Experimentation on Strengthening of R. C. Long Columns with Externally Bonded Glass Fiber Wrapping

Amit. R. Chougule*
*Assistant Professor,
Department of Civil Engineering,
Tatyasaheb Kore Institute of Engineering & Technology (TKIET),
Warananagar, 416113, Kolhapur, Maharashtra, India

Abstract: **The aim of this paper is to highlight effectiveness and efficiency of externally bonded fiber reinforced polymer. This paper summarizes the results of experimental study related to the strengthening of R C long column strengthened with GFRP wrap under axial loading. The columns were externally bonded with Glass Fiber Reinforced Polymer (GFRP) with different layers and configuration. Fourteen reinforced concrete columns were cast and strengthened with GFRP. These were tested under axial loading. Experimental results indicate significant strength enhancement due to GFRP wrap and showed better performance than the reference column.**

Key Words: Long columns, Glass Fiber Reinforced Polymer, Ultimate load, Displacement ductility ratio,

I. INTRODUCTION:

Concrete is the most widely used man made construction material. We take concrete for granted in our everyday activities and tend to be impressed by the more dramatic impacts of technology. Concrete competes with all major construction materials like timber, steel, plastic, and asphalt because of its versatility in its applications. It is versatile and moldable in its various applications. It is having high compressive and low tensile strength. So to overcome the drawbacks of low tensile strength new techniques of reinforcing were developed. There have been fast improvements and discoveries in concrete technology.

In recent years, the construction industry has seen an increased reinstate, rejuvenate, strengthen and upgrade the structures. This may be attributed to various causes such as environmental degradation, design inadequacies, poor construction practices, increase in load due to change in usage or unexpected seismic loading condition in addition to corrosion induced distress.

Repair, rehabilitation and strengthening of structures have become a major part of construction activity in recent past. In North America approximately about 40% of the available bridges are deemed deficient, some of these deficient bridge are damaged, while other need strengthening, because design code have changed for making this structure substandard, or larger loads are permitted on the roads. This is a technique that technically sound and economically feasible to upgrade structure.

Externally bonded FRP has emerged as a new structural strengthening technology for strengthening of RC structures. It has higher strength to weight ratio, durable, less labor and equipments required for installation, ease in handling.

The main objective of this experimental study to carry out to investigate the performance of RC column strengthened with glass fiber reinforced polymer (GFRP) plates externally with different layers and configuration wise wrapping under axial loading.

II. EXPERIMENTAL PROGRAM:

A. Details of the R C long columns:

The experimentation consisted of testing of fourteen long columns. All columns had the same dimensions and reinforcement. The columns had circular cross section with 136mmϕ dia. 1700 mm height (L/D ratio = 12.59). 6mm diameter steel bars were used for longitudinal reinforcement and 6 mm diameter stirrups were spaced at every 150 mm as lateral reinforcement. The reinforcement details of the columns are given in fig. 1. The concrete mix was proportionate to target strength of 20 N/mm². Each cast used machine mixed concrete. The concrete consisted of coarse aggregate maximum size of 20 mm sieve and retained on 10mm sieve, locally available river sand and 53 grades Portland cement. The specimens were compacted by a tamping rod for good compaction.

The concrete mix was prepared to strength of 20 N/mm². Each cast used machine mixed concrete consisted of coarse aggregates passing through 20mm sieve. Locally available river sand is used as fine aggregate and 53 grades Portland cement

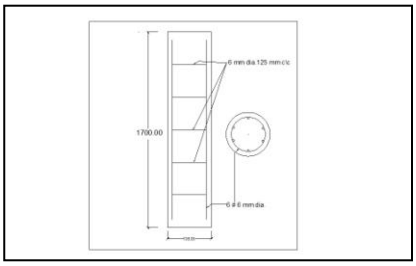

Fig.1. Reinforcement Details for long column

B. Preparation of the specimen:

The column was casted by using mould of PVC pipes. Specimens were filled using concrete and compacted using tamping rod after 24 hr. mould was removed and place specimen in a water tank for 28 days.

The test column specimens were divided into seven groups. Group I- Control column(CL), Group II- single layer full wrap(SFL), Group III- Double layer full wrap(DFL), Group IV- single layer horizontal strip wrap(SHL), Group V- double layer horizontal strip wrap(DHL), Group VI- single layer vertical strip wrap(SVL), Group VII- double layer vertical strip wrap(DVL). Strip of 100mm wide with 100mm gap between each strip. GFRP wrapping was done as per procedure given by manufacturer.

