, and the RCA structural behaviour was tested with the help of beam-column joints under loading test. Control specimens were made of SCC with natural aggregates which are used to compare the behaviour of SCC made up of RCA. Variables considered for this research is the percentage of RCA in SCC, it is varied from 30% to 50 %.

Revised Manuscript Received on 30 July 2019.
* Correspondence Author
Frank Stephen. S*, Civil Engineering, Bharath institute of Higher education and Research, Chennai, India
Chockalingam. M.P, Civil Engineering, Bharath institute of Higher education and Research, Chennai, India
Nalanth. N, Civil Engineering, Noorul Islam Centre for Higher Education, India

II. MATERIALS

Ordinary Portland cement of Grade 43 which meets the requirement of IS 8112 (2013) used as a blender in this investigation [4]. Fineness test, soundness test, compressive test, and setting time test requirements were tabulated in table I. Virgin aggregates such as gravel (22 mm maximum), fine gravel (12 mm maximum), sand (5 mm maximum) and fine sand (4 mm maximum) were taken for this investigation. RCA was used as partial replacement of coarse aggregate which ranges from 30% to 50%. RCA was taken from nearby demolished buildings. Normally demolished building waste average composition are 84% concrete, 13 % masonry and 3% of miscellaneous by volume [5]. Class C fly ash obtained from Tuticorin power plant was used as a partial replacement of cement to enhance the binding capacity of cement in SCC.

. TABLEI Physical requirement of OPC grade 43

Sl. No	Character	Requirement according to IS	Testing method
1.	Fineness	Min 225 370 for 43-S grade	IS 4031 (Part 2)
2.	Soundness a) By Le Chatliers method b)By autoclave test method	 10 0.8	IS 4031 (Part 3) IS 4031 (Part 3)
3.	Setting time: a) Initial, min, b) Final, min, Max	 30, 60 for 43-S grade 600	 IS 4031 (Part 5)
4.	Compressive strength, MPa a) 72 ± 1 h, Min b) 168 ± 2 h, Min c) 672 ± 4 h, Min 43 Max 58	 23 33 37.5 for 43-S grade	IS 4031 (Part 6)

Polyvalent (SIKA VISCOCRETE TEMPO 12). based super-plasticizer was used as a water reducer in this investigation to enhance the workability of Self Compacting concrete. To determine the physical properties of RCA, the laboratory tests were conducted based on the methods directed in the Indian standard IS: 383-1970.[6]

Steel fibres with aspect ratio 50 was used to reinforce the beam column joints in this investigation.

III. PRODUCTION OF SCC

All the ingredients of the self-compacting concrete mix were weigh batched according to the mix design and taken in separate containers. Both the fine and coarse aggregates were free from moisture and foreign matter. The SCC constituents were thoroughly mixed in an electrically operated mixer machine of quarter bag capacity as shown in Figure 1.

Fig.1 Concrete mixer

Figure.2 SP trial dosage addition

Fig.3 Curing

Fig.4 SCC specimens UNITS

Figure 2 –5 shows the various stages in the preparation, casting and curing of SCC.The dosage of cement (291.2 kg/m^3), water, fly ash, fine aggregate was kept constant. On the other hand, RCA dosage is varied from 30% to 50 % and the super plasticizer volume is about 1 to 2%. To maintain the concrete workability RCA is soaked in water before it mixed with the concrete mixture [8].Since no specific mixing procedure is available regarding the mixing procedure of SCC the mixing time was determined by practical trials.

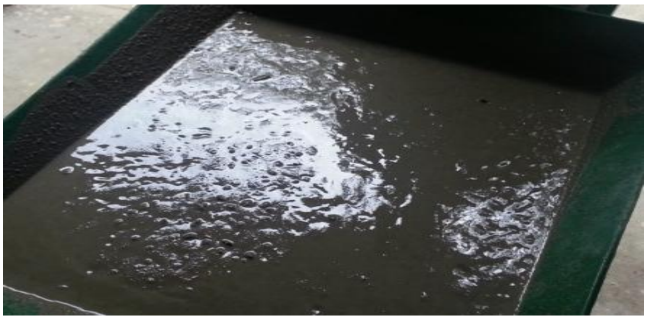

Fig.5 SCC trial mix

Fig.6 Specimen casting

It was found that a long time was required to complete mixing of SCC mixes. Repeated workability tests were conducted with a different combination of materials until an ideal mixture proportion satisfying the fresh state properties as specified in IS 10262 was obtained [7]. This ideal mix proportion was adopted in the production of beam-column joint specimens with variation in steel fibre content.

