International Conference on Advances in Materials, Computing and Communication Technologies
In Association withInternational Journal of Scientific Research in Science and Technology
Volume 9 | Issue 1 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)

Performance Assessment of Hollow RC Column with Diagonal Bracing

S. Rivetha[1], R.Vandhiyan[2]

[1]PG Student, Department of Civil Engineering, PSNA College of engineering and technology, Dindigul, Tamil Nadu, India

[2]Associate Professor, Department of Civil Engineering, PSNA College of engineering and technology, Dindigul, Tamil Nadu, India

ABSTRACT

Hollow concrete columns reinforced with steel bars have been employed extensively for bridge piers, ground piles, and utility poles because they use fewer materials and offer higher structural efficiency compared to solid concrete columns with the same concrete area. And achieving a good degree of strength and ductility. The purpose of this study is to assess the structural performance of hollow column with diagonal reinforcement. Hollow sections are often used for tall bridge columns to reduce their mass, reduce seismic inertia forces, and reduce foundation forces. However, the seismic performance of hollow columns is still not fully understood although a few experimental works were conducted previously. There are several interesting areas which must be investigated for the hollow columns, i.e., ductility capacity, shear strength, effect of diagonal loading in square section. This report presents the flexural ductility capacity of the hollow circular columns with diagonal reinforcement placed near the outside face of the section. And achieving a good degree of strength and ductility. The purpose of this study is to assess the structural performance of hollow column with diagonal confining reinforcement.

Keywords : Hollow Column, Diagonal Reinforcement.

I. INTRODUCTION

A hollow concrete section is often used for column design, particularly for very tall bridge columns in seismic areas and it is reducing the mass and therefore minimizing the self-weight contribution to the inertial mode of vibration during an earthquake. The hollow columns also enable to reduce foundation dimensions and thus save the construction cost substantially. Therefore, these advantages have promoted the use of hollow columns instead of similar solid members. The effect of the hollow section should be adequately assessed in the seismic design, because the structural response of the hollow column under seismic loading may be significantly different from that of solid column due to existence of a void section. However, there are several unknown areas which must be understood, that is, assessment of ductility capacity and shear strength, retrofit measures etc,. Hollow column cross-sections are widely used because they offer the advantages of high bending and torsional stiffness, reduced substructure weight, and resulting in savings in foundation costs. For these reasons, reinforced concrete bridge columns with hollow cross-sections are widely designed and constructed for highway, high speed rail, and other bridge columns. The triangular confining reinforcement also plays a role in preventing longitudinal reinforcement buckling. The main aim of this study is to expand the application of the triangular confinement modules to hollow columns. Additionally, current study extends the application of precast concrete bridge columns along with the triangular confinement modules.

II. EXPERIMENTAL INVESTIGATION

2.1. Test specimens and materials

Materials

Portland cement (often referred to as OPC 53 grade, from ordinary Portland Cement) is the most common type of cement in general use around the world because it is a basic ingredient of concrete, mortar and most non –specialty grout it usually originates from limestone. it is a fine powder produced by grinding Portland cement clinker (more than 90%), a limited amount of calcium sulfate (which control the set time) and up to 5% minor constituents as allowed by various standards such as the European standard EN197-1