C. Test procedure and Instrumentation:

The entire long column specimens were tested on loading frame (1000KN) as shown in photo 1. The load was applied until complete failure took place. Axial deformation of column noted down at equal interval of 5KN with the help of dial gauge. Then ultimate load and corresponding deformation noted down. The load deformation curve was plotted and load deformation characteristics were studied as displacement ductility ratio. It was calculated as ratio of deformation at maximum load and deformation at yield.

Photo.1 Compression test set-up for long column

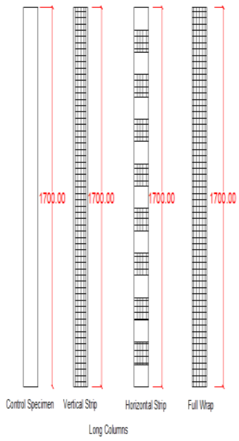

Photo.2 GFRP Wrapping Details

III. RESULT AND DISCUSSION:

The experimental result is as follows:

Group I- Control Specimen Long Column (CL):

Table .1 Long columns control specimen

Identification	Ultimate load (kN)	Average ultimate load (kN)	Deformation at yield (Δy) mm	Deformation at ultimate load (Δu) mm	Displacement ductility ratio $\mu_\Delta = \Delta u / \Delta y$	Average displacement ductility ratio μ_Δ
CL1	145	138	6.25	11.5	1.84	1.775
CL2	131		7.6	13	1.71	

Group II- single layer full wrap Specimen (SFL):

Table.2 Single layer full wrap specimen

Identification	Ultimate load (kN)	Average ultimate load (kN)	Deformation at yield (Δy) mm	Deformation at ultimate load (Δu) mm	Displacement ductility ratio $\mu_\Delta = \Delta u / \Delta y$	Average displacement ductility ratio μ_Δ
SFL1	236	250	8.85	21.8	2.46	2.43
SFL2	265		9.9	23.9	2.41	

Group III - Double Layer Full Wrap specimen (DFL):

Table.3 Double layer full wrap specimen

Identification	Ultimate load (kN)	Average ultimate load (kN)	Deformation at yield (Δy) mm	Deformation at ultimate load (Δu) mm	Displacement ductility ratio $\mu_\Delta = \Delta u / \Delta y$	Average displacement ductility ratio μ_Δ
DFL1	302	293.5	9.5	25.50	2.68	2.86
DFL2	285		8.5	25.95	3.05	

Group IV- Single Layer Horizontal Strip Wrap (SHS):

Table 4 Single layer horizontal strip specimen

Identification	Ultimate load (kN)	Average ultimate load (kN)	Deformation at yield (Δy) mm	Deformation at ultimate load (Δu) mm	Displacement ductility ratio $\mu_\Delta = \Delta u / \Delta y$	Average displacement ductility ratio μ_Δ
SHL1	188	198	7.0	15.60	2.23	2.20
SHL2	208		8.5	18.50	2.17	

Group IV- Double Layer Horizontal Strip Wrap (DHS):

Table 4 Double layer horizontal strip specimen

Identification	Ultimate load (kN)	Average ultimate load (kN)	Deformation at yield (Δy) mm	Deformation at ultimate load (Δu) mm	Displacement ductility ratio $\mu_\Delta = \Delta u / \Delta y$	Average displacement ductility ratio μ_Δ
SHL1	231	237.5	10.6	22.3	2.1	2.14
SHL2	244		10.5	22.9	2.18	

Group IV- Single Layer Vertical Strip Wrap (SVS):

Table 4 Single layer vertical strip specimen

Identification	Ultimate load (kN)	Average ultimate load (kN)	Deformation at yield (Δy) mm	Deformation at ultimate load (Δu) mm	Displacement ductility ratio $\mu_\Delta = \Delta u / \Delta y$	Average displacement ductility ratio μ_Δ
SHL1	145	148.5	7.55	14.40	1.90	1.89
SHL2	152		6.80	12.80	1.88	

Group IV-Double Layer Vertical Strip wrap (DHS):

Table 4 Double layer vertical strip specimen

Identification	Ultimate load (kN)	Average ultimate load (kN)	Deformation at yield (Δy) mm	Deformation at ultimate load (Δu) mm	Displacement ductility ratio $\mu_\Delta = \Delta u / \Delta y$	Average displacement ductility ratio μ_Δ
SHL1	156	166	9.5	18.5	1.94	1.92
SHL2	176		10.2	19.3	1.90	