A. Fresh state properties

Fresh state properties of SCC mix with RCA is determined at the early stages of concrete mix.

Table II Fresh state properties of SCC

MIX ID	Fresh state test				
	Slump flow		J-ring (mm)	L-Box (mm)	V- Funnel (Sec)
	D (mm)	T_{500} (Sec)			
NSCC	740	2	7.3	1.0	8.31
RC1	731	2.18	7.5	0.95	8.96
RC2	727	2.95	7.9	0.91	9.13
RC3	723	3.05	8.3	0.89	9.47
RCSF1	721	3.61	8.8	0.86	10.22
RCSF2	716	3.85	9.4	0.84	10.89
RCSF3	704	4.09	9.8	0.83	11.07

Table III Mixture Proportion

Sl. No.	Mix ID	Steel Fibers %	Cement (kg/m^3)	Fly ash (kg/m^3)	Water (1/m^3)	Water to binder ratio	FA (kg/m^3)	CA (Kg/m^3)	RCA (Kg/m^3)	SP % CM	SP (L/m^3)
1	NSCC	-	291.2	124.8	208	0.5	989.84	809.87	-	1.68	7
2	RC-1	-	291.2	124.8	208	0.5	989.84	566.9	242.9	2.16	9.5
3	RC-2	-	291.2	124.8	208	0.5	989.84	485.93	323.94	2.58	10.75
4	RC-3	-	291.2	124.8	208	0.5	989.84	404.93	404.93	2.95	12.28
5	RCSF-1	0.5	291.2	124.8	208	0.5	989.84	566.9	242.9	2.35	9.8
6	RCSF-2	0.75	291.2	124.8	208	0.5	989.84	485.93	323.94	2.64	10.98
7	RCSF-3	1	291.2	124.8	208	0.5	989.84	404.93	404.93	3.04	12.67

The values of slump flow and V-funnel times are used to evaluate the flowability of tested mixtures. The passing ability was assessed by conducting an L-box test and measuring the difference between slump and J-ring diameters and also, these tests were carried out to verify the performance of the initial SCC trial mixes. Whenever satisfactory values of the fresh state performance of SCC mixes was not attained, adjustments to the mix composition was made. The required results obtained and tabulated in table III.

B. Hardened state Properties of SCC

Compressive strength, tensile strength and flexural strength are evaluated according to IS 516 (1959) on cube specimens after 3, 7 and 28 days of curing [9]. From the test results mentioned in the table IV. Compressive strength of the RCSF1 is slightly coincide with the values of control mix this is due to the higher degree of compaction factor in the cube specimens. Flexural strength of RCASF 1 is slightly higher than that of control mix. Similarly split tensile strength of the RCSF1 also higher than that of control mix.

IV. SPECIMEN DETAILS

The analysis of the bond behaviour of beam column joint is observed in three types of specimens named as RCA1, RCA2 and RCA3 these specimens are produced with the help of SCC with 30%, 40% and 50% replacement of natural aggregates by recycled concrete aggregates. Similarly, these RCA specimens are reinforced with Steel fibre and named as RCSF1, RCSF2 and RCSF3.

A. Specimen Geometry

The material used for the fabrication of the mould was plywood of thickness 3/4th inch. The mould was locally fabricated and it was so designed as to enable easy demoulding after the casting has been done.Also, it was so made to be reused multiple times.

TABLE IV HARDENED STATE PROPERTIES

	Hardened state test								
	Compressive strength (N/mm²)			Flexural strength (N/mm²)			Split tensile strength (N/mm²)		
	7day	14 days	28 days	7day	14 days	28 days	7day	14 days	28 days
NSCC	18.34	24.72	37.45	2.51	3.29	3.53	1.95	2.65	2.99
RCA-1	17.75	21.12	34.32	2.34	2.56	3.24	1.88	2.43	2.85
RCA-2	14.71	18.89	28.14	2.25	2.55	3.05	1.77	2.16	2.77
RCA-3	11.32	15.56	25.61	2.2	2.85	2.86	1.68	2.06	2.66
RCSF-1	16.89	22.30	35.68	2.56	2.80	3.20	1.98	2.48	2.99
RCSF-2	16.76	20.24	30.14	2.42	2.78	3.35	1.88	2.25	2.94
RCSF-3	13.25	17.37	27.45	2.54	2.96	3.50	1.96	2.45	2.95