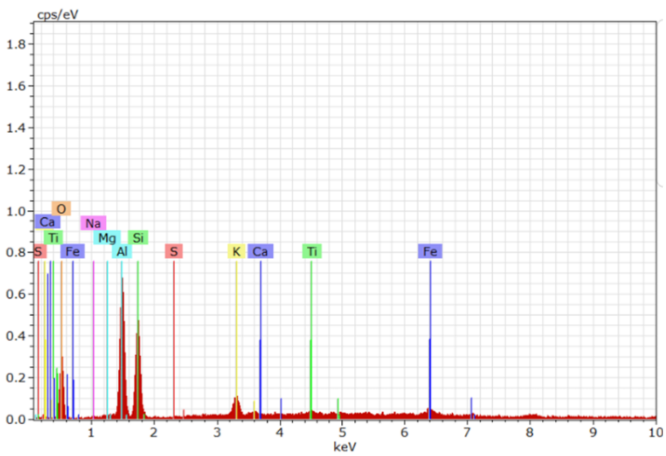


Fig. 1Chemical composition of Cement

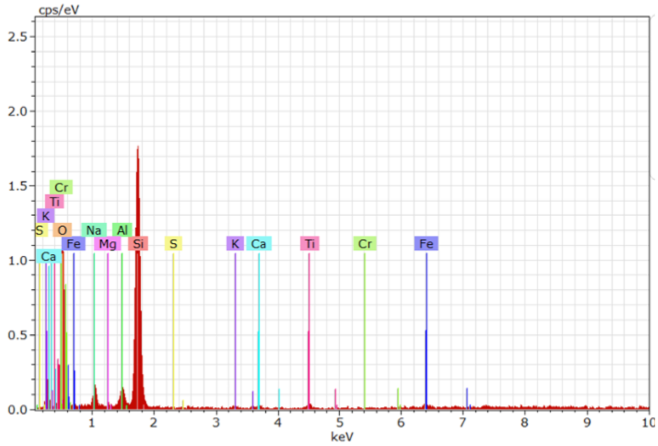


Fig. 2 Chemical composition of steel plate

2.2. Mix Proportion

BIS: 10262-2019 was used to build the concrete mix. With a water cement ratio of 0.5, the concrete mix proportions were 1 part cement, 1.65 part fine aggregates, and 2.87 part coarse aggregates. Both concrete mixtures were rendered with a constant water-to-cement ratio of 0.5. Table 1shows the proportions of the mixture.

Table 1

Concrete mix proportions

Mix Designation	**CC**	**A**	**B**	**B1**
Cement (kg/m3)	394.32	354.8	315.46	276.02
Fine Aggregate (kg/m3)	649.25	454.475	454.475	454.475
Coarse Aggregate (kg/m3)	1130.77	1130.77	1130.77	1130.77
Slump Value (mm)	90	92	90	91

2.3. For Arriving Optimum Percentage

Table 2 shows the four concrete mixes that were prepared for compressive strength, from which an optimum percentage was determined at 7 days for certain mechanical properties, as well as micro structural analysis. Table 2 shows the different mix proportions for concrete with compressive power.

Table 2
Concrete different mix proportion with compressive strength

Mix Ratio	Compressive Strength N/mm2
Conventional Concrete (CC)	25.52
Group A (M_1)	27.85
Group B (M_2)	25.06
Group B1(M_3)	16.56

The compressive strength of M_2can be used to achieve higher concrete strength for various mixes.

2.4. Specimen Preparation and Casting

BIS: 1199-1959 [8] was used to prepare all of the specimens. Test specimens were held in the casting room for 24 hours after casting, at a temperature of around 27 1 _C. After 24 hours, they were remould and placed in a water-curing chamber before testing. For each property, three specimens were cast and examined, and the average value was taken.

2.5. Fresh Concrete Properties

The properties of fresh concrete, such as slump flow, are calculated using the Indian standard specification IS: 1199 – 1959[8]. Furthermore, when preparing concrete for various mixes, the workability of the concrete is unaffected by the substitution of CK and UFS for cement and fine aggregate, respectively.

2.6. Hardened Concrete Properties

2.6.1. Compressive Strength Test

Column and Cube specimens of size 150 mm x 150 mm x 150 mm and 120mm x 120mmx 850mmwere taken out from the curing tank at the ages of 7 and 28 days in compliance with Indian Standard Specifications BIS: 516-1959 [7]and tested immediately on removal from the water (while they were still in the wet condition). Surface water was wiped off, the specimens were tested shown in Fig. 3.