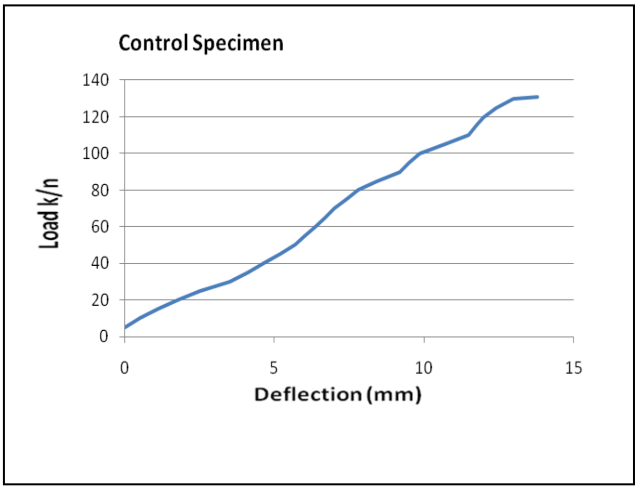

Fig.2. Load-deformation curve for control long column

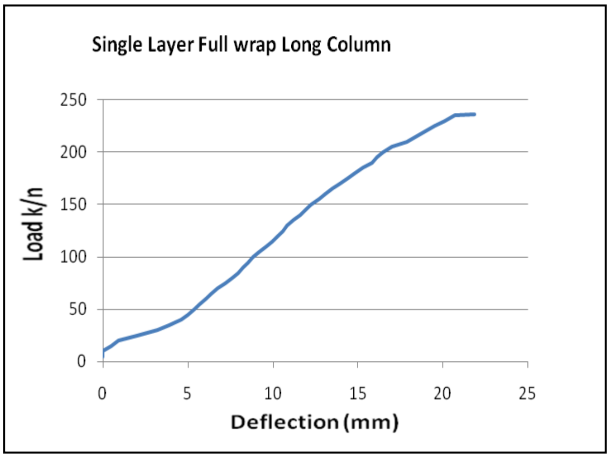

Fig.3. Load-deformation curve for single layer full wrap

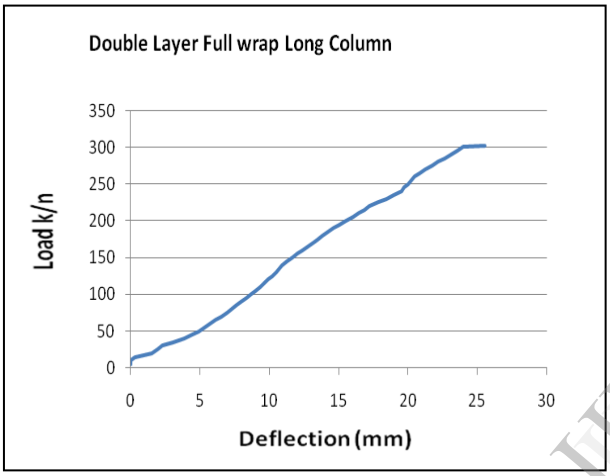

Fig.4. Load-deformation curve for Double layer full wrap

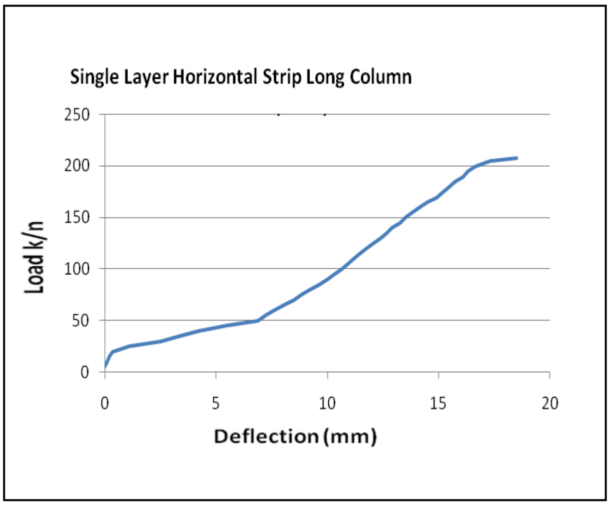

Fig.5. Load-deformation curve force Single layer horizontal strip wrap

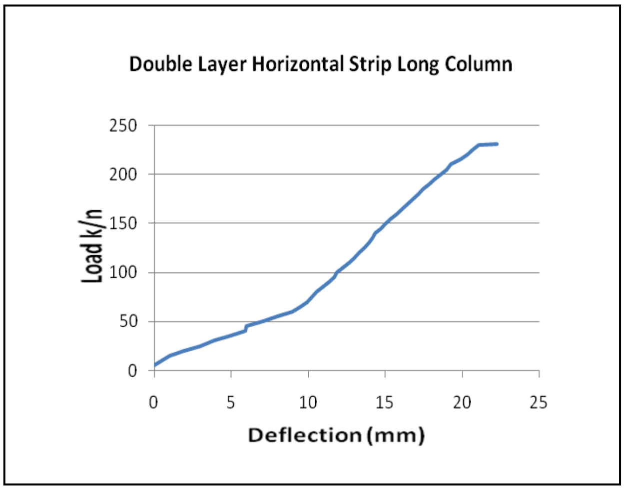

Fig.6. Load-deformation curve force Double layer horizontal strip wrap

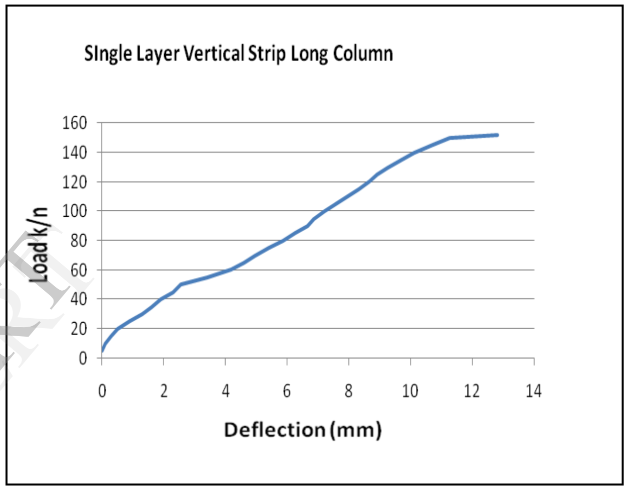

Fig.7. Load-deformation curve force Single layer Vertical strip wrap

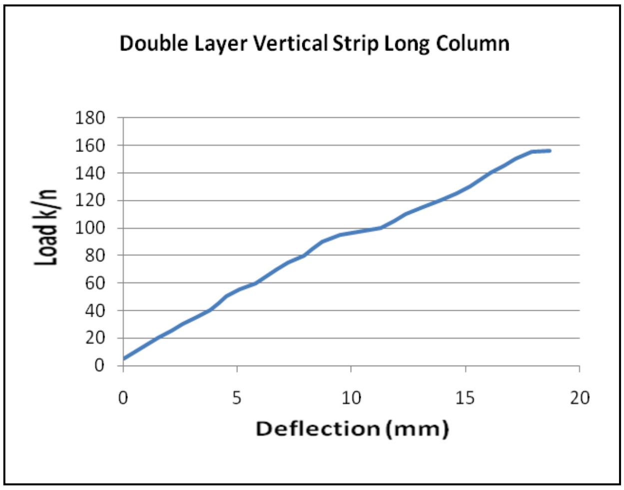

Fig.8. Load-deformation curve force Double layer Vertical strip wrap

A. Overall Results:

Test results of RCC long columns with various cases of GFRP wrapping are given in Table below and the results are compared with RCC reference column.

Table.8.Overall results for long columns with various cases of GFRP wrapping

Column marks	Description	Ultimate load (kN)	Percentage increase in ultimate load	Displacement ductility ratio $\mu_\Delta = \Delta u / \Delta y$	Percentage increase in displacement ductility ratio
CS	RCC column without GFRP wrapping (Control specimen)	138	--	1.775	--
SFS	RCC column with single layer full GFRP wrapping	250.5	81.52	2.437	37.30