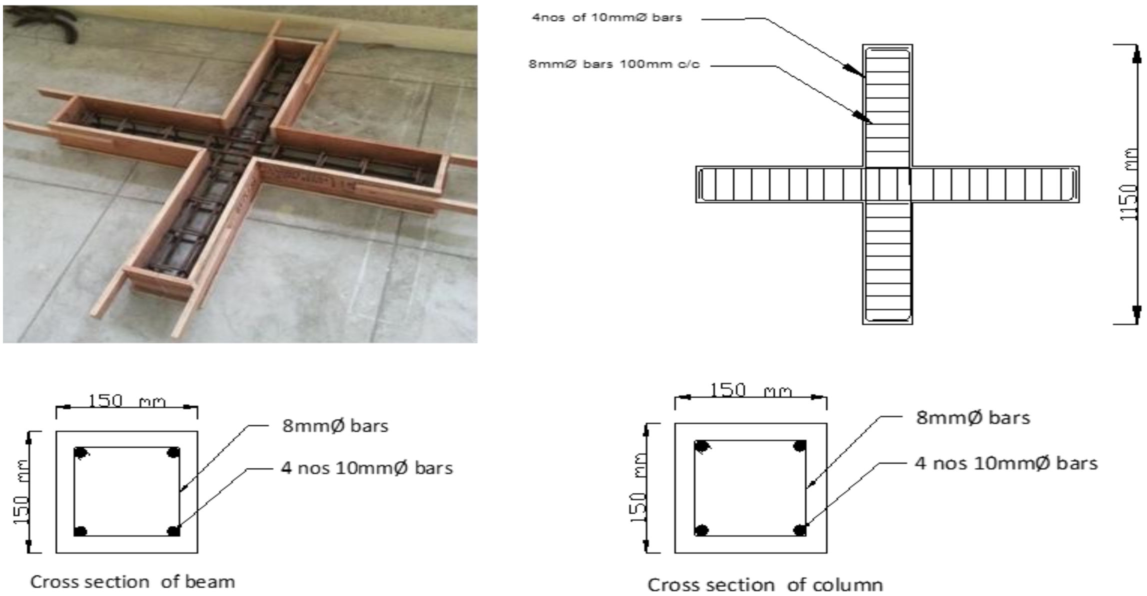

Fig.7 Mould for beam column joint Specimen

The Inner sides of the plywood were coated with oil to get the smooth concrete surface finishing and also easy to remove from the work. Reinforcements were fabricated as per the requirements. Fig 7 shows the mould used for the casting beam-column joint specimens.

B. Beam Column Joints ready for Testing

Finally, the test specimens are demoulded and labelled properly for the identification**.**Test specimens are shown in fig 8

Fig 8. Demoulded Specimen

Fig 9Beam-column joint specimens

V. TEST ON BEAM- COLUMN JOINT

The common point of union of the beam and column in a structure is called a beam column joint. According to ACI 352 R-02 A beam-column joint is outlined as that portion of the column along the depth of the deepest beam that spans into the column. The major classification of BCJ includes corner joint, interior joint and exterior joint. The constituent materials used in concrete play an important role in the behavior of the joint. Under extreme conditions of earthquake damage of severe nature is caused to the joints. Hence, adequate attention has to be given while making use of alternative constituent materials in concrete since it may have a direct impact on the performance of the joint. The bond behavior of the beam column joints is analyzed by conducting load tests over the beam column joints. Schematic view of the test setup is shown in figure 10. The specimens are subjected to normal loading on a loading frame of capacity 100T.The column was subjected to a constant load of 150 kN which is about 20% of the capacity of the column. This was to hold the column in an upright position without movement. In all the cases cracks started to appear near the joints after the yield load. In steel fiber reinforced beams, numerous fine cracks with a small crack width appeared.

A. Load-Displacement Behavior of Beam Column Joint Specimens

The load was applied over the specimens such as NSCC, RCA1, RCA2, RCA3 RCSF1, RCSF3 and RCSF3. The yield displacement, ultimate load at failure and the corresponding maximum displacement are given in Table V. junction with a yielding displacement of 5.85 mm.

