

Experimental Study on RC Columns Wrapped With Hybrid FRP Sheets

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ABSTRACT: One of the techniques of strengthening reinforced concrete structural member is through external wrapping with high strength fibre composites. In this paper an attempt has made to study the behavior of RC columns wrapped hybrid fibre sheets. The experiment consist total 14 columns includes 2 control columns, 2 columns wrapped with single layer of CFRP sheets, 2 columns wrapped with single layer of BFRP sheets, 2 columns wrapped with 2 layer of BFRP sheets, 2 columns wrapped with 2 layer of CFRP, 2 columns wrapped with BFRP-CFRP hybrid sheets and 2 columns wrapped with CFRP-BFRP hybrid sheet. Effects of number of layers of individual FRP sheets and effectiveness of using hybrid FRP sheet to confine RC columns are investigated. The entire test specimens loaded to fail in axial compression and the ultimate load carrying capacity, axial deformation and failure or crack patterns, are investigated and the test results are compared with unwrapped specimens. The result obtained shows that the hybrid wrapping increases the load carrying capacity as well as reduces the sudden collapse of columns during loading.

KEYWORDS: Hybrid fibre sheets, Load Carrying Capacity, Axial deformation, Crack pattern.

I. INTRODUCTION

Existing reinforced concrete structures may be structurally insufficient to carry the new loading conditions requirements. Moreover, they suffer from structural degradation, reinforcement steel bars corrosion, bad weather condition etc. Due to these reasons, structural strengthening became an essential requirement and different strengthening techniques appeared in market. Fiber Reinforced Polymer (FRP) strengthening techniques established a good position among all other techniques, giving good structural results and low time required with the other techniques. Concrete columns in a structure are critical members because their failure can cause partial or even total collapse of the structure. One of the important applications of the FRP strengthening technology is in the enhancement of load-carrying capacity of RC column through the provision of confining FRP jackets (or wraps). Fiber Reinforced Polymer (FRP) is a relatively new class of composite material manufactured from fibers and resins and has proven efficient for the development and repair of new and deteriorating structures in civil engineering.

Among the FRP sheets CFRP sheets are commonly used for the purpose of retrofitting of concrete structures due to its high tensile strength, corrosion resistance, high modulus, light weight and flexibility. CFRP sheets are extremely strong and they are very costly too. This make the retrofitting technique of concrete structures by CFRP sheets become uneconomical. Even though CFRP sheets are uneconomical current practice of retrofitting of bridge columns make use of CFRP sheets because of its high strength. This study aims to investigate effectiveness of a retrofitting technique using hybrid fiber reinforced polymer sheets. Hybrid FRP sheet means instead of using multiple layers of single FRP sheet two different types of FRP sheets are used. For this study CFRP and BFRP sheets are used as hybrid sheets in order to increase the load carrying capacity of RC columns.

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II. MATERIALS USED FOR EXPERIMENTAL WORK

The materials used in this study included ordinary Portland cement, fine aggregate (manufactured sand), coarse aggregate, mixing water, CFRP sheets, BFRP sheets and epoxy resin. The cement used in all mixtures of the study was 53 grade Ordinary Portland cement, which conforming to IS 12269:2013. The fine aggregate type used in the study was manufactured sand. The coarse aggregate of size 20mm was used in the study. Potable water was used for mixing and curing of specimens throughout the experimentation. Unidirectional CFRP and BFRP sheets of thickness 0.3mm were used for the study shown in fig 1(a) and fig 1(b) respectively. Araldite AW106 with Hardener HV 953 IN was used as epoxy resin in order to bind frp sheets to concrete and also to bind layers of frp sheets together shown in fig 1(c). Equal amount of Araldite and Hardener are mixed thoroughly in order get adequate binding property.

