A Study on Hybrid FRP Wrapped Axially Loaded RC Capsule Column

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Abstract- The use of fiber reinforced polymer (FRP) materials for structural repair and strengthening has been continuously increasing in recent years, due to several advantages associated with these composites when compared to conventional materials like steel. The study is undertaken to find out the strength of the columns by adopting hybrid FRP rovings. Four chosen wrapping patterns are wrapped around the column of different specimens of same size are preferred for the research and the strength obtained from the wrapping pattern is compared with that of the unconfined column. The cross section of the column measuring up to 150x380mm and shorter face radius measuring 75mm is casted. Three types of FRP are used in the experimental stages namely Glass, Basalt and Jute fibres. After thorough analysis the specimen CBGJ wrapped with Basalt, Glass and Jute fibre has got more axial compressive strength than other specimen chosen for study and also CBGJ wrapping pattern has got 25% more compressive strength than the unconfined column.

Index Terms-BFRP, GFRP, Jute, Strengthening, Axial compression.

1. INTRODUCTION

Over the years, engineers have used different methods and techniques to retrofit existing structures by providing external confining stresses. For the past few years, the concept of jacketing has been investigated to provide such forces [1].
Externally applied jackets, have been used as a reinforcement to contain concrete for different reasons. Engineers have used traditional materials such as wood, steel, and concrete to confine and improve the structural behavior of concrete members. Section enlargement is one of the methods used in retrofitting concrete members. This method is as old as the concrete industry itself. Steel jacketing has been proven to be an effective technique to enhance the seismic performance of old bridge columns (Priestley et al.1996) [2]. Nowadays, the use of fiber reinforced polymer has been considered the best strengthening material due to their excellent performance in the field of strengthening, repairing and retrofitting of concrete structures especially in columns. The use of FRP composites as a jacketing material around the square concrete columns can increase the strength and ductility of square columns [3]. Such strengthening technique has proved to be very effective in enhancing their ductility and axial load capacity. However, most of the available studies on the behavior of FRP confined concrete columns have concentrated on circular shaped columns with normal strength. The data available for columns of square or rectangular cross sections have increased over recent years but are still limited [5-7].

Fiber Reinforced Polymers (FRP) has emerged over the last decade as a new material to be used in structural engineering, due to its attractive mechanical properties.FRP systems, however, have recently gained world-wide recognition as strengthening measures to increase the ductility and load carrying capacity of existing structural members. As a result, these materials have shown great potential in becoming an attractive alternative to concrete and even steel jackets. One important application of this composite retrofitting technology is the use of FRP jackets to provide external confinement to RC columns when the existing internal transverse reinforcement is inadequate. The application of FRP in the construction industry can eliminate some unwanted properties of high strength concrete, such as its brittle behaviour.FRP is particularly useful for strengthening columns and other unusual shapes.

1.1 Scope and Objective

The Main Endeavour of this work is to experimentally scrutinize the effects of upgrading the load carrying capacity of Reinforced Concrete Capsule shaped columns subjected to axial compression by confining with GFRP, BFRP, Jute flexible wraps.
The objectives of this study are as follows:
i. To evaluate the effectiveness of external Hybrid FRP strengthening for Capsule shaped concrete columns.

1.2 External Confinement with FRP

The application of FRP in the construction industry can eliminate some unwanted properties of concrete, such as the brittle behaviour of high-strength concrete. FRP is particularly useful for strengthening columns and other unusual shapes (Li, Hadi 2003) [4]. As already mentioned, the use of FRP materials in concrete compression members produces an increase in strength depending on the FRP properties (material type, strength, thickness etc.), on the concrete properties, and prevalently on the shape of the transverse cross-section (Campione, Miraglia 2003). Bonding hoop FRP to the column surface enhances axial load capacity and ductility of columns. The hoop FRP resists lateral deformations due to the axial loading, resulting in a confining stress to the concrete core, delaying rupture of the concrete and thereby enhancing both the ultimate compressive strength and the ultimate compressive strain of the concrete.