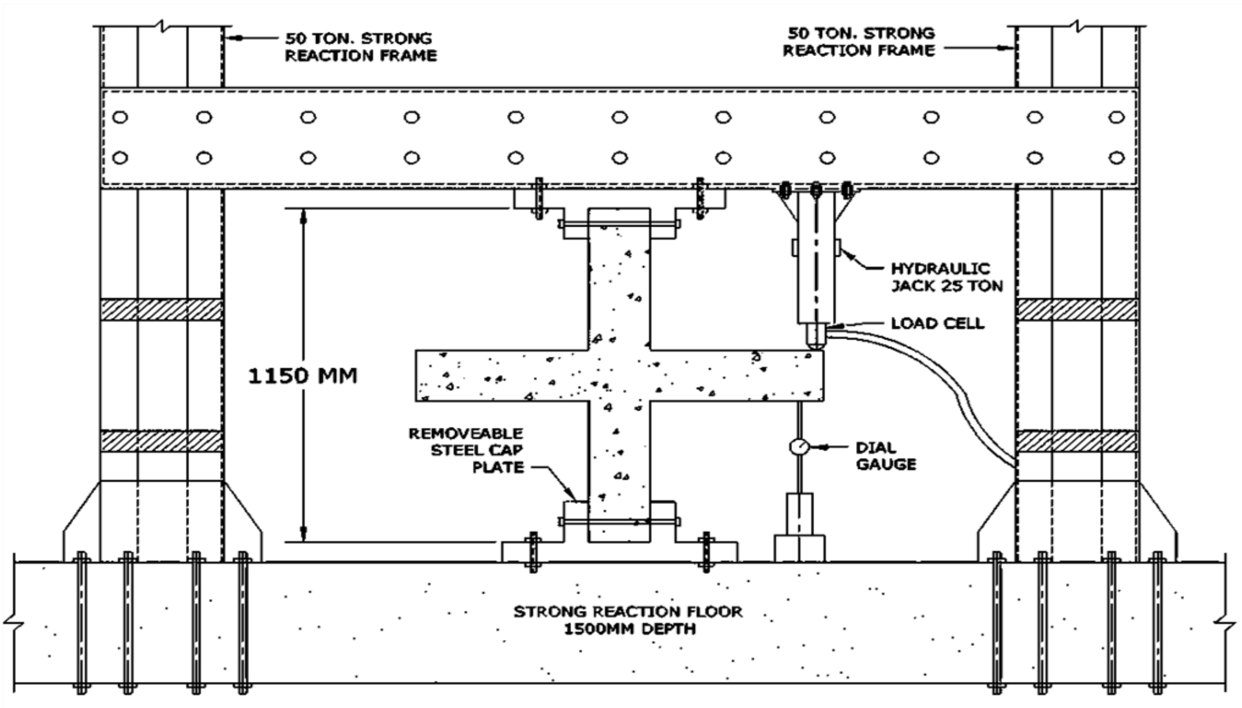

Fig 10 Schematic diagram of loading test set up

For NSCC specimen initial flexural cracks were noticed in the beam-column assemblage in the column joint where the beam is connected to the column the loading was continued until the ultimate load of 41.9 kN with a corresponding displacement of 48.66 mm, as indicated in Table V. After reaching the ultimate load, there were no signs of diagonal cracks on the shear panel area of the joint core. Similarly, specimen RCA, RCSF1, RCSF2, RCSF3 was loaded, and the corresponding yield displacement, ultimate load at failure and the maximum displacement are given in Table V From the analysis of the load displacement curve (Figure 11), it is clear that the RCA and steel fibers have considerable influence on the load carrying capacity of the beam column joint. When compared to NSCC, the RC specimen exhibited a decrease in the load bearing capacity.

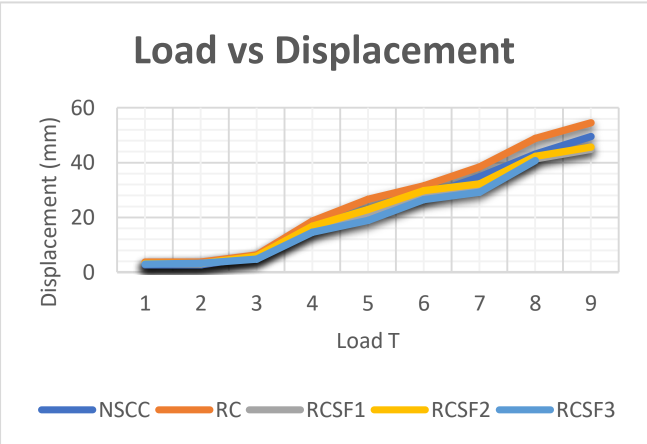

Fig 11 Load vs Displacement graph for beam column joint

Table V Load displacement of beam column joint

Specimen Id	Yielding displacement in mm- δ_y	Ultimate load in kN P_u	Ultimate displacement in mm δ_u
NSCC	5.85	41.9	48.66
RC	4.65	36.4	35.48
RCSF1	4.94	38.7	38.21
RCSF2	5.32	39.1	40.37
RCSF3	5.43	40.3	42.94