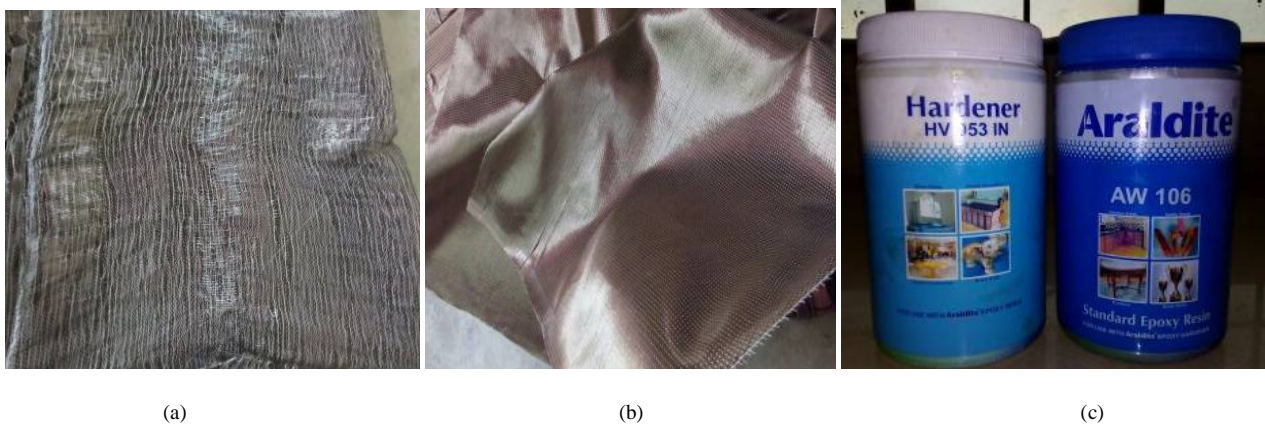


Fig. 1.(a) Unidirectional CFRP sheet (b) Unidirectional BFRP sheets (c)Epoxy Resin (Araldite plus Hardener)

III. METHOD OF CASTING OF COLUMN SPECIMENS

For the experimental study size of column considered is 150mm diameter and 600mm height and M25 grade concrete Experiment consist of total 14 columns includes 2 control columns (C0) shown in fig 2(b), 2 columns wrapped with single layer of CFRP sheets (CC1), 2 columns wrapped with single layer of BFRP sheets (CB1), 2 columns wrapped with 2 layer of BFRP sheets (CB2), 2 columns wrapped with 2 layer of CFRP (CC2), 2 columns wrapped with BFRP-CFRP hybrid sheets (CB1C1) shown in fig 2(e) and 2 columns wrapped with CFRP-BFRP hybrid sheet (CC1B1) shown in fig 2(f). Effect of number of layers of individual FRP sheets and effectiveness of using hybrid FRP sheet to confine RC columns is investigated. 4 Nos of 8mm diameter bars are used as main reinforcement and 6mm diameter bars @ 100mm c/c spacing stirrups are provided.



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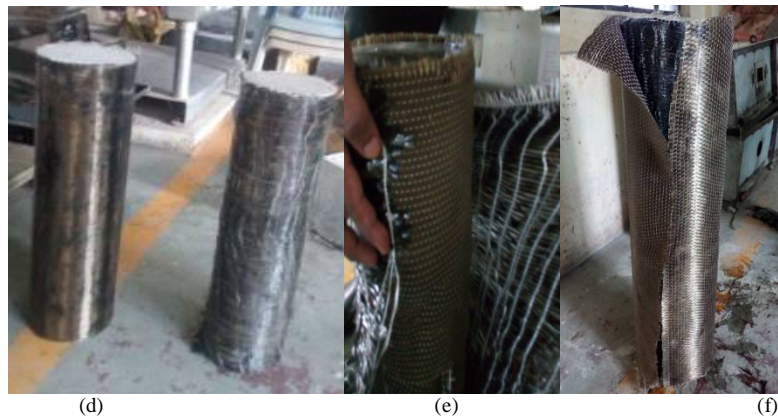


Fig. 2. (a) Mould Used for Casting of RC Column (b) Casted RC Column (c) Applying Epoxy Resin to Fix FRP Sheets to Concrete (d) Column Wrapped With 2 Layer of BFRP and 2 Layers of CFRP Sheets (e) CFRP-BFRP Hybrid Wrapping (f) BFRP-CFRP Hybrid Wrapping

IV. TEST SETUP

Compression testing of RC columns is carried out on a universal testing machine of capacity 1000kN and a dial gauge is used to measure axial deformation shown in fig 3.



Fig. 3. Test set up for RC column

V. TEST RESULTS AND DISCUSSIONS

To understand the behavior of RC columns wrapped with FRP sheets structural parameters like ultimate load carrying capacity, axial deformations and failure patterns were evaluated for control and FRP wrapped columns, respectively.

