Non-metallic and natural fibre sheets wrapped in rc short circular column

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Abstract— *The present study deals about the short circular column of slenderness ratio 3,6,9 and C/S as 150 mm diameter and 450 mm,900 mm,1350mm height. Totally 21 Number of columns are casted. The columns are wrapped using Basalt fiber reinforced polymer, Glass fiber reinforced polymer and jute fiber composites of three layers, four layers and five layers in combination for these specimens the following data are to be obtained, Load vs Deflection, ultimate compressive strength.*
Keywords— Confinement, FRP, Compressive strength

I. INTRODUCTION

1.1 General: Many older structures today are in the need of strengthening their existing civil engineering infrastructure. The reasons are deterioration by ageing or corrosion caused by environmental factors, load increase because of change of function in the structure or poor design which does not meet the present more stringent design requirements such as in earthquake areas. The low probability of major seismic events and high cost of structural rehabilitation make it difficult to justify economically.

Strengthening or retrofitting of older structures to resist higher design loads or increase ductility has been accomplished with traditional materials such as externally bonded steel plates and steel jackets since in the 1960s. Concrete columns are important structural elements which are vulnerable for exceptional loads. In older structures, columns often have insufficient transverse reinforcement which is unable to provide sufficient confinement to the concrete core or to prevent buckling of the longitudinal reinforcement. This can lead to unacceptable premature strength degradation.

1.2 Strengthening using BFRP: Only a few years ago, the construction market started to use BFRP for structural reinforcement, generally in combination with other construction materials such as wood, steel, and concrete. BFRPs exhibit several improved properties, such as high strength-weight ratio, high stiffness-weight ratio, flexibility in design, non-corrosiveness, high fatigue strength, and case of application. The use of BFRP sheets or plates bonded to concrete beams has been studied by several researchers, Strengthening with adhesive bonded fibre reinforced polymer has been established as an effective method applicable to many types of concrete structures such as columns, beams, slabs, and walls. Because the BFRP materials are non-corrosive, non-magnetic, and resistant to various types of chemicals, they are increasingly being used for external reinforcement of existing concrete structures. From the past studies conducted it has been shown that externally bonded basalt fibre-reinforced polymers (BFRP) can be used to enhance the flexural, shear and torsional capacity of RC beams. Due to the flexible nature and ease of handling and application, combined with high tensile strength-weight ratio and stiffness, the flexible glass fibre sheets are found to be highly effective for strengthening of RC beams. The use of fibre reinforced polymers (BFRPs) for the rehabilitation of existing concrete structures has grown very rapidly over the last few years. Research has shown that BFRP can be used very efficiently in strengthening the concrete beams weak in flexure, shear and torsion. Unfortunately, the current Indian concrete design standards (IS Codes) do not include any provisions for the flexural, shear and torsional strengthening of structural members with BFRP materials. This lack of design standards led to the formation of partnerships between the research community and industry to investigate and to promote the use of BFRP in the flexural, shear and torsional rehabilitation of existing structures. BFRP is a composite material generally consisting of high strength carbon, aramid, or basalt fibres in a polymeric matrix (e.g., thermosetting resins) where the fibres are the main load carrying element.

Among many options, this reinforcement may be in the form of preformed laminates or flexible sheets. The laminates are stiff plates or shells that come pre-cured and are installed by bonding them to the concrete surface with a thermosetting resin. The sheets are either dry or pre-impregnated with resin (known as pre-preg) and cured after installation onto the concrete surface. This installation technique is known as wet lay-up. BFRP materials offer the engineer an outstanding combination of physical and mechanical properties, such as high tensile strength, lightweight, high stiffness, high fatigue strength, and excellent durability. The lightweight and formability of BFRP and JFRP reinforced systems easy to install. Since these systems are non-corrosive, non-magnetic, and generally resistant to chemicals, they are an excellent option for external reinforcement. The properties of BFRP and JFRP composites and their versatility have resulted in significant saving in construction costs and reduction in shut down time of facilities as compared to the conventional strengthening methods.

Strengthening with externally bonded BFRP and JFRP sheets has been shown to be applicable to many types of RC structural elements. BFRP and JFRP sheets may be adhered to the tension side of structural members (e.g., slabs or beams) to provide additional flexural strength. They may be adhered to web sides of joists and beams or wrapped around columns to provide additional shear strength, they may be wrapped around columns to increase concrete confinement and thus strength and ductility of columns. Among many other applications, BFRP and JFRP sheets may be used to strengthen concrete and masonry walls to better resist lateral loads as well as circular structures (e.g., tanks and pipelines) to resist internal pressure and reduce corrosion. As of today, several millions of square meters of surface bonded BFRP and JFRP sheets have been used in many strengthening projects worldwide.