This may be due to the replacement of coarse aggregate with RCA. RCA has a lesser crushing strength when compared to natural coarse aggregates, and hence, it contributes to the reduction in strength. FEM also conducted to predict the values of displacement values of beam column joint. Fig 12 – Fig 16 have shown the deformation values of beam column joint. Form the ANSYS results it is evident that the FEM analysis values matched with the experimental results mentioned in table V.

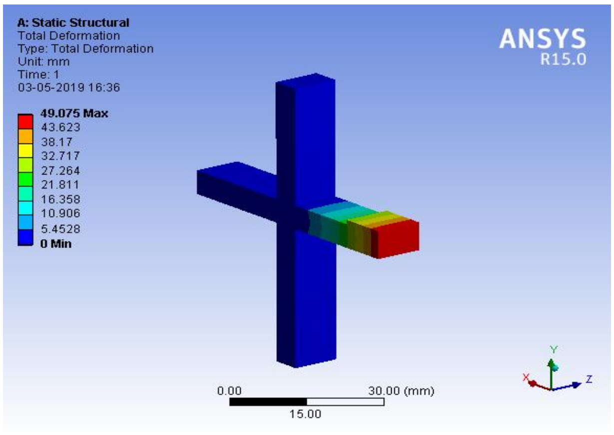

Fig 12 Deformation curve for NSCC

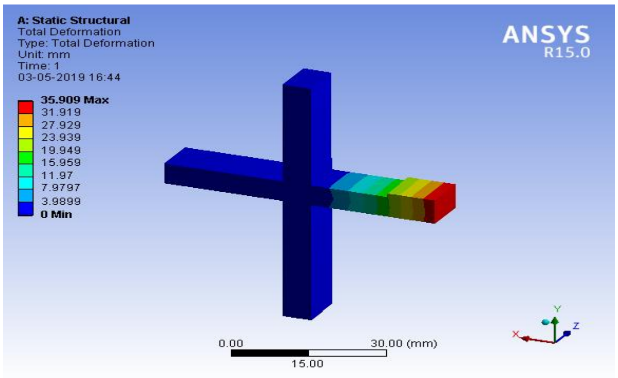

Fig 13 Deformation curve for RC

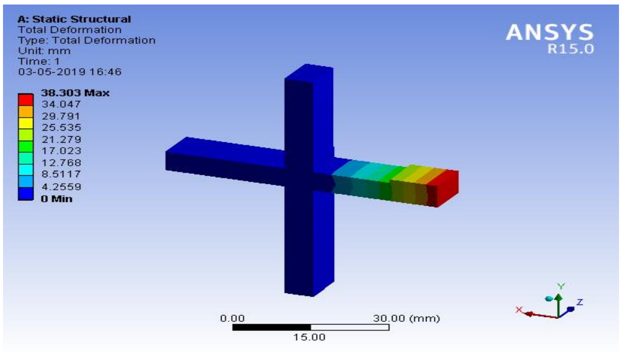

Fig 14 Deformation curve for RCSF1

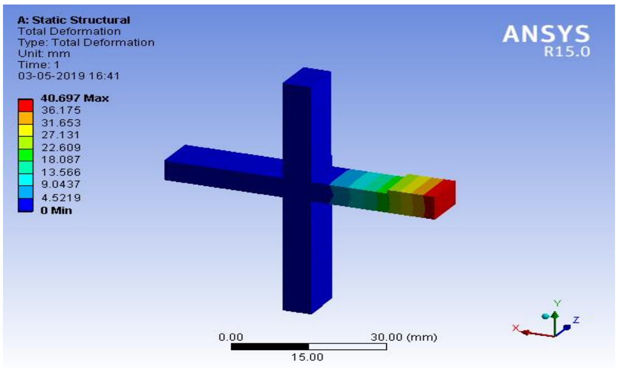

Fig 15 Deformation curve for RCSF2

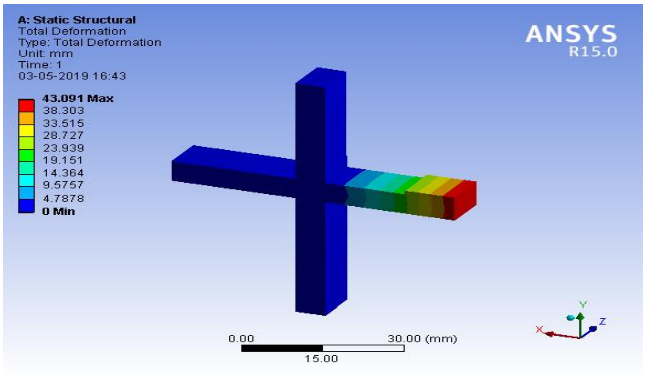

Fig 16 Deformation curve for RCSF2

VI. CONCLUSION

This study presented the seismic behaviour of beam column joints under cyclic loading conditions. Various percentages of Steel fibre and RCA were used to produce SCC mix. Each mix is tried and the influence of SF and RCA was observed based on the values such as Yielding displacement, Ultimate load and Ultimate displacement. According to the experimental values, the following results were drawn. From the results of mechanical properties, the replacement of RCA up to 30% of virgin aggregates provided satisfactory values in terms of compressive strength, splitting tensile strength and flexural strength. The usage of RCA in SCC has exhibited better mechanical performance than control specimens. The optimum percentage of replacement of the aggregate is about 30% by aggregate volume. The replacement of virgin aggregates by RCA does not affect the bond strength between concrete and steel fibres. Proper design of RAC and SF content was made to achieve safe structural performance.

REFERENCES

1. Valeria Corinaldesi, Viviana Letelier, Giacomo Moriconi, Behaviour of beam–column joints made of recycled-aggregate concrete under cyclic loading, Construction and Building Materials, Volume 25, Issue 4, 2011, Pages 1877-1882, ISSN 0950-0618, https://doi.org/10.1016/j.conbuildmat.2010.11.072