A. Load Carrying Capacity

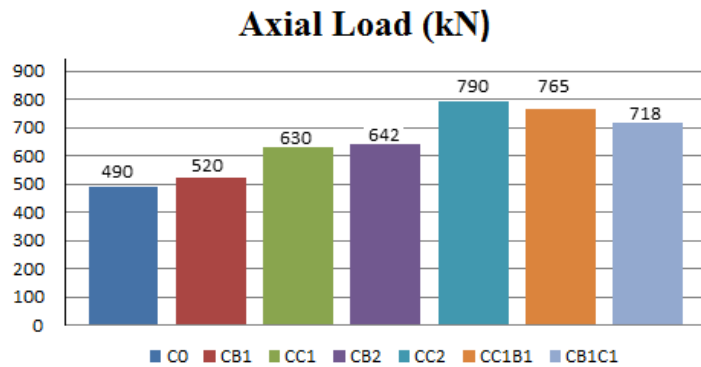


Fig. 4. Ultimate Load Failure for Columns

Fig 4 shows the load carrying capacity of RC and FRP wrapped columns and following points were concluded

- Among CB2, CC2, CC1B1, CB1C1, the highest load carrying capacity is obtained for the column CC2 (column wrapped with 2 layers of CFRP sheets) and lowest load carrying capacity is obtained for CB2 (column wrapped with 2 layers of BFRP sheets).
- The load carrying capacity of hybrid column CC1B1 (CFRP-BFRP hybrid column) is almost near to the column CC2 (column wrapped with 2 layers of CFRP sheets).
- For the columns CB2, CB1C1, CC1B1, CC2, the load carrying capacity increases to 31.02%, 46.53%, 55.5%, 61.22% respectively as compared to that for control columns.
- The load carrying capacity of RC column increases with increase in number of layers of FRP sheets. The load carrying capacity of CC1 is almost nearer to that of CB2.

B. Failure Patterns



(a)

(b)

(c)

(d)

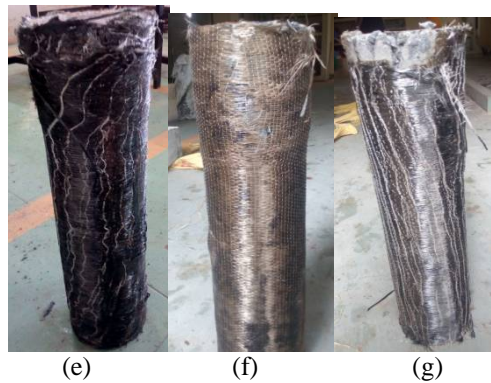
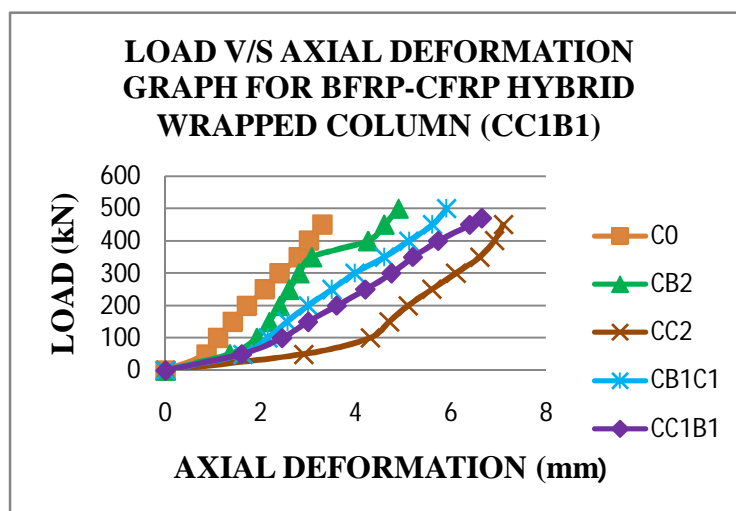


