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Slenderness Effect on Axially Loaded RC Columns Confined with FRP Sheets and Ferrocement

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Abstract - The aim of providing column confinement is to increase the load carrying capacity, enhancement of ductility and for seismic up gradation. In this paper an analytical investigation on columns confined with FRP sheets and ferrocement is carried out. The deformation characteristics of confined and unconfined columns are investigated under various support conditions and varying slenderness ratio. From the study it is observed that ferrocement confinement is more effective in terms of deformation.

Key Words: Confinement, Column, Deformation, Ferro cement, Fibre reinforced polymer (FRP), Retrofitting

1. INTRODUCTION

Retrofitting technique is an emerging as well as most widely used technique in construction industry. It is used to strengthen structurally deficient member. Among this column retrofitting play an important role, this is because column is an important structural element which transfer the entire load of the super structure to foundation safely. Now a days various retrofitting techniques are available. Among the various technique, jacketing is mostly acceptable one. Column jacketing can be done by following ways, confinement with ferrocement and confinement with FRP etc.

Confinement with FRP and ferrocement are effective retrofitting technique for axially loaded short RC columns. But its effectiveness with varying slenderness ratio is to be investigated. The aim of the present study is to investigate the effectiveness of axially loaded circular RC column with FRP and ferrocement confinement. Finite element software ANSYS 17 is used for analytical investigation. Therefore, the study program has been performed to:

1. Evaluate the effectiveness of external jacketing of CFRP sheets and ferrocement on circular RC columns with varying slenderness ratio

2. Compare and study the deformation characteristics of both axially loaded confined columns and unconfined columns.

2. ANALYTICAL INVESTIGATION

In the current scenario analytical investigation regarding ultimate load carrying capacity of column confinement is limited. So the present study is to develop finite element models for circular unconfined columns and columns confined with FRP sheets as well as ferrocement to investigate the ultimate load carrying capacity of column confinement. The details of the model are discussed The details of the model are discussed in the following sections.

2.1 MODELLING OF THE COLUMN

Two possible retrofitting strategies using ferrocement and FRP sheets is considered. Thirty-nine circular confined and unconfined columns with varying slenderness ratios are modelled and analysed under constant axial load 1000kN. All columns were 200 mm in diameter and were reinforced with six numbers of 12 mm diameter main bar and 6mm diameter lateral ties

The full analytical investigation comprised of:

1. Analysis of unconfined and confined columns with varying slenderness ratio 3 to 15

2. Analysis of columns with varying support conditions such as fixed free, fixed hinged, hinged hinged

Material properties and column modelling details are shown in tables 2.1 to 2.4

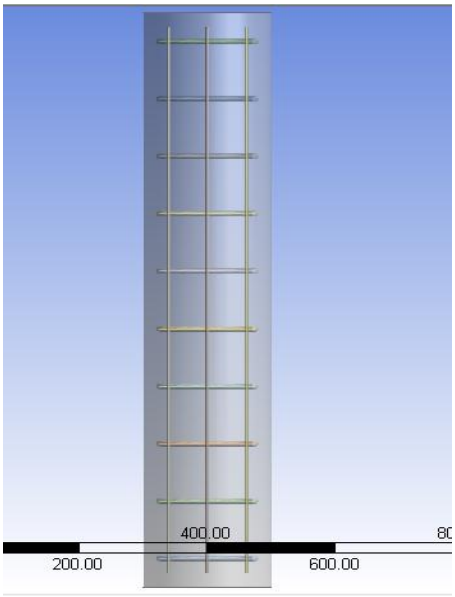

Fig 2.1-Finite element model of Unconfined concrete

Table 2.1 – Column modelling details are given

Compressive strength	20MPa
Reinforcement	Fe 415
Main bar	6 nos,10mm diameter

Lateral ties	6mm dia bar @ 100 mmc/c spacing
Ferrocement layer thickness	16mm
Diameter of column	200mm
Number of CFRP layer	1
Number of wire mesh layer	4

Table 2.2 Properties of Epoxy.

Tensile strength (MPa)	72.4
Compressive strength (MPa)	-
Tensile modulus (GPa)	3.18
Elongation	5%
Flexural strength (MPa)	123.4
Flexural modulus (GPa)	3.12

Table 2.3 Properties of Weber.tec EP high-build mortar.

