AN EXPERIMENTAL INVESTIGATION ON CONCRETE FILLED ALUMINIUM TUBULAR SECTION RETROFITTED BY USING BASALT STRIPS

JONI M[1], REXIN C[2], ADAL MENGESHA[3], HIBRETU KASKE KASSA[4]

[1,3 & 4] *Department of Civil Engineering, Debre Tabor University, Debre Tabor, Amhara Region, Ethiopia.*
[2] *Department of Civil Engineering, Maria Engineering College, Kanyakumari District, Tamil Nadu, India.*

***

Abstract- *An experimental investigation on concrete filled aluminium tubular section retrofitted using basalt Strips is presented in this paper. Different methods are being adapted for retrofitting and repairing works. The external strengthening of basalt fibre material is emerging as a new trend in enhancing the structural performance of tubular members to counteract the drawbacks in using the past rehabilitation work. In this present study, an experimental investigation has been carried out on compression behaviour of concrete filled rectangular aluminium tubular column and strengthening by basalt fibre reinforced plastic under axial compression.*

For the experimental work, totally ten columns of 44.75mm x 101.6mm x 1.35mm with 300mm height were casted. Out of the ten columns, one column was a control column and remaining columns were tested up to the failure of 60%, 70% and 80% of the ultimate load of control column under axial compression. The nine specimens are strengthened after damaged by three layers of 40mm width basalt strips and with three different spacing of 25mm, 46mm and 90mm respectively. The retrofitted specimens were tested for finding the ultimate load capacity under axial compression.

Finally, the experimental results of a normal sample are compared with the retrofitted samples. From the comparison the results show that the column with less spacing of basalt strips gives better performance when compared with a column with the larger spacing of basalt strips.

Key Words- Compression behaviour, Aluminium Tubular column, basalt strips, retrofitting.

1. INTRODUCTION

For the past few decades, Concrete Filled Tubes were widely used in the construction industry due to its attractive solutions. These members are ideally suited for all applications because of their effective usage of construction material which leads to high compressive strength, excellent fire resistance, low cost and rapid construction. The steel and the concrete element in a composite member complement each other ideally thus the advantages of both are maximally utilized.

Aluminium tubular column (ATC) members are increasingly used in structural applications in recent years due to their lightness, high strength-to-weight ratio, corrosion resistance, ease of production, recyclable and availability. Vinyl Ester Resin is an adhesive material used for binding Aluminium and basalt fibres. The local buckling of composite column is delayed because it can only buckle outwards due to the concrete core inside. Concrete filled tube columns are suitable in high seismic regions since concrete delays the local buckling of steel hollow sections and increases the ductility of the section significantly [2]. The structural behaviour of CFST elements are considerably affected by the difference between the Poisson‘s ratios of the steel tube and concrete core, From the stress distribution diagram the stresses in steel tubes occurs 1.5 to 2.5 times more than concrete is observed[3]. Mostly deflection was delayed due to the increased in wrap fibre of CFRP and BFRP [4][5]. The majority of these studies found that using of different fibres improving the load carrying capacity of column as well as their ductility index[2][4][5][10]. Commonly the buckling problems lead to strength reduction which can be reduced by the wrapping of FRP sheets [6]. Ultimate load capacity values changes according to the cross sectional shape, steel wall thickness and concrete compressive strength [7]. Also very few researches examined the structural behaviour of aluminium tube, alloy columns sections with CFRP under axial loads. The failure mode of the strengthened aluminium tubular sections changed as the slenderness ratio increases [8]. To prevent the column failure at the ends it is strengthening using FRP sheets [9]. This paper aims to investigate the behaviour of concrete filled aluminium tubular section retrofitted using basalt Strips with different spacing under different loading stages.

2. MATERIAL SELECTION

2.1 Material Description

2.1.1 Aluminium Tube

For this experimental investigation the aluminium tubular sections are provide by Jindal Aluminium Ltd with the test certificate which contains the mechanical and chemical properties of the section shown in table 1 and 2

Table -1: Properties of Aluminum Tubular Section

Parameter	Symbol	Value	Unit
Height of the section	H	101.60	mm
Width of the section	B	44.75	mm
Thickness of the section	T	1.35	mm
Cross sectional area	A	387.9	mm^2
Weight per meter	W	1.013	Kg/m
Mass	M	16	kg
Second moment of inertia	I_{xx}	521249.156	mm^4
Second moment of inertia	I_{yy}	145945.625	mm^4
Section modulus	S_{yy}	6522.709	mm^3
Radius of gyration	R_x	36.66	mm
Radius of gyration	R_y	19.398	mm
COG distance in x direction	X_{cog}	22.375	mm
COG distance in x direction	Y_{cog}	50.8	mm