1.3 Basalt fibre reinforced polymer (BFRP): Continuous Basalt fibre-reinforced materials with polymeric matrix (BFRP) can be considered as composite, heterogeneous, and anisotropic materials with a prevalent linear elastic behaviour up to failure. They are widely used for strengthening of civil structures. There are many advantage of using BFRPs light weight, good mechanical properties, corrosion-resistant, etc. Composites for structural strengthening are available in several geometries from laminates used for strengthening of members with regular surface to bi-directional fabrics easily adaptable to the shape of the member to be strengthened. Composites are also suitable for applications where the aesthetic of the original structures needs to be preserved (buildings of historic or artistic interest) or where strengthening with traditional techniques cannot be effectively employed.

Basalt fibre reinforced polymer (BFRP) is a composite material made by combining two or more materials to give a new combination of properties. However, BFRP is different from other composites in that its constituent materials are different at the molecular level and are mechanically separable. The mechanical and physical properties of BFRP are controlled by its constituent properties and by structural configurations at micro level. Therefore, the design and analysis of any BFRP structural member requires a good knowledge of the material properties, which are dependent on the manufacturing process and the properties of constituent materials. BFRP composite is a two phased material, hence its anisotropic properties. It is composed of fibre and matrix, which are bonded at interface. Each of these different phases has to perform its required function based on mechanical properties, so that the composite system performs satisfactorily as a whole. In this case, the reinforcing fibre provides BFRP composite with strength and stiffness, while the matrix gives rigidly and environmental protection.

Basalt fibres: Basalt is a natural material belonging to the family of igneous rocks, which has the capability of melting at certain temperature (14300c-14500c) in a way similar to thermoplastic materials. And its grey, dark in colour, formed from the molten lava after solidification. The production of basalt fibre consists of melt preparation, extrusion, fibre formation, application of lubricates and finally winding. This method is also known as spinning.

FIG.1 BI-DIRECTION OF BASALT FIBRE

1.4 Jute fibre reinforced polymer (JFRP): Jute, sisal, banana, and coir the major sources of natural fibres, are grown in many parts of the world. Some of them have aspect ratios (ratio of length to diameter) > 1000 and can be woven easily.

These fibres are extensively used for cordage, sacks, fishnets, matting and rope, and as filling for mattresses and cushions (e.g., rubberised coir).

Cellulosic fibres are obtained from different parts of the plants. E.g., Jute is obtained from stem.

FIG.2 BI-DIRECTION OF JUTE FIBER

1.5 Resin system: The resins that are used in fibre-reinforced composites are sometimes referred to as polymers. All polymers exhibit an important common property in that they are composed of long chain-like molecules consisting of many simple repeating units. Man-made polymers are generally called synthetic resins or simply resins. Polymers can be classified under two types viz., thermosetting and thermoplastic, according to effect of heat on their properties.

Thermoplastics, like metals soften with heating and eventually melt and harden again with cooling. This process of crossing the softening or melting point on the temperature scale can be repeated as often as desired without any appreciable effect on the material properties in either state.

Thermosetting materials or thermosets from a chemical reaction, where the resin and hardener or resin and catalyst are mixed and then undergo a non-reversible reaction to form a hard, infusible product

Resin types: The commonly used resin systems for structural purpose are

1. Polyesters
2. Vinyl esters
3. Epoxies

Among these, polyester resins are the best one for BFRP and JFRP. Because Polyester has a strength and hardness.

Polyester: Polyesters are the most widely used polymers in the manufacture of FRP components for infrastructure applications due to their relatively low cost and ease of processing (these resins cure at ambient temperatures). Numerous specific types of polyesters are available for use, with varying degrees of thermal and chemical stability, moisture absorption, and shrinkage during curing.

1. Easy to use
2. Cost effective
3. Moderate mechanical properties
4. High cure shrinkage
5. Limited range of working time.

II. EXPERIMENTAL INVESTIGATION

2.1 General: The details of the experimental investigations carried out to study the RC short column wrapped with BFRP and JFRP design is based on IS 456:2000. The investigation was mainly directed towards to study RC short column with BFRP and JFRP wraps in terms of stress-strain curve, ultimate compressive load in axial load conditions.