Fig. 3 Compressive Strength Test

Fig.4 Solid Column

Fig.5 Hollow Column

Fig.6 Buckling Of Column

2.6.2. Splitting Tensile Strength Test

The split tensile strength of concrete is determined by casting cylinders of size 150 mm x 300 mm in compliance with Indian Standard Specifications BIS: 516-1959 [7]. The cylinders were tested by placing them uniformly. Specimens were taken out from curing tank at age of 28 days of moist curing and tested shown in Fig. 6 after surface water dipped down from specimens. This test was performed on compression Testing Machine.

Fig. 7 Splitting Tensile Strength Test

2.6.3. Flexural Strength Test

The flexural strength of concrete is determined by casting beam of size 100 mm x100 mm x500mmin compliance with Indian Standard Specifications BIS: 516-1959 [7]. The beams were tested by placing them uniformly. Specimens were taken out from curing tank at age of 28 days of moist curing and tested shown in Fig. 7 after surface water dipped down from specimens. This test was performed on compression Testing Machine on beam attachment.

Fig.8 Flexural Strength Test

2.6.4. Modulus of Elasticity Test

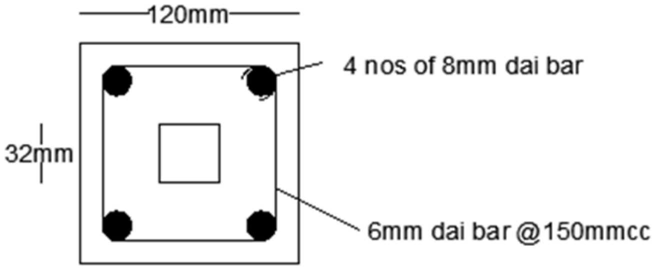
The modulus of elasticity of concrete is determined by casting cylinders of size 150 mm x 300 mmin compliance with Indian Standard Specifications BIS: 516-1959 [7]. Specimens were taken out from curing tank at age of 28 days of moist curing and tested shown in Fig. 8 after surface water dipped down from specimens. The cylinders were tested with dial guage to get the readings for stress-strain curve to plot the graph.