Table -2: Chemical properties of Aluminum Tubular Section

Compou	Mg	Si	Mn	Fe	Cu	Zn	Ti	Cr	Al
% of Composition	0.53	0.42	0.01	0.24	0.01	0.06	0	0.01	98.8

2.1.2 Basalt Fibre

Basalt fibre is a material made from extremely fine fibres of basalt, which is composed of the minerals plagioclase, pyroxene, and olivine. It is similar to carbon fibre and fibreglass, having better physical and mechanical properties than fibre glass, but being significantly cheaper than carbon fibre. For the experimental work the following specified dimensions are use

Width of the fiber to be used = 40mm

Spacing of fiber to be adopted =90mm,

46.67mm and 25mm

Number of fiber layers = 3 No's

2.1.3 Vinyl Ester Resin

The vinyl ester resin is prepared in the sequence of adding vinyl ester, promoter, accelerator and acid in the ratio of 100:2:2:1. The vinyl esters with its components are shown in Fig 1.

Fig -1: Aluminium Tube Sample, Pictorial View of Basalt Fibre and Vinyl Ester Resin.

3. EXPERIMENTAL WORK

In the experimental work totally 10 number of aluminium tubular column specimens filled with M25 grade concrete were tested after 28 days of curing. The Aluminium tubes had a dimension of 44.75mm x 101.65mm x 300mm with a thickness of 1.35mm is used. At the initial stage of testing among these 10 specimens, ultimate compressive strength of one specimen is determined. The rest of specimens are grouped into three categories and they are damaged to 60%, 70% & 80% of the ultimate loading. These damaged specimens are then retrofitted using basalt fiber strip and with different spacing of 90mm, 46mm and 25mm. Three specimens are required for one category and after 7 days of curing these samples are tested in the compressive testing machine with axial loading condition to determine the ultimate loading capacity of the retrofitted sample.

3.1 Casting and Curing

The compaction of the specimen is done by the table vibrator. For filling the aluminium tube a base plate is provided at the bottom of the specimen, so that the concrete can be placed as shown in Fig 2. After the initial setting of concrete the base plates are removed.

Fig -2: Casting and Curing of ATC

The aluminium tubular column filled with concrete is cured by closing the top and bottom opening of the sample using the glass paper and plastic tape without any opening as shown in Fig 2. So that there will not be any loss in water.

3.2 Retrofitting

After damaging the specimen to 60%, 70% and 80% of the ultimate load the retrofitting can be done. For the process of retrofitting basalt fiber strips of 40mm wide is used as a restoring member. To avoid the column failure at both the end of the column basalt strips are provided at both the ends. The remaining strips are placed at 90mm, 46mm and 25mm spacing from both the end strips of the specimen. The number of basalt strip layers is maintained constantly as 3 throughout the experiment. The basalt fiber details are shown in table 3. The rapped basalt fiber strip is bonded to the aluminium tube by vinyl yester resin is cured by placing the sample in room temperature for 7 days to ensure proper bonding. The retrofitted sample is shown in Fig 3.

Fig -3: Retrofitted ATC sample

Table -3: Basalt Fiber Details

Specimen Designation	No. of Layers	Width of Fiber (mm)	Spacing of Fiber (mm)
1ATC	-	-	-
2ATC60(I)	3	40	90
3ATC60(II)	3	40	46
4ATC60(III)	3	40	25
5ATC70(I)	3	40	90
6ATC70(II)	3	40	46
7ATC70(III)	3	40	25
8ATC80(I)	3	40	90
9ATC80(II)	3	40	46
10ATC80(III)	3	40	25

3.3 Specimen Labelling

The test specimens were labelled such that the type of material, Percentage of loading, spacing of basalt fibre and number of the specimen can be identified from the label.

The 60, 70, 80 in the specimen label indicates the percentage of initial loading of the sample. The specimen without this number is the nominal sample in which the ultimate load has been find out. The following notation I, II & III indicates 90mm, 46mm & 25mm spacing of basalt fiber respectively i.e. ATC60(I), ATC70(I), `ATC80(I) indicates 90mm spacing between the strips. The specimen details are shown in table 4.