2. EXPERIMENTAL INVESTIGATION

2.1 Specimen Layout

A total of 4 FRP wrapped and one unconfined control concrete columns with dimensions of 150x 380mm with shorter face radius 75mm were prepared and tested under axial compression loading. The main experimental parameters were included different layers of hybrid FRP with different pattern.

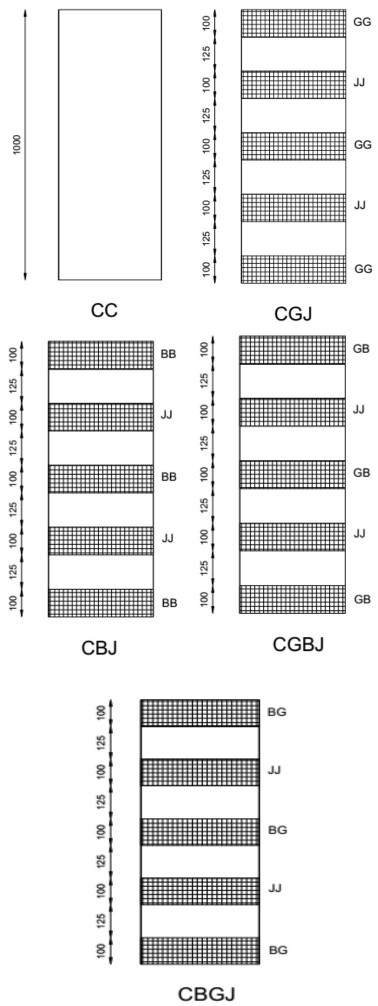

Fig. 1 Wrapping Pattern of Specimen

Table 1 Specimen Wrapping Configuration

Specimen ID	CC		CGJ		CBJ		CGBJ		CBGJ	
Wrap strip No	Layer		Layer		Layer		Layer		Layer	
	1	1	1	2	1	2	1	2	1	2
i	-	-	G	G	B	B	G	B	B	G
ii	-	-	J	J	J	J	J	J	J	J
iii	-	-	G	G	B	B	G	B	B	G
iv	-	-	J	J	J	J	J	J	J	J
v	-	-	G	G	B	B	G	B	B	G

G- GFRP B - BFRP J- JUTE

Width of wrapping for all strips was 100mm.

2.2 Material Properties

2.2.1 Internal steel reinforcement

Details of the internal reinforcing bars are shown in fig 2. 4nos of 16mm dia and 2nos of 12mm dia bars used as main reinforcement and 8mm dia bars used as stirrups 200mm C/C spacing.

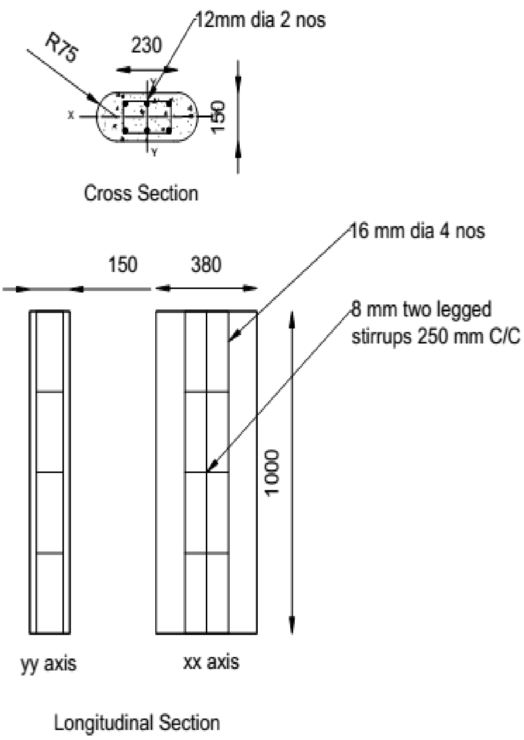

Fig. 2 Reinforcement Details

2.2.2 Concrete

Portland Pozzolana cement , natural sand (fine aggregate) and crushed coarse aggregate 20mm & 10mm size were used for the concrete mix. The mix proportion of M20 is

Fig. 3 Location of Strain gauge

1:1.33:3.14 by weight of cement, sand, coarse aggregate and water cement ratio 0.5 was adopted.