Fig. 9 Modulus of Elasticity Test

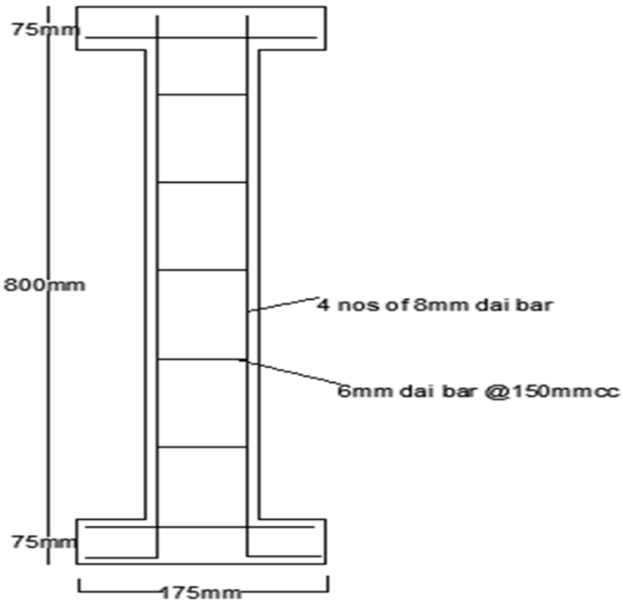
III. RESULT AND DISCUSSION

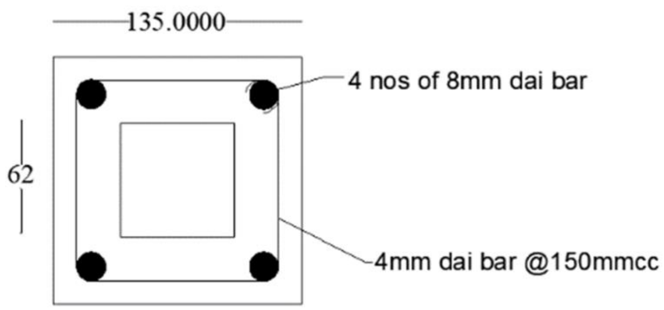
3.1 RETROFITTING

Fig. 10 RETROFITTING OF CUBE



120×120mm Hollow Column





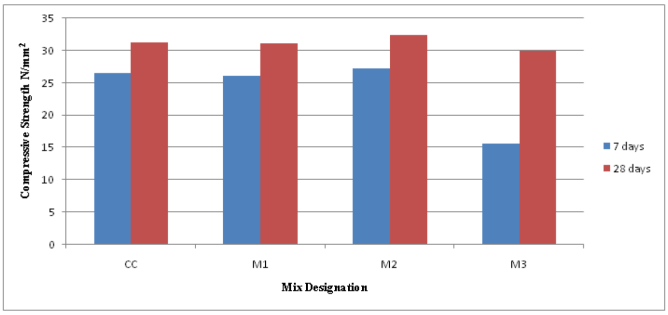
135×135mm Hollow Column

Eight square columns 120 mm x 120 mm and 135mm x 135mm were prepared and casted with two different cube strength values and the total heightofthespecimenswas850mm.Allthetestedcolumn s werereinforcedwiththesamelongitudinal4barsofdiame ter 8mmandtiedwith6mmsteelsquarestirrupsspacedat 150 mm along the column height and 50 mm at both ends of the column as demonstrated in Fig. 6.1.

Both the ends of the specimens were protected using 8 mm steel heads wherethe gap between the end of columns and the steel head was filled vertically with a flowable cementitious grout material.

Two reference columns were kept un-strengthened; one in each main group. The other six columns' specimens were strengthened using four longitudinal steel angles and horizontal strips of width equal to 50 mm which were welded to the longitudinal angles at specific spacing.

The spacing between horizontal strips was reduced to 50 mm at both ends close to the steel head to avoid the risk of local failure at these ends and to enforce failure to occur at the middle of the column as shown in Fig. 6.2.



The left gap between the steel angles and strip was vertically filled with grout to fill the 10 mm gap. Table 1shows the details of the test specimens. The properties of the used grout mortars are given in Table 2as provided by the manufacturing company.

Also the mechanical properties of the steel angles, steel strips, and steel reinforcement are presented in Table 3. The tested columns were divided into two main groups; group 1 was strengthenedusing four angle 50x 50x4.5 mm while in Group 2, columns were strengthened using four vertical angles 30x 30x 3mm.