2.2 Preparation of test specimens

2.2.1 Preparation of concrete: For concrete, the maximum aggregate size used was 20 mm. Nominal concrete mix of M20 by weight is used to achieve the strength of 26.6 N/mm2.The water cement ratio 0.5 is used. Three cube specimens were cast and tested at the time of column test (at the age of 28 days) to determine the compressive strength of concrete. The average compressive strength of the concrete was 33N/mm2.

2.2.2 Casting and Curing: The mould is arranged properly and placed over a smooth surface. The sides of the mould exposed to concrete were oiled well to prevent the side walls of the mould from absorbing water from concrete and to facilitate easy removal of the specimen.

The concrete contents such as cement, sand, aggregate and water were weighed accurately and mixed. The mixing was done till uniform mix was obtained. The concrete was placed into the mould immediately after mixing and well compacted.

The test specimens were remoulded at the end of 24 hours of casting. They were marked identifications. They are cured in water for 28 days. After 28 days of curing the specimen was dried in air.

2.3 Preparation of BFRP,GFRP and JFRP sections:

Step 1: Specimen were wrapped externally by 3layers, 4layers and 5 layers of BFRP and JFRP sheets.

Step 2: Before strengthening the specimens with BFRP and JFRP sheets, which included cleaning, and then polyester adhesive was used for bonding BFRP and JFRP sheets on the specimen.

Step 3: Additional layers of polyester adhesive were applied between BFRP and JFRP sheets.

2.4 Wrapping of specimen by hand layup process: In this stage the cylinders were wrapped with FRP. Wrapping of FRP laminates to concrete surface is a delicate job and needs special attention. Cylinders were wrapped following standard procedure indicated below:

Step 1: Surface Preparation: The surface of the cylinders was cleaned using wire brush.

Step 2: Primer Application: The polyester resin were mixed in equal proportions and thoroughly mixed for 2-3 minutes using a wooden stick. The coat of Primer was applied to the cylinder surface by brush. The primer prepares the surface of the concrete for the application of the FRP sheets and has low viscosity.

Step 3: Now polyester resin were mixed in equal proportions and thoroughly mixed for 2-3 minutes using a wooden stick. The coat of polyester resin was applied to the cylinder surface by paint brush. The surface is now ready for installation of FRP sheets.

Step 4: Now the FRP Sheet was wrapped around the cylinder surface. The sheet was pressed against the surface of cylinder to see that there are no air bubbles developed. And overlap of 150 mm ensured that no splitting occurs at the end..

Step 5: A second hand coat of epoxy was given on this wrapped FRP to saturate it fully. A second application is necessary to ensure good penetration of the saturate around the fibers.

Step 6: In case of cylinder having second wrap polyester coat was given on first layer and wrapping was continued for second layer. This second layer was the then coated with polyester to saturate it further. After the required layers of the sheet were installed, the FRP wrapped cylinders were cured for 10days. These cylinders are now ready for testing.

TABLE 1
COLUMN CONFIGURATIONS

S.NO	SECTION (Circular column)	SLENDERNESS RATIO	WRAPPING PATTERN(FULLY&PARTIALLY WRAPPING)			
			layers	BFRP	GFRP	JFRP
1	150*450mm	3	3	1	-	2
			4	2		2
			5	3		2
2	150*900mm	6	3		2	1
			4		2	2
			5		3	2
3	150*1350mm	9	3		2	31
			4		2	2
			5		3	2

FIG.3 BFRP AND JFRP FULLY AND PARTIALLY WRAPPING.

FIG.4: GFRP AND JFRP FULLY AND PARTIALLY WRAPPING

III. RESULTS AND DISCUSSION

3.1 Test results and discussion: To understand the behavior of RC columns of different shapes structural parameters like load, deformation & strain were evaluated for control and GFRP wrapped columns, respectively.

3.2 Ultimate load carrying capacity: Strengthening of circular columns exhibited higher axial load carrying capacity as compared to that for control columns. Axial load carrying capacity increases from 3 layers, 4 layers, 5 layers of with confined circular RC columns. Without confined column exhibits lowest axial load carrying capacity. Results clearly demonstrated that variation in shape plays limited role in increasing the amount of axial load carrying capacity for control RC columns

3.3 Axial deformation: Load vs. axial deflection behaviour for all columns is presented in Fig. 8. The effects of geometry as well as effect of BFRP, GFRP & JFRP wrapping on load-deformation behaviour for columns are exhibited in Fig. 8. Minor difference in axial deformation behaviour is observed for control columns of different sizes. BFRP, GFRP & JFRP wrapped columns have exhibited higher axial deformation as compared to that of control columns. With the size of column changes from confined to without confined circular, strength and ductility of the columns increases considerably.