2.2.3 FRP system

Glass FRP, Basalt FRP, Jute rovings were used as confinement reinforcement.

2.2.4 Strain gauge

The strain gauge type was BICSA-10 with a gauge length of 10mm fixed in the longitudinal reinforcement. The detail of the locations of strain gauges on steel reinforcements shown in fig 3

3. RESULT AND DISCUSSION

3.1 Observed behaviour

At the early stages of loading of the confined specimens, the noise related to the micro cracking of concrete core was evident. At the latter stages of loading, a plastic-like sound was produced by the stretching of the FRP sheets.

3.2 Axial Load-Displacement Behaviour

The variation of displacement with that of the load was plotted for all the specimens as shown in Fig 4. From the load – displacement curves it is observed that the unwrapped specimen CC failed at a load of 750kN with a displacement of 1.24mm. The FRP wrapped specimens CGJ, CBJ, CGBJ and CBGJ failed at loads of 850kN, 900kN, 950kN, 1000kN with the corresponding displacements of 1.46mm, 1.49mm, 1.608mm and 1.76mm.

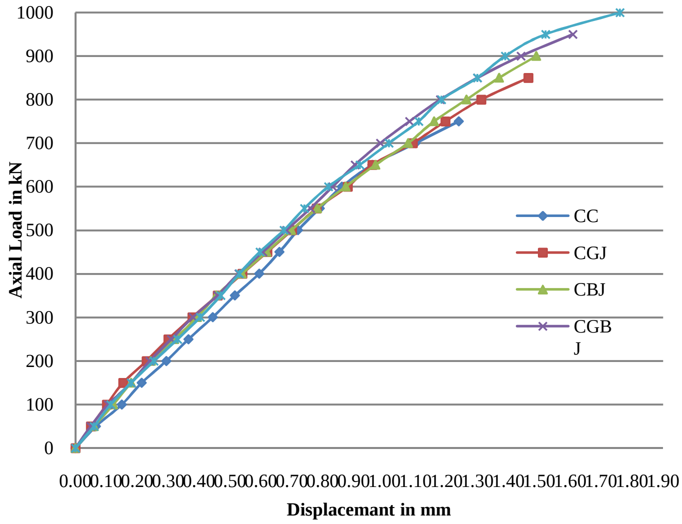

Fig.4 Axial load – displacement of Specimens

The specimen CBGJ has higher displacement compared to controlled specimen and other specimen.

The Basalt fiber has produce larger displacement compared to glass fibre.

3.3 Axial load- Strain behaviour

The behaviour of axial load vs strain for specimen CC, CGJ, CBJ, CGBJ, CBGJ are as shown in fig 5.

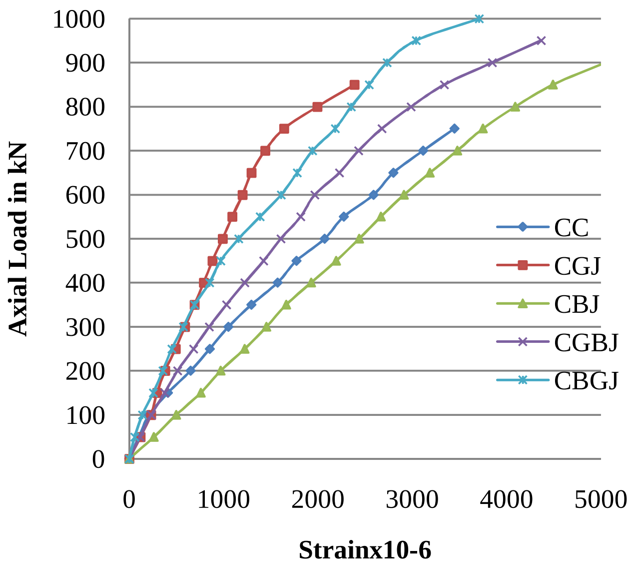

Fig 5 Axial Load – Strain curves

The specimen CBJ has observed higher strain with lower load and specimen CBGJ has observed lower strain with higher load.