DFS	RCC column with double layer full GFRP wrapping	293.5	112.7	2.865	61.40
SVS	RCC column with single layer vertical strip GFRP wrapping	148.5	8.39	1.89	6.48
DVS	RCC column with double layer vertical strip GFRP wrapping	166	20.28	1.92	6.48
SHS	RCC column with single layer horizontal strip GFRP wrapping	198	43.48	2.20	23.94
DHS	RCC column with double layer horizontal strip GFRP wrapping	237.5	72.10	2.14	20.56

B. Discussion:

The overall test results of Long RCC columns with various cases of GFRP wrapping are presented in table

[1] It has been observed that the ultimate load of RCC long columns with GFRP wrapping using various configuration and layers are higher than that of RCC long columns without GFRP wrapping. The increase in ultimate load for RCC long columns with Single layer full wrap, double layer full wrap, single layer horizontal strip wrap, double layer horizontal strip wrap, single layer vertical strip wrap and double layer vertical strip wrap are 81.52%, 112.7%, 43.48%, 72.1%, 8.39%, and 20.28% respectively.

This increment in ultimate load is obviously due to confinement offered by GFRP to RCC column. Full wrap single and double layer provide more confinement in lateral direction over the other configuration. Therefore full wrap GFRP confined column take more ultimate load. Means confinement offered by GFRP is responsible for increment in ultimate load.