Table -4: Specimen Details

Specimen designation	Depth (mm)	Width (mm)	Thickness (mm)	Length (mm)	L/D Ratio	Weight (gm.)
1ATC	44.75	101.65	1.35	300	6.7	3401
2ATC60 (I)	44.75	101.65	1.35	300	6.7	3366
3ATC60 (II)	44.75	101.65	1.35	300	6.7	3372
4ATC60 (III)	44.75	101.65	1.35	300	6.7	3346
5ATC70 (I)	44.75	101.65	1.35	300	6.7	3346
6ATC70 (II)	44.75	101.65	1.35	300	6.7	3365
7ATC70 (III)	44.75	101.65	1.35	300	6.7	3353
8ATC80 (I)	44.75	101.65	1.35	300	6.7	3409
9ATC80 (II)	44.75	101.65	1.35	300	6.7	3423
10ATC80(III)	44.75	101.65	1.35	300	6.7	3454

3.4 Specimen Testing Procedure

A typical concrete-filled aluminium composite column is shown in Fig 4. A servo-controlled hydraulic compressive testing machine was used to apply compressive axial force to the column specimens. Before testing both ends of the columns were milled flat and levelled to ensure the load was applied uniformly on the column specimens. The column specimen was centred inside the testing machine to ensure that the compressive axial load was applied without any eccentricity on the specimen. The load was applied on the columns in uniform axial compression over the concrete and aluminium tube from the bottom, as shown in Fig 4. The application of the load was continued until the failure of columns takes place and then the load was noted from the display of CTM. The dimensions of the sample are measured to find the displacement.

Fig -4: Experimental Setup

4. RESULTS AND DISCUSION

4.1 Compressive Strength of Concrete

Testing the 150 x 150 x 150 mm cube after 28 days of curing the following test results are obtained is shown in table 5.

Table -5: Compressive Strength of Cube

Grade of concrete	Ultimate Load (KN)	Average Ultimate Load (KN)	Average Compressive Strength (N/mm2)
M25	655.0	651.03	28.94
	647.5		
	650.6		

4.2 Ultimate Compressive Strength

The ultimate compressive strength has been measured for the entire concert filled aluminium tubular column. The test strength of the samples is shown in table 6.

Table -6: Ultimate Load of the Samples

Specimen Designation	Control Beam Ultimate Load (KN)	Initial load (KN)	Ultimate Load After Retrofitting (KN)
ATC60(I)	215	129	327.7
ATC60(II)	215	129	346.4
ATC60(III)	215	129	371.7
ATC70(I)	215	150.5	329.1
ATC70(II)	215	150.5	359.5
ATC70(III)	215	150.5	372.3
ATC80(I)	215	172	324.5
ATC80(II)	215	172	360.5
ATC80(III)	215	172	379.5

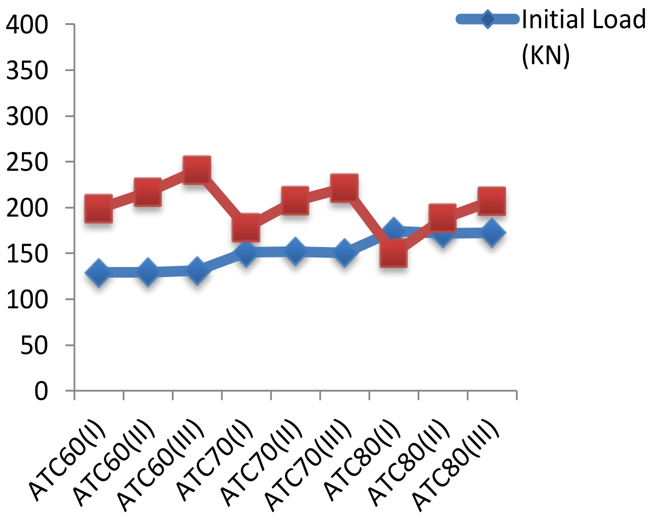

Chart -1: Initial load Vs. Ultimate Load for the samples

The specimens bonded with basalt fibre sustained higher strength and greater lateral deformation control than the normal specimen. While during damaging the specimen at various percentages of ultimate loads local buckling of aluminium tube was observed for relatively every specimen. From the above Chart 1, it was evident that all the specimens wrapped with BFRP showed a considerable increase in ultimate load carrying capacity over normal sample. This increase in load carrying capacity of the specimen's increases with the increase in number of layers and it decreases with the increase in space between the fibre strips. The confinement provided by the fibre is more in case of ATC (III) wrapped specimens when compared to ATC (I) and ATC (II) wrapped specimens of all cases. The percentage increases for the retrofitted samples are shown in the Chart 2 and the values are shown in table 7.