Property	Days	MPa
Compressive strength	7	50
Tensile strength	7	8
Flexural strength	7	21
Modulus of elasticity	-	1500

Table 2.4 Material properties of CFRP

Elastic modulus (MPa)	Poisson's ratio	Shear modulus (MPa)	Tensile strength(MPa)	Thickness of layer (mm)
E_X =96032	υ_{XY} =0.29	G_{XY} = 2001	1353	0.37
E_Y=5400	υ_{YZ} =0.43	G_{XY} =1882		
E_Z=5400	υ_{ZX} =0.016	G_{XY} =2001		

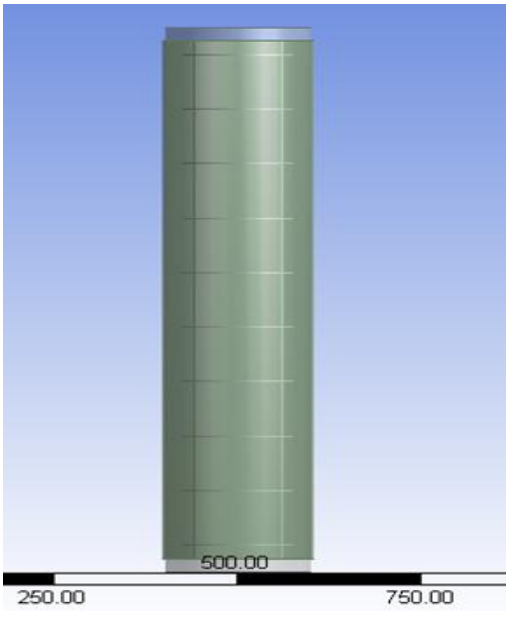

Fig 2. 2- Finite element model of FRP Confined column

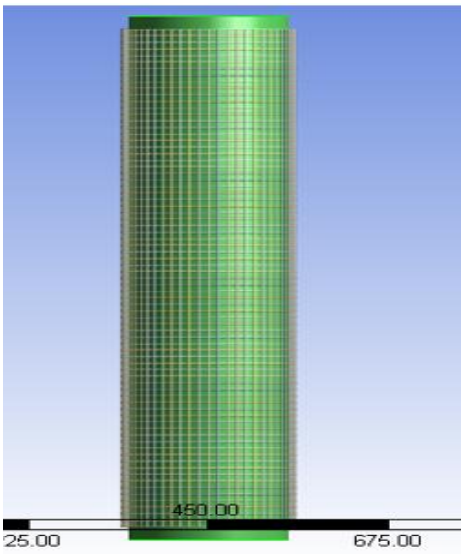

Fig 2.3- Finite element model of Ferrocement confined column

3. RESULTS AND DISCUSSIONS

The FEM analysis of columns confined with ferrocement and FRP sheet is carried out using finite element software ANSYS Workbench 17.0. The maximum load observed for unconfined column is 800kN, hence a higher load 1000kN is selected for studying the deformation characteristics on the confinement of CFRP sheets and ferrocement. The deformations of all types of columns are recorded for a constant axial load 1000kN for different support conditions (bottom fixed top free, fixed hinged support and hinged hinged support). The characteristics of the deformation- L/D ratio curves for the unconfined, FRP confined and ferrocement confined columns are summarized in Tables 3.1 to 3.4.

3.1 DEFORMATION CHARACTERISTICS OF COLUMNS UNDER FIXED FREE SUPPORT CONDITION

Under fixed free condition a constant axial 1000kN is applied on unconfined and confined columns with L/D ratio varying from 3 to 15. The values obtained in the analyse is given in table 3.1 and Fig no.3.1

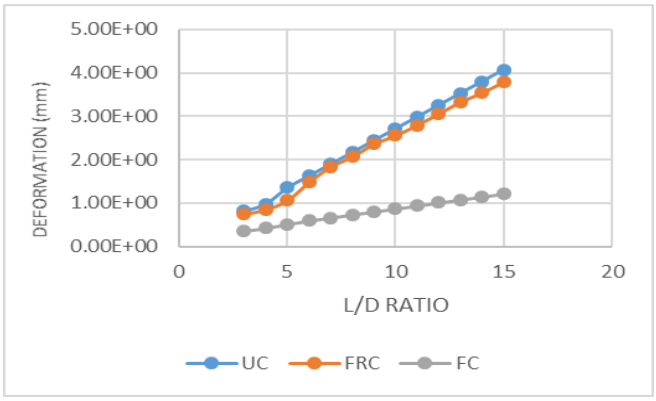

Fig 3.1 Deformation Vs L/D ratio of fixed free support

Table :3.1 –Deformations of unconfined and confined columns under fixed free support with a constant load 1000kN

L/D RATIO	DEFORMATION(mm)		
	UC	FRC	FC
3	8.13E-01	0.74785	3.54E-01
4	9.81E-01	0.8539	4.23E-01
5	1.36E+00	1.0589	5.12E-01
6	1.63E+00	1.48015	5.93E-01
7	1.90E+00	1.83625	6.63E-01
8	2.17E+00	2.0696	7.34E-01
9	2.44E+00	2.35925	7.99E-01
10	2.72E+00	2.55625	8.69E-01
11	2.99E+00	2.795	9.38E-01
12	3.26E+00	3.0531	1.01E+00
13	3.53E+00	3.32755	1.08E+00
14	3.80E+00	3.5379	1.14E+00
15	4.07E+00	3.78715	1.21E+00