[2] It has been observed that the Displacement Ductility ratio of RCC long columns with GFRP wrapping using various layers and configuration are higher than that of RCC columns without GFRP wrapping. The increase in Displacement ductility ratio of RCC columns with Single layer full wrap, double layer full wrap, single layer horizontal strip wrap, double layer horizontal strip wrap, single layer vertical strip wrap and double layer vertical strip wrap are 37.30%, 61.40%, 23.94%, 20.56%, 6.48%, and 6.48% respectively. Means due to GFRP confinement in lateral direction specimens deform more plastically before failure. Therefore confinements offered by the GFRP wrapping are responsible for increase in displacement ductility ratio.

IV. CONCLUSION

- Load carrying capacity for double layer full GFRP wrap was increased by 112.7% as compared to reference column.
- The value of displacement ductility ratio of RCC short column for single & double layer full wrapped with GFRP is observed to increase by 37.30% & 61.40% as compared to that of reference column.
- GFRP confinement in lateral direction is responsible for increment in Ultimate load, Displacement ductility ratio.
- The results shows that, applying GFRP system of double layers to the RC column is most effective than the single layer for different configuration. The ultimate load carrying capacity of RC columns can be increases by using a proper combination of GFRP sheets coupled with the proper epoxy.

V. REFERENCES

[1] A. Rajasekaran, P. N. Raghunath, K. Suguna(2008), " Effect on confinement the axial performance of fiber reinforced polymer wrapped RC column", American J. of Engineering and Applied Sciences, February., Pp 110-117
[2] Azadeh Parvin, Wei Wang (2008), "Tests on concrete square columns confined by composite wraps", The university of Toledo, Toledo, Ohio, U.S.A., Pp 1-10
[3] Baris Binici, Khalid Mosalam (2006), " Analysis of reinforced concrete column retrofitted with fiber reinforced polymer lamina", Journal of composites part B 38, May., Pp265-276
[4] B. G. Vishnuram, S. C. Natesan, K. Subramanian(2006), "Seismic retrofit of reinforced concrete columns with glass fiber reinforced polymer composites", CE & CR, October ., Pp 70-76
[5] Christopher cole And Belarbi abdeldjelil (2001), "FRP Confined characteristics of rectangular FRP – jacketed RC columns",Proceedings of the Fifth International Symposium on Fiber Reinforced Concrete Structures, Cambridge, UK, July ., Pp 823-832

[6] Dr. S. Rajamohan, M. C. Sunderaja (2007), "Strengthening of compression members with externally bonded composite fabrics – An experimental study", Journal of the Institute of Engineers – Vol.87, February., Pp 43-49

[7] M. Reza Esfahani and M. Reza Kianoush (2005), "Axial Compressive Strength of Reinforced Concrete Columns Wrapped With Fiber Reinforced Polymers (FRP)", IJE Transactions B: Applications,Vol. 18, No.1, April. pp. 1- 11

[8] M.N.S. Hadi (2007), "Behavior of FRP Strengthened Concrete Columns Under Eccentric Compression Loading" Composite Structures., pp.92-96

[9] M. S. Venkatesh, Vijay Kulkarni (2007), "Composite Fiber Wrapping For Structural Strengthening – Case Studies",CC & CR, October., Pp 50-55

[10] Nicolae Taranu, Gabriel Oprisan, Dorina Isopescu (2005), "Advanced polymeric composites and strengthening concrete structural members" Composite Structure, Vol no 31, January., pp 4-14

[11] Riad Benzaid, Nasr-Eddine Chikh, Habib Mesbah (2008), "Behavior of square concrete confined with GFRP composite wrap" Journal of Civil Engineering And Management ,March., pp 115-120

[12] R. Kumutha, R. Vaidyanathan, M. S. Palanichamy (2008), "Behavior of concrete compression specimen strengthened using glass fiber reinforced plastics" Journal of Structural Engineering, Vol. 33, No. 5, January., pp. 401-405

[13] S. W. Bae, A. Belarbi, J. J. Myers "Performance of Corrosion-Damaged RC Columns Repaired by CFRP Sheets", A report submitted to the Civil Engineering department, University of Missouri – Rolla.

[14] Tarek M. Bahaa, Hossam Z. El-Karmoty (2007), "Behavior of sandwich FRP wrapped RC columns under eccentric loading", HRBC journal, Vol. 3, August., Pp. 13-26

[15] Venkataraman Nagaradjane, Pulipaka Narasimhrao Raghunath, Kannan Suguna (2009), "Realiability of axially loaded fiber reinforced polymer confined reinforced concrete circular columns", American J. engg & Applied Sciences January. Pp. 31-38