Table -7: Load Details of Retrofitted Samples

Specimen Designation	Initial Load (KN)	Load After Retrofitting (KN)
ATC60(I)	129	198.7
ATC60(II)	129.6	216.8
ATC60(III)	131.2	240.5
ATC70(I)	151.1	178
ATC70(II)	152	207.5
ATC70(III)	150.8	221.3
ATC80(I)	174.3	150.2
ATC80(II)	172	188.1
ATC80(III)	172.5	207

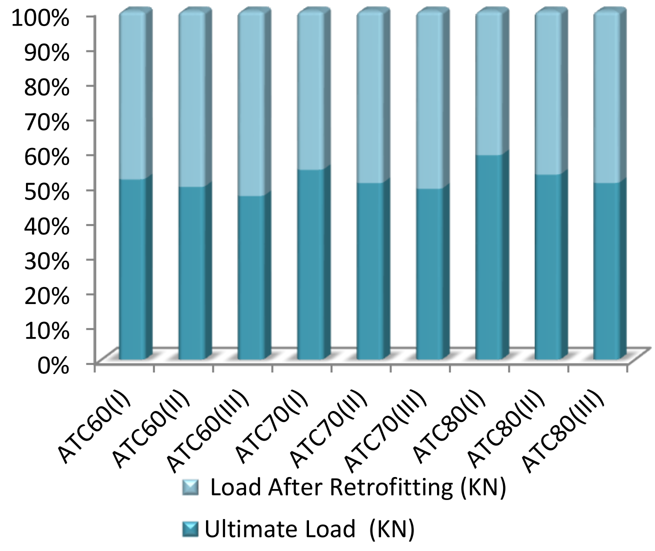

Chart -2: Load Percentage between specimens before and after retrofitting

4.3 Effect of Distribution of BFRP Layers

Basalt fiber gives good lateral confinement to the aluminium tubes in the aspect of increasing the axial load carrying capacity of the specimen. In the experimental work the number of layer is constantly maintained and the effect of change in spacing of basalt strips is shown in the chat 3. It shows that for ATC (I) the ultimate load increase from 52% to 55%, ATC (II) the ultimate load increase from 61% to 67% and for ACT (III) the load increase from 72% to 76%. in ATC60 specimens in the bar chart clearly shows that for the partially wrapped specimens the enhancement in load carrying capacity and deformation control decrease with the increase in the spacing between the basalt strips because the confinement provided by the fibre decreases.

4.4 Effect Due To Damage Percentage

In the experimental work the aluminium tubular column are damaged at 60%, 70% and 80% of the ultimate load. From the above results the efficiency of BFRP strips on damaged columns are notified in the chart 4.

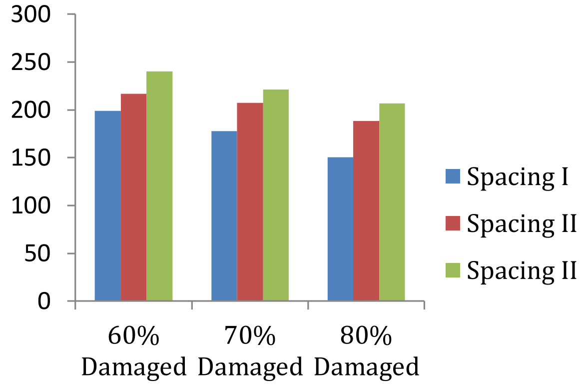

Chart -3: Variation of Load With Respect to BFRP Spacing

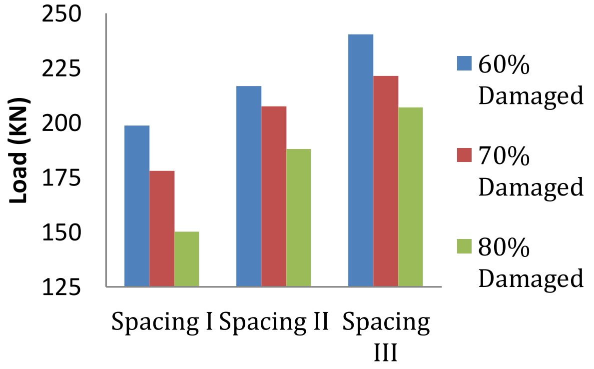

Chart -4: Variation of Load With Respect to Damage Percentage

It clearly shows that when the damage of the specimen increases the efficiency of BFRP decreases. For 80% damaged specimen the ultimate load is less comparing 60% and 70% damaged specimens even though the spacing of the fiber is reduced it did not take much effect on the sample.