TABLE-2
FOR COMPRESSION TESTING FOR COLUMN SPECIMEN

Specimen size			150*1350mm		150*900mm		150*450mm	
TYPE OF WRAPPING PATTERN			Partially Wrapping	Fully Wrapping	Partially Wrapping	Fully Wrapping	Partially Wrapping	Fully Wrapping
Load (KN)	Layers	0	265	265	265	265	265	265
		3	400	650	320	550	289	478
		4	550	850	435	730	385	637
		5	670	1035	540	850	482	797
Deflection	Layers	0	0.65	0.65	0.65	0.65	0.65	0.65
		3	1.6	0.835	0.42	0.726	0.76	3.2
		4	2.2	4.9	2.1	1.8	2.9	6.9
		5	5.1	6	4.2	4.1	5.6	10

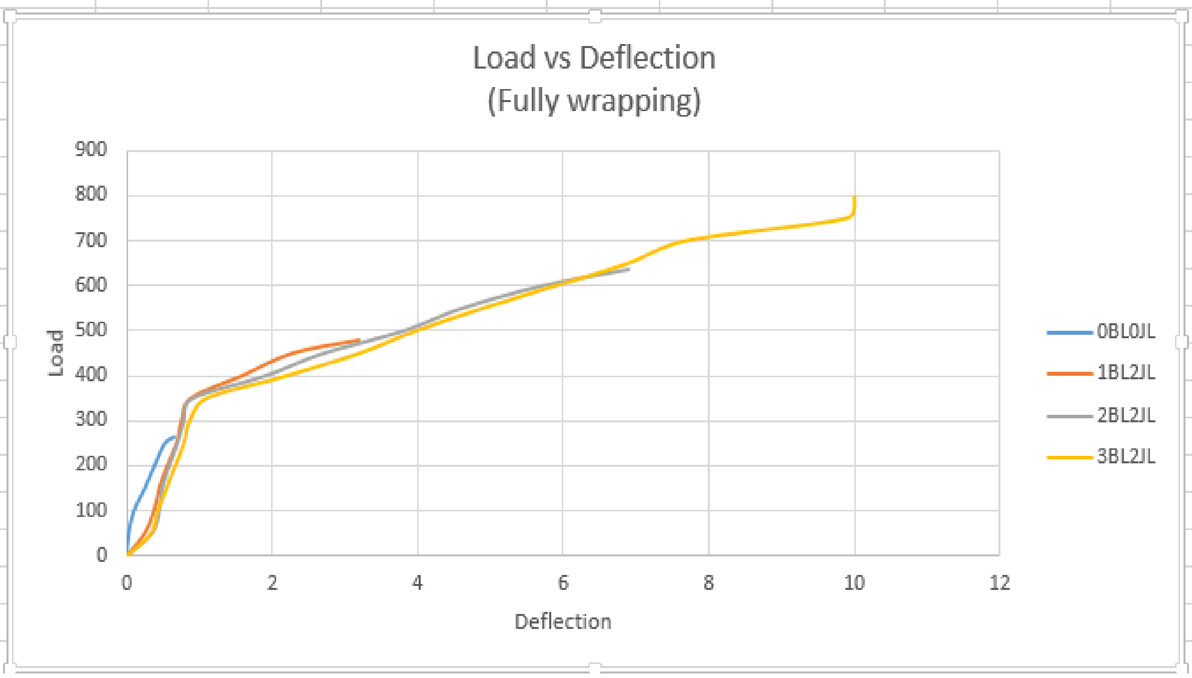

FIG.5 LOAD VS DEFLECTION BEHAVIOUR FOR COLUMNS (150*450MM)

0B0JL-0 Basalt layer 0Jute layers

1BL2JL-1Basalt layer 2Jute layers (in alternative layers)

2BL2JL-2Basalt layers 2Jute layers (in alternative layers)

3BL2JL-3Basalt layers 2 Jute layers (in alternative layers)