UC – Unconfined column

FRC- FRP confined column

FC- Ferrocement confined column

Under fixed free support condition, the deformation of columns is Increased with increasing slenderness ratio. The deformation is more in unconfined columns. Due to confinement the deformation is decreased to an extent. From the graph it is clear that under fixed free support condition the deformation of FRP confined column and unconfined column is somewhat similar. That is FRP shows greater deformation under higher slenderness ratio. In short for slender column under fixed free support condition ferrocement confinement is more effective in terms of deformation. For L/D ratio 3, the deformation of unconfined column is 2.29 times that of ferrocement confined column and for L/D ratio 15 the corresponding value is 3.36.

3.2 DEFORMATION CHARACTERISTICS OF COLUMNS UNDER FIXED HINGED SUPPORT CONDITION

Table no:3.2 Deformations of unconfined and confined columns under fixed hinged support with a constant load 1000kN

L/D RATIO	DEFORMATION(mm)		
	UC	FRC	FC
3	5.47E-01	0.50505	2.43E-01
4	6.34E-01	0.5747	2.80E-01
5	7.00E-01	0.6357	3.12E-01
6	7.57E-01	0.6894	3.46E-01
7	8.02E-01	0.72875	3.79E-01
8	8.39E-01	0.75275	4.04E-01
9	8.71E-01	0.7832	4.33E-01
10	8.96E-01	0.80565	4.48E-01
11	9.20E-01	0.8296	4.85E-01
12	9.41E-01	0.84435	5.09E-01
13	9.59E-01	0.86835	5.26E-01
14	9.76E-01	0.8752	5.47E-01
15	9.91E-01	0.8813	5.67E-01

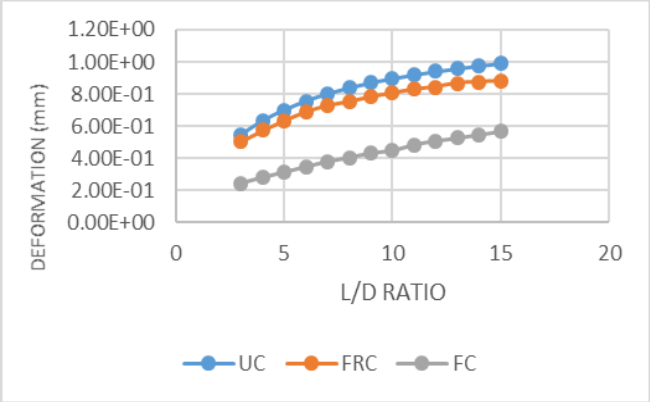

Fig 3.2. Deformation Vs L/D ratio of fixed hinged support

Under fixed hinged support condition, for L/D ratio 3 the deformation of unconfined column is 1.08 times that of FRP confined column and 2.25 times of ferrocement confined column and for L/D ratio 15 the values are 1.12 and 1.74 respectively.

3.3 DEFORMATION CHARACTERISTICS OF COLUMNS UNDER HINGED HINGED SUPPORT CONDITION

Table:3.3 – Deformations of unconfined and confined columns under hinged hinged support with a constant load 1000kN

L/D RATIO	DEFORMATION(mm)		
	UC	FRC	FC
3	7.98E-01	0.7162	0.62495
4	8.35E-01	0.74605	0.6347
5	8.61E-01	0.77355	0.649175
6	8.91E-01	0.80785	0.6646
7	9.15E-01	0.8287	0.67895
8	9.35E-01	0.83905	0.683025
9	9.56E-01	0.8557	0.69825
10	9.72E-01	0.87105	0.7095
11	9.85E-01	0.889	0.719425
12	9.99E-01	0.89575	0.731875

13	1.05E+00	0.91405	0.73785
14	1.06E+00	0.9177	0.749125
15	1.10E+00	0.91985	0.758425

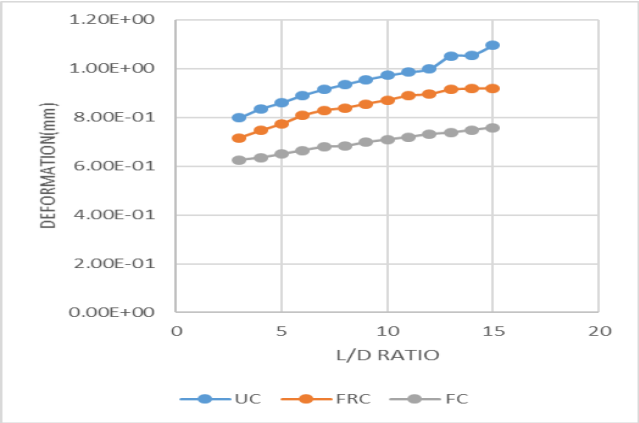

Fig 3.3 Deformation Vs L/D ratio ofr fixed hinged support

In hinged hinged support condition, for L/D ratio 3 the deformation of unconfined column is 1.14 times that of FRP confined column and 1.276 times of ferrocement confined column and for L/D ratio 15 the values are 1.19 and 1.45 respectively.