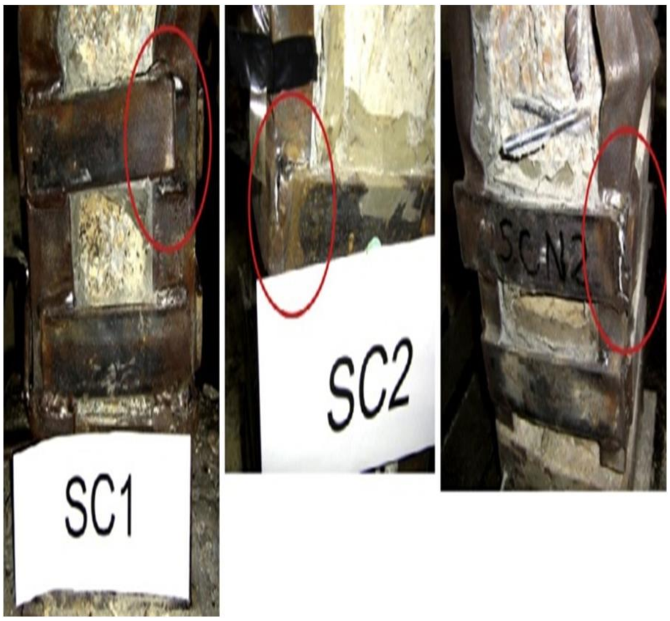


Fig. 11 Compressive Strength in N/mm2

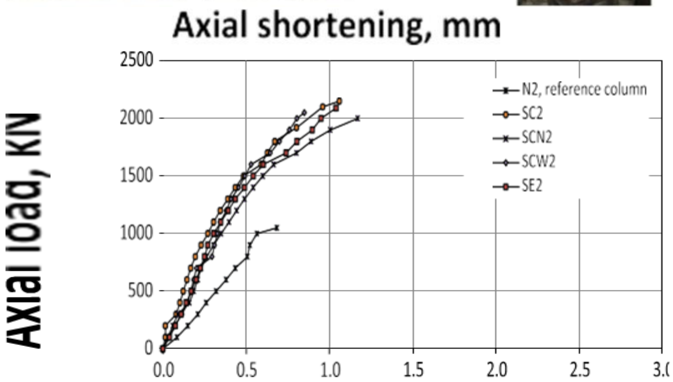
3.2 FAILURE MODES

For reference columns, N1 and N2 the behavior was similar. The axial shortening increased in a linear manner till failure.A sudden failure occurred when parts of the concrete cover spelled-off and buckling of the longitudinal reinforcement bars was observed as shown inFig 10.

During failure of column N2, the lock of one stirrup started to open outside the section during failurestage. In the case of the strengthened columns, the relation between load and axial shortening was almost linear till about 75% of the failure load followed by some nonlinear increase in the axial shortening.

The failure in these specimens started with the buckling of the one or more of the vertical angles followedbythebucklingofthereinforcementsteelbarsan deventually a crushing of concrete section near these bars as shown infig 10.

In some specimens, it was noted that the weld between the horizontal strip and vertical angle was broken, most probably after the occurrence of buckling of the vertical angles as it is obvious from the buckling shape of the angles as demonstrated in fig 10



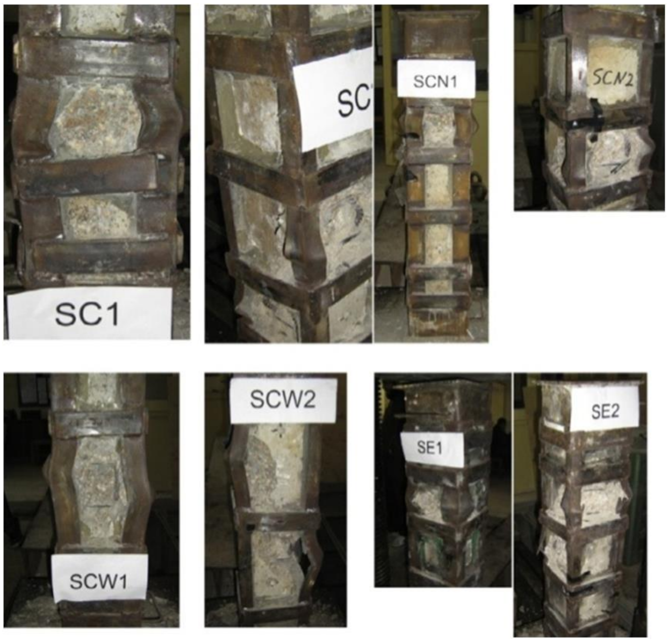
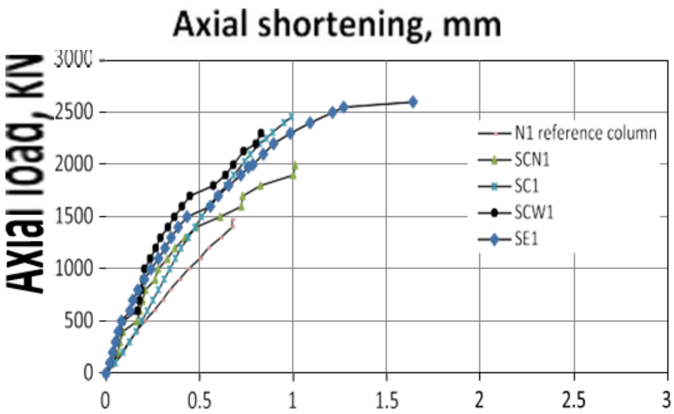