4.5 Deformation Control

The control of deformation is clearly observed in BFRP strengthened aluminium tubular columns when compared with the normal specimen. The BFRP as a strengthening material efficiently delays the buckling and hence significantly controls the deformation of aluminium tube. From the observed experimental results it has been evident that the deformation control is much greater since damaging the sample before retrofitting cause initial deformation on the structure. After the deformation the specimens are strengthen by BFRP. After strengthening the specimen with stand the same amount of loading without any deformation. While the deformation accrues in between the spacing of the strips it shows that there is reduction of BFRP confined area in those cases.

4.6 Failure Modes

The columns were symmetrically loaded until failure so that the influence of BFRP on the compressive behaviour of ATC can be analysed. Furthermore the columns were still loaded after failure to understand the failure pattern. The unstrengthen ATC exhibited a distinctive buckling failure i.e. elephant's foot buckling at the end of the column in which Ring buckles were developed along the circumference of the unstrengthen columns which is shown in Fig 5. Columns which are strengthened with three layers of BFRP the same failure pattern was observed and outward buckling near the column ends causes the rupture of BFRP due to higher deformation caused by smaller thickness.

Fig -5: Elephant's Foot Buckling, Buckling Fold & Ruptured BFRP

But the buckling was delayed significantly in these columns and some amount of inward buckling also was observed which was due to the resistance offered by the BFRP against outward buckling. In the ATC specimens, a noticeable elephant's foot buckling fold at the bottom end was observed and crushing of BFRP was occurred with further increase in load, the fibre also starts rupturing and the failure was dominated mainly by the buckling of the aluminium only. The buckling fold was observed at the space between the strips of the columns and is shown in Fig 5. It is due to space between two consecutive BFRP strips the confining pressure offered by the BFRP is absent and those areas were subjected to additional strain compared to the confined area.

Even after failure there is not much deformation but further increase in load leads to the rupture of fibre and breaking of aluminium tube occurs afterwards. The ruptured BFRP is shown in Fig 5. There was no observation of delamination of fibres in any of the wrapped specimens and the reason is due to good bond between the aluminium tube and the BFRP.

5. CONCLUSION

This paper presented an experimental study on concrete-filled aluminium rectangular columns. Longitudinal wrapping of bidirectional BFRP strips over aluminium tubular columns was put forth in this research work. The performance was observed and discussed in terms of failure modes, retrofitting effect and load carrying capacity. Based on the axial compression tests on the BFRP wrapped aluminium tubular columns, the following conclusions are made.

- The axial compressive behaviour of BFRP strengthened aluminium tubular columns was enhanced in terms of strength, by reducing the lateral deformation and increasing the load carrying capacity when compared to unstrengthen aluminium tubular column.

- In unwrapped aluminium tubular column, the outward buckling of aluminium tube was observed as the inward buckling was prevented by in filled concrete it shows the composite action of the specimen.

- The overall buckling of the aluminium tube was delayed and it was followed by crushing of resin and rupture of BFRP strips.

- The retrofitted sample with stand above 5 minutes after the failure load without any crushing of material so that it can be used in high earth quake zone to prevent sudden collapse of buildings can be prevented.

- For the damaged samples after retrofitting strength increased from 60 to 80 % of its ultimate strength it shows that BFRP can be used as an restoring element in the damaged structures.

- The Bonding between the aluminium tube and BFRP shows greater efficiency so that this combination can be used for future experimental works.

- The crushing of concrete is not exhibited in any samples it shows the concrete reaches its maximum compressive strength as per design mix which indicate the curing method works perfectly for these kinds of composite members.

- In the experimental work it shows that for 80% damaged structures after retrofitting the strength increase up to 76% it shows that for highly damaged buildings and damaged members this method can be applied.