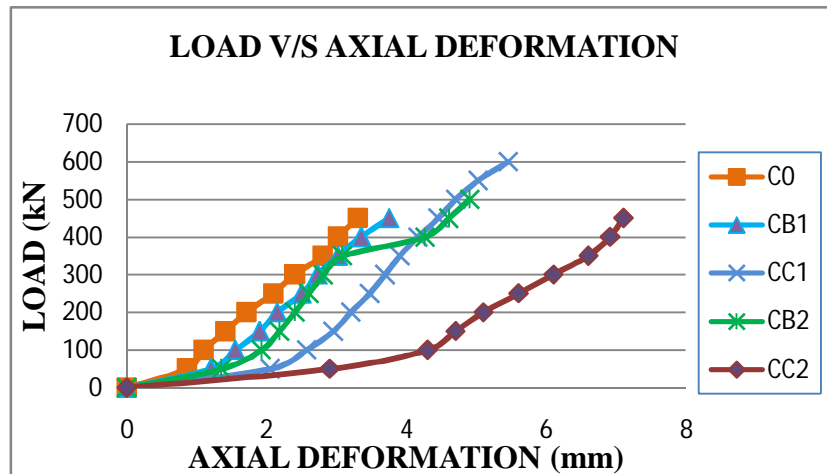
Fig. 5. Failure Pattern (a) failure of control RC column (b) Failure of Column CB1 (c) Failure of Column CC1 (d) Failure of Column CB2 (e)) Failure of Column CC2 (f) Failure of Column CC1B1 (g)) Failure of Column CB1C1

Control RC column have failed after reaching to their ultimate load carrying capacity with a blasting effect shown in fig 5(a). During the load application of all the FRP confined columns, typical sound was heard signifying the stretching of FRP sheets and crushing of epoxy resin. CB1 (column confined with 2 layers of BFRP sheets) and CB2 columns (column confined with 2 layers of BFRP sheets) were failed by the rupture of BFRP sheets at the top shown in fig 5 (b) and fig 5 (d). In case of column CC2 (column confined with 2 layers of CFRP sheets) the CFRP at the top and bottom of the column is found to be undamaged at the time of failure shown in fig 5 (g) . Among all FRP confined columns BFRP wrapped column failed suddenly by the rupture of BFRP sheets. In case of CC1B1 and CB1C1 hybrid wrapped columns failure is found to be bulging of column at the top without bursting the FRP sheets shown in fig 5 (e) and and fig 5 (f) respectively.

C. Axial Deformation



(a)



(b)

Fig. 6. Axial Deformation (a) Comparison of Effect of Hybrid Wrapping on Load v/s Deformation Graph for Columns (b) Effect of Number of Layers of Individual FRP Sheets on Load v/s Deformation Graph for Columns

FRP wrapped RC column exhibit higher axial deformation as compared to that of control column. The maximum axial deformation is obtained for the column CC2 (column wrapped with 2 layers of CFRP sheets). The axial deformations of hybrid wrapped columns CB1, CC1 are higher than that of CB2 (column wrapped with 2 layers of BFRP sheets). The axial deformations of columns are increases with increase in number of layers of FRP sheets. Comparison of axial deformation due to the effect of hybrid wrapping and effect of number of individual FRP layer are shown in fig 6(a) and fig 6(b) respectively.

VI. COST ANALYSIS OF FRP SHEETS FOR ONE COLUMN

- Cost of CFRP = 1500 Rs /m²
- Cost of BFRP = 320 Rs / m²

Column name	Cost of FRP in Rs/- for one column
C0	-
CB1	91
CC1	425
CB2	182
CC2	850
CB1C1	516
CC1B1	516

Table 1 Cost Analysis of FRP Sheet for One Column Comparing the cost of FRP required for one column, the cost of hybrid wrapped column is 40% less than that of CFRP wrapped columns.

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VII. CONCLUSION

Experimental investigations were carried out on the control and FRP wrapped column specimens using CFRP-BFRP and BFRP-CFRP hybrid wrapping. Load carrying capacity, axial deformation and failure patterns were analysed for control and FRP wrapped columns and the following conclusions were drawn.

- FRP wrapping of columns results in increasing the load carrying capacity as compared to control columns.
- Load carrying capacity of columns increases with increase in number of layers of individual FRP sheets. Load carrying capacity of single layer CFRP wrapped column (CC1) is similar to that of column wrapped with 2 layers of BFRP sheets (CB2).
- Best wrapping is found to be column wrapped with 2 layers of CFRP sheets. The load carrying capacity of hybrid columns (CB1C1 and CC1B1) is almost near to that of column wrapped with 2 layers of CFRP sheets.
- Among hybrid wrapped columns CFRP – BFRP hybrid wrapping is found to be more effective.
- Control and BFRP wrapped columns failed suddenly with blasting effect. Hybrid and CFRP wrapped columns failed without breaking of FRP sheets
- Comparing the cost of FRP required for one column, the cost of hybrid wrapped column is 40% less than that of CFRP wrapped columns. So it can be concluded that instead of using multiple layers of CFRP sheets, we can use either CFRP –BFRP hybrid wrapping or BFRP – CFRP hybrid wrapping from economical point of view.

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