Fig 12 Fracture of weld in HS and VS

3.3 LOAD AXIAL SHORTENING BEHAVIOUR

The relationships between applied axial load and column axial shortening of the tested specimens are presented.

Also, the ratio of the ultimate load of each column to that of the reference column of the same group generally, the ultimate axial load and the maximum vertical deformations are higher in Group 1 than those of Group 2 due to the higher concrete compressive strength.



Axialload Group2.

Mechanical properties

Grout material	Compressive strength	Flexural strength(N/MM2)
Cement mortar	18 -20	6.95
Epoxy grout	100	40

Main result of the tested columns

SP	GROUP	fcu (mpa)	P failure kn	Max axial	Strain	P ¼ P/fck .Ac	P failure/p reference
N1	1	57	1475	0.67	0.0017	1.13	1.00
HC 1	1	57	2570	0.99	0.0025	1.98	1.74
SC N1	1	57	1990	1.0	0.0025	1.46	1.35
HC W1	1	57	2310	0.83	0.0021	1.77	1.57
HE 1	1	57	2600	1.64	0.0041	2.00	1.76
SE	0	0	0	0.1	0	-	-
SE	0	0	0	0.1	0	-	-

Main result of the tested columns in group

SP	GROUP	fcu (mpa)	P failure kn	Max axial	Strain	P ¼ P/fck .Ac	P failure/p reference
N2	2	47	1075	0.67	0.0017	1.13	1.00
HC 2	2	47	2770	0.99	0.0025	1.98	2.80
SC N2	2	47	1890	1.0	0.0025	1.46	1.90
HC W2	2	47	2310	0.83	0.0021	1.77	1.95
HE 2	2	47	2600	1.64	0.0041	2.00	1.96
SE	0	0	0	0.1	0	-	-
SE	0	0	0	0.1	0	-	-

Group 1

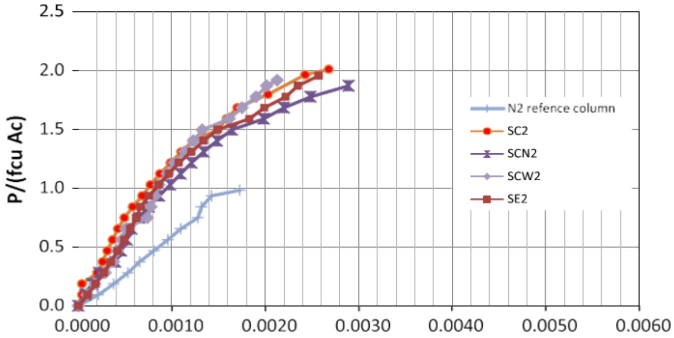


Fig 7.4 axial concrete strain group 2

IV. CONCLUSION

This study investigated the performance of hollow RC column sections with reinforcement details for material quantity reduction. The proposed reinforcement details were designed with the aim of achieving a certain degree of strength and ductility. An analytical model was developed to predict the behaviour of hollow RC bridge column sections with reinforcement details for material quantity reduction subjected to simultaneous axial load.

1. An experimental and analytical study was conducted to quantify performance measures and examine one aspect of detailing for the developed reinforcement details. The design concepts and construction methods are promising solutions to the application of hollow RC bridge column sections with reinforcement details for material quantity reduction.
2. It was found that all 8 of the analyses predicted the experimental failure loads fairly well. These include both general criteria for methods of analysis and specific recommendations for detailing of reinforcement.
3. Regarding the implementation of full-scale structures, an investigation of alternative construction details, performance under cyclic rather than quasi-static monotonic loading and

the development of design procedures and guidelines will be carried out in the future.