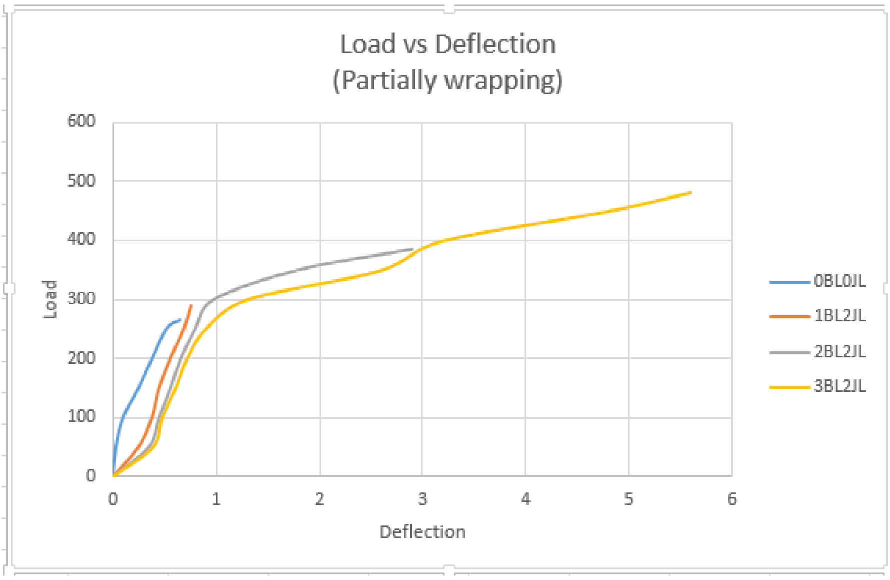

FIG.6 LOAD VS DEFLECTION BEHAVIOUR FOR COLUMNS (150*450MM)

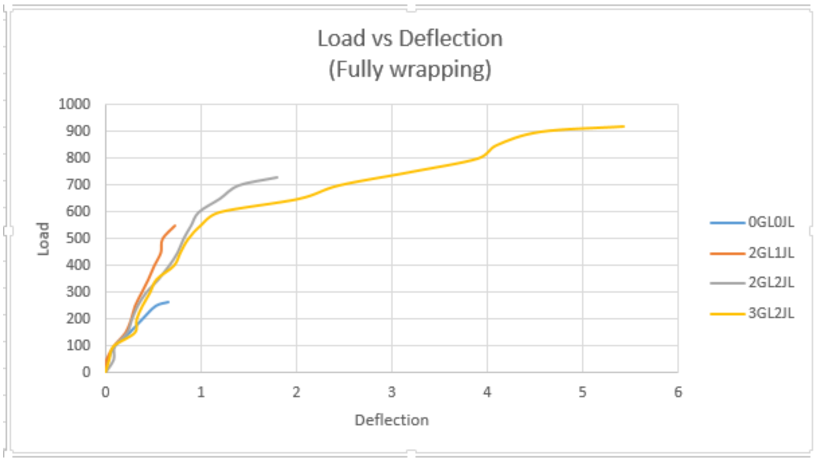

FIG.7 LOAD VS DEFLECTION BEHAVIOUR FOR COLUMNS (150*900MM)

0B0JL-0 Glass layer 0Jute layers (in alternative layers)

2BL2JL-2 Glass layer 2Jute layers (in alternative layers)

2BL2JL-2 Glass layers 2Jute layers (in alternative layers)

3BL2JL-3 Glass layers 2 Jute layers (in alternative layers)

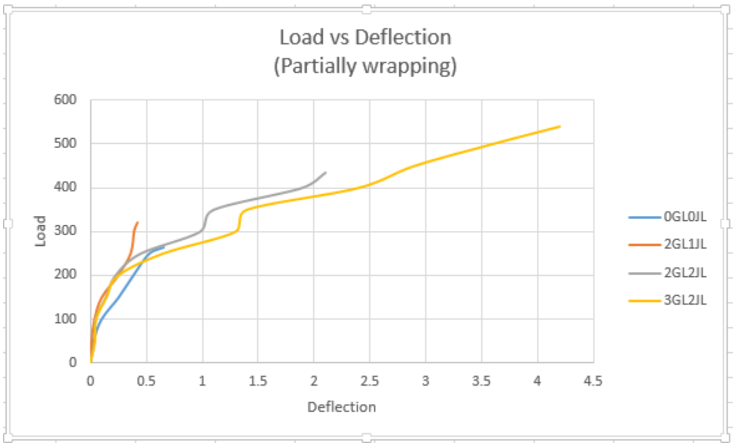

FIG.8. LOAD VS DEFLECTION BEHAVIOUR FOR COLUMNS (150*900MM)