3.4 DEFORMATION CHARACTERISTIC UNDER DIFFERENT SUPPORT CONDTTION

Table :3.4 – Deformations of unconfined and confined columns under various support with a constant load 1000 kn

SUPPORT CONDITION	AXIAL LOAD 1000kN DEFORMATION(mm)						
	L/D RATIO						
	3	5	7	9	11	13	15
FIXED FREE UC	8.13E-01	1.35515	1.9002	2.4438	2.98745	3.5311	4.0748
FIXED FREE FRP	7.48E-01	1.0589	1.83625	2.35925	2.795	3.32755	3.78715
FIXED FREE FC	3.54E-01	0.51215	0.6625	0.7992	0.9381	1.0777	1.2133
HINGED HINGED UC	7.98E-01	0.8606	0.91505	0.9555	0.98535	1.05185	1.0953
HINGED HINGED FRP	7.16E-01	0.77355	0.8287	0.8557	0.889	0.91405	0.91985
HINGED HINGED FC	3.25E-01	0.4175	0.62895	0.69825	0.719425	0.73785	0.758425
FIXED HINGED UC	5.47E-01	0.7004	0.80175	0.871	0.91985	0.959	0.991
FIXED HINGED FRP	5.05E-01	0.6357	0.72875	0.7832	0.8296	0.86835	0.8813
FIXED HINGED FC	2.43E-01	0.31245	0.37875	0.4326	0.48483	0.526	0.5667

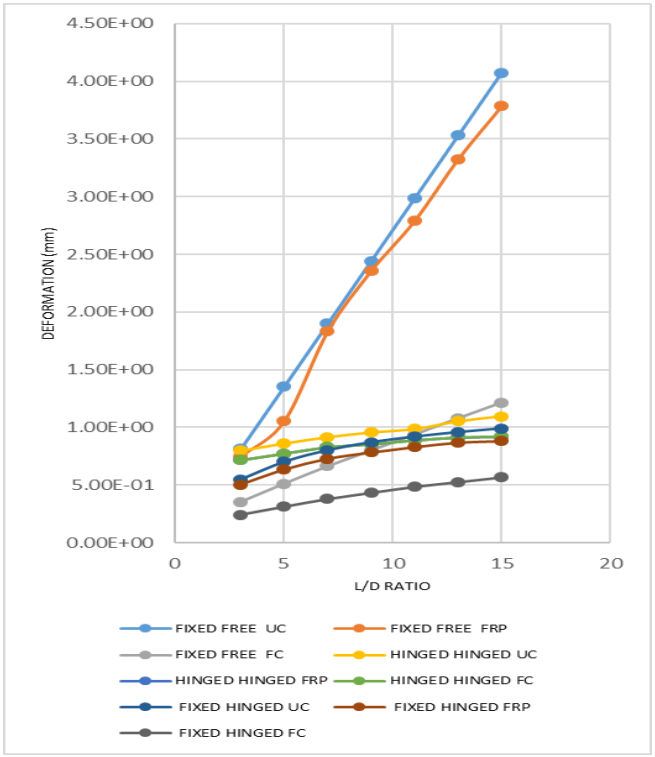

Fig 3.4 Deformation Vs L/D ratio

DISCUSSIONS

- Under all support, the deformation of columns due to the application of a constant axial load 1000kN is Increased with increasing slenderness ratio.
- Compared to fixed free support condition the deformation of columns with fixed hinged condition suffer less. For L/D ratio 3 the deformation of unconfined column is decreased to 49.5% and for L/D ratio 15 the deformation decreased 4 times that of fix free condition. Similarly, for FRP confined column corresponding values are 48% and 4.3 times and for ferrocement the values are 45.6% and 2.14 times.
- In hinged hinged support the deformation of unconfined column increased 1.46 times for L/D ratio 3 and 1.1 times for L/D ratio 15 with respect to corresponding deformation of fix hinge condition. The corresponding variation of FRP confined column is 1.41 times and 1.04 times respectively. Similarly, for ferrocement confined column the variation is 2.57 times and 1.34 times respectively.

4. CONCLUSIONS

From the study the following conclusion can be drawn:

- The deformations are maximum for unconfined columns under all conditions such as support as well as loading.

- Column confinement decreases the deformation of columns to a great extent.
- Ferrocement confinement are more effective in reducing deformations.
- Ferrocement confined columns are more stiff compare to FRP confined column, due to its increased cross sectional area.
- For slender columns ferrocement confinement is more effective under moderate load.

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