V. REFERENCES

[1]. Paolino Cassese, Paalo Ricci, Gerardo M.Verderame (2017) “Experimental study on the seismic performance of existing reinforcement concrete bridge piers with hollow rectangular section”, Engineering Structures Vol. 144, page No. 88-106.

[2]. Cheon, Kim, Lee, and Shin 2012 “Inelastic Behavior and Ductility Capacity of circular Reinforced Concrete Bridge Piers”. Magazine of Concrete Research Volume 64 Issue 10 Page No. 919–930.

[3]. Choi, Kim, Lee, and Shin. 2012 “Performance assessment of hollow RC bridge column sections with reinforcement details for material quantity reduction”.Magazine of Concrete Research Volume 65 Issue 21 Page No. 1277-1292.

[4]. Kim, Shin and Chang-Ho Sun 2012“Concrete contribution to initial shear strength of RC hollow bridge columns”. Structural Engineering and Mechanics, Vol. 41, No. 1 Page No. 43-65.

[5]. Dr. Vassilis K.Papanikolaou and Kappos A.J 2009“Numerical Study Of Confinement Effectiveness In Solid And Hollow Reinforced Concrete Bridge Piers”. Engineering Structures Vol.131 Page No. 90-100.

[6]. Giulio RANZO and M J N Priestley 2000 “Seismic Performance Of Large RC Circular Hollow Columns”. University of California San Diego, La Jolla, CA, USA 12 WCEE Page No. 0250

[7]. J.B. ManderM.J.N. Priestley and R. Park (1983) “Behaviour Of Ductile Hollow Reinforced Concrete Columns”. Conference on Earthquake Engineering. Page No. 273-290.

[8]. ck-Hyun Kim, Chang-Ho Sun and Myoungsu Shin (2012) “Concrete contribution to initial shear strength of RC hollow bridge columns”,Structural Engineering and Mechanics, Vol. 41, No. 1 (2012) 43-65–

[9]. K.R. Bindhu and K.P. Jaya 2010 “Strength And Behaviour Of Exterior Beam Column Joints With Diagonal Cross Bracing Bars”, Asian journal of civil engineering (building and housing) vol. 11, no. 3 pages 397-410

[10]. Bo Wang, Tao Wu, Huijuan Dai, Yongtao Bai January 2018 “Experimental Investigation on Seismic Behavior of Steel Truss RC Column Hybrid Structure With Steel Diagonal Braces”, Applied Sciences Vol 8,131.

[11]. Rahmani Kadarningsiha, Imam Satyarnoa, Muslikha, Andreas Triwiyono (2014) “Proposals of beam column joint reinforcement in reinforced concrete moment resisting frame”, Procedia Engineering 95 Page No. 158 – 171

[12]. Zigang , Qiang Han, Chao Huang 2016 “Behavior Evaluation For Reinforced Concrete Columns With Rectangular Hollow Section Subjected To Axial Compression And Biaxial Bending”, The Baltic Journal

[13]. Of Road And Bridge Engineering Volume 11(1): 53–61.

[14]. Hadi, M. N. S., Jameel, M. T. & Sheikh, M. Neaz. 2017 “Behavior of circularized hollow RC columns under different loading conditions”, Faculty of Engineering and Information Sciences - Papers: Part B. 18.

[15]. Shetty M.S. Concrete Technology, Chand S. and Co. Ltd., India (2005)

[16]. IS: 456-2000, 'Plain and Reinforced Concrete - Code of Practice" Bureau of Indian Standards, New Delhi, India.

[17]. IS 10262 : 2019 , “Concrete Mix Proportioning – Guidelines” Bureau of Indian Standards , New Delhi, India