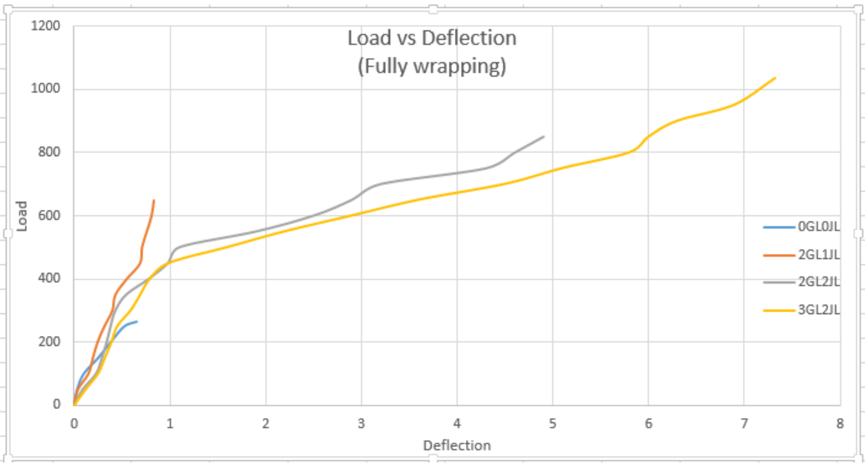

FIG.9. LOAD VS DEFLECTION BEHAVIOUR FOR COLUMNS (150*1350MM)

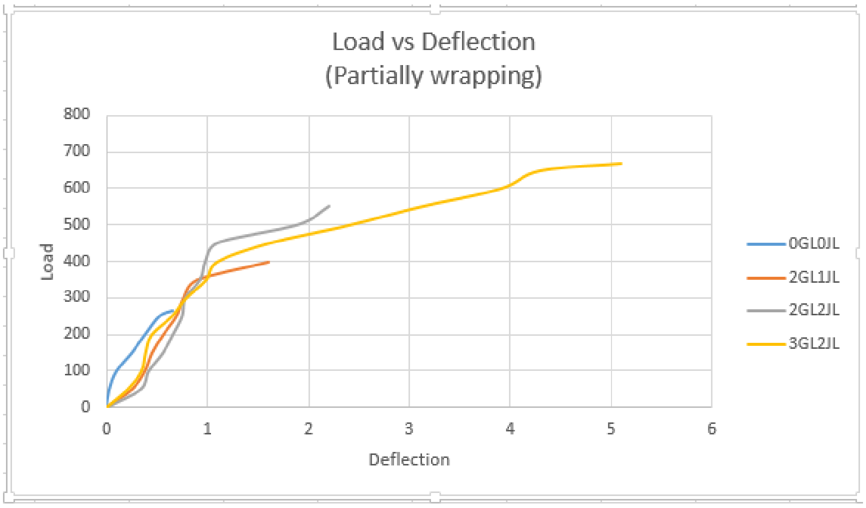

FIG.10. LOAD VS DEFLECTION BEHAVIOUR FOR COLUMNS (150*1350MM)

3.4 **Failure Modes and Crack patterns:** Control RC columns have failed after reaching to their ultimate compressive strength and that resulted into splitting of concrete in between the stirrups. Majority of control columns were failed with blasting effect. The mode of failure has been characterized by shearing and splitting of the concrete in case of the control columns. Circular columns failed due to shearing effect under axial loading. Due to buckling of reinforcement at ultimate compression load the concrete pulled out in between two stirrups as shown in Fig. 11 respectively.

FIG.11 CONTROL CIRCULAR COLUMN

FIG.12.WRAPPING FAILURE OF CIRCULAR COLUMN

FIG.13 WRAPPING FAILURE OF CIRCULAR COLUMN

IV. CONCLUSION

4.1 The confinement in the form of GFRP,BFRP & JFRP sheets increases the compressive strength of the specimens remarkably.

4.2 If the specimen is Fully wrapped with 5 layers of GFRP & JFRP sheets the strength increases to 60% of the strength without confinement. And BFRP &JFRP Sheets the strength increases to 65% of the strength without confinement. From the study it can be concluded that the column can be confined with GFRP,BFRP, JFRP sheets to increase their strength to a great extent**.**

4.3 If the experimental results show that full wrapping of the specimen increases the maximum load carrying capacity compared to the partial wrapping and without confinement column.

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