- In the experimental work deformation accrues less at the centre of the specimen than at the ends after retrofitting which shows the thickness provided for the specimen was not sufficient so for future works the thickness of specimens should be increased.

- From the results, it was clear that the spacing of BFRP strips played a dominant role in the strengthening of aluminium tubular columns, as the ultimate compressive strength increases with respect to the increase in BFRP area.

REFERENCES

[1] Rexin C, Sakthieswaran N, "Effect of Retrofitting on Concrete Filled Aluminium Tubular Section Using Basalt Strips" International Journal for Research in Applied Science & Engineering Technology, Vol. 04, Issue V, May 2016, Issn 2321-9653.

[2] Ghorapade A P & Jadhav H S, "Study of Behaviour of Hollow Square Steel Column Strengthened with CFRP" International Journal of Engineering Research, Vol. 03, Issue 03, June2015, Issn 2321-7758.

[3] Bedage S D & Shinde D N, "Comparative Study of Concrete Filled Steel Tubes Under Axial Compression" International Journal of Engineering Research, Vol. 03, 2015, PP. 465-471.

[4] Kiruthika P, Balasubramanian S & Jegan J, "Strengthening of Concrete Filled Steel Tubular Columns using FRP Composites" International Journal of Innovative Research in Science, Engineering and Technology, Vol. 04, Issue 4, April 2015, e-Issn 2319-8753, p-Issn 2347-6710.

[5] Akshay P Mote & Jadhay H S, "Experimental Study of Axially Loaded RC Short Columns Strengthened With Basalt Fibre Reinforced Polymer Sheets" Journal of Engineering Research and Applications, Vol. 04, Issue 7, July 2014, Issn 2248-9622.

[6] Sundarraja M C & Shanmugavalli B, "Experimental Investigation on the Behaviour of CHS Short Columns Strengthened Using FRP Composites under Compression", International Journal of Advanced Structures and Geotechnical Engineering, Vol. 03, Issue 2, April 2014, Issn 2319-5347.

[7] Burak Evirgen, Ahmet Tuncan & Kivanc Taskin, "Structural Behaviour of Concrete Filled Steel Tubular Sections (CFT/CFSt) Under Axial Compression" Thin-Walled Structures, Vol. 80, March 2014.

[8] Zahurul Islam S M & BenYoung, "Web Crippling of Aluminium Tubular Structural Members Strengthened by CFRP" Thin-Walled Structures, Vol. 59, October 2012.

[9] Feng Zhou & Ben Young, "Tests of Concrete-filled Aluminum Stub Columns" Thin-Walled Structures, Vol. 46, March 2008.

[10] Selvamony C, Anandakumar R & Kannan S U, "Retrofitting of Concrete Specimens and Reinforced Concrete Piles Using Basalt Fibres" International Journal of Engineering Science, Vol. 02, Nov 2015, e-Issn 0974-6846, p-Issn 0974-6846.

[11] Darshika K Shah, Merool D Vakil & Patel M N, "Behaviour of Concrete Filled Steel Tube Column" International Journal of Engineering Development and Research, Vol. 02, Issue 1, 2014, Issn 2321-9939.

[12] Dundu M, "Compressive Strength of Circular Concrete Filled Steel Tube Columns" Thin-Walled Structures, Vol. 56, April 2012.

[13] Feng Zhou & Ben Young, "Concrete-filled Aluminum Circular Hollow Section Column Tests" Thin-Walled Structures, Vol. 47, May 2009.

[14] Kadhim Zuboon Nasser, "Structural Behaviour of Concrete Filled Aluminium Tubular Columns" Basrah Journal for Engineering Science, Vol. 01, 2012.

[15] Anil Kumar Patidar, "Behaviour of Concrete Filled Rectangular Steel Tube Column" IOSR Journal, Vol. 04, Issue 4, Dec 2012, Issn 2278-1684.

[16] Zahurul Islam S M & Ben Young, "FRP Strengthened Aluminium Tubular Sections Subjected to Web Crippling" Thin-Walled Structures, Vol. 49, Issue 11, Nov 2011.

[17] Zeghiche J & Chaoui K "Experimental Behaviour of Concrete-Filled Steel Tubular Columns" Constructional Steel Research, Vol. 06, Issue1, January 2008.

[18] Shetty M S, "Concrete technology Theory and Practice" Chand S & Company Ltd, 2012.