2. Corinaldesi V, Moriconi G. Behavior of beam–column joints made of sustainable concrete under cyclic loading. J Mater CivEng 2006;18(5):650–8.
3. Padmini AK, Ramamurthy K, Mathews MS. Influence of parent concrete on the properties of recycled aggregate concrete. Constr Build Mater 2009;23:829–36.
4. IS: 8112. Specification for OPC-43 grade cement. New Delhi: Bureau of Indian Standard; 1989
5. Viviana C. Letelier Gonzalez, Giacomo Moriconi, The influence of recycled concrete aggregates on the behavior of beam–column joints under cyclic loading, Engineering Structures, Volume 60, 2014, Pages 148-154, ISSN 0141-0296, https://doi.org/10.1016/j.engstruct.2013.12.024
6. IS 2386a. Methods of test for aggregates for concrete - part 1: particle size and shape. New Delhi: Bureau of Indian Standard; 1963
7. IS 10262. Guidelines for concrete mix design proportioning (CED 2: cement and concrete). New Delhi: Bureau of Indian Standard; 2009
8. Corinaldesi V, Moriconi G. Recycling of rubble from building demolition for low-shrinkage concretes. Waste Manage 2010;30(4):655–9..
9. IS 516: 1959 Methods of Tests for Strength of Concrete (CED 2: cement and concrete). New Delhi: Bureau of Indian Standard; 2009

AUTHORS PROFILE

Frank Stephen. S is working as Assistant Professor in Civil Engineering department at St. Xavier's Catholic College of Engineering, Chunkankadai, Tamilnadu. INDIA since 2013. Now he is also doing his research work on beam column joints. His areas of interest are Structural designing, Analysis and Concrete technology.

Dr.M.P. Chockalingam is a Professor in Department of Civil Engineering at Bharath institute of Higher Education and Research, Chennai, Tamilnadu, INDIA. He is a member ofIndian Society for Technical Education He has published more than twenty national and international journals and his research focused on Environmental protection.

Dr. N. Nalanth is a Professor in the Department of Civil Engineering at Noorul Islam Centre for Higher Education, Kumaracoil, Kanyakumari District, Tamilnadu, INDIA. He has published over fifteen national and international journals and his research isfocused on the area of Selfcompacting concrete.