3.4 Comparison of Compressive Strength

From the graphs shown in the Figures 6 and 7 it is found that due to the high tensile strength of the hybrid FRP confinement, the compressive strength of column specimen CGJ is increased by 11.76% when compared with specimen CC. And also the compressive strength of column specimen CBJ is increased by 16.67% when compared with specimen CC. The compressive strength of column specimen CGBJ is increased by 21.06% when compared with specimen CC. The compressive strength of column specimen CBGJ is increased by 25% when compared with specimen CC.

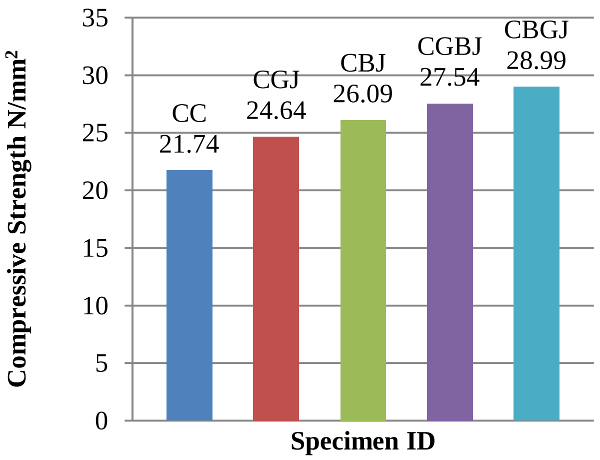

Fig.6 Comparison of Compressive Strength

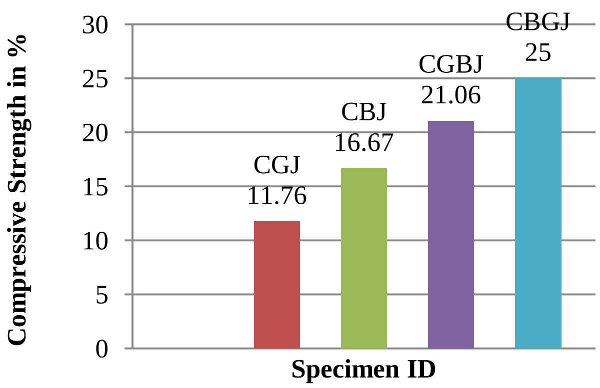

Fig.7 Comparison of % Increase in Compressive Strength

4. CONCLUSION

This research was aimed to propose and to investigate the new strengthening technique of strip pattern for hybrid FRP confinement of capsule shaped RC columns. The following conclusions can be drawn from the test results.

The wrapping of FRP has increased the compressive strength and ductility compared to the specimen without wrapping. The compressive strength of column specimen CGJ is increased by 11.76% when compared with control specimen CC and the maximum strain is reached 0.002386 at the axial load of 850kN. The compressive strength of column specimen CBJ is increased by 16.67% when compared with control specimen CC and the maximum strain is reached 0.005048 at the axial load of 900kN. The compressive strength of column specimen CGBJ is increased by 21.06% when compared with control specimen CC and the maximum strain is reached 0.004365 at the axial load of 950kN. The compressive strength of column specimen CBGJ is increased by 25% when compared with control specimen CC and the maximum strain is reached 0.003707 at the axial load of 1000kN.

The hybrid FRP wrapping containing Basalt, Glass, and Jute absorbs more strength than the other hybrid FRP wrapping patterns involved in this research. The wrapping procedure adopts capsule shaped columns because if we use rectangular shaped columns it may debond the corner of the column. There is enough literature available to justify the fact that rectangular shaped columns have damaged the column in the previous research studies. The capsule shaped column wrapping is done in parts of the column through stripping pattern in the vulnerable region of the column alone to reduce the cost of the FRP materials involved in stripping the column.

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