COMPARATIVE STUDY OF CONCRETE PRISMS CONFINED WITH G-FRP WRAPPING UNDER COMPRESSIVE LOADING

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Abstract - *The strength of confined columns is higher for circular section due to stress concentration at corner. To expand the strong constraint zone and diminish the stress concentration the sharp edge can be done rounded and chamfered. Fiber Reinforced Polymer (FRP) materials are composites consisting of high strength fibers embedded in polyester resin. Fiber in on FRP composites are the load carrying elements, while the resin maintains the fiber alignment and protects them against the environment and possible damage. Among fibers, glass one exhibit the highest strength and stiffness when compared with steel Present paper deals with experimental results in terms of load carrying capacity and stress – strains behavior of fiber reinforced polymer (FRP) confined prism. The ultimate stress of prism with corner radius of 13mm and 19mm is 1.06 and 1.12 times more than the sharp edge prism. Similarly the failure strain is 3.6 and 1.31 times more than the sharp edge prism. The ultimate stress of prism with chamfered corner of 13mm and 19mm is 1.12 and 1.31 times more than the sharp edge prism. Similarly the failure strain is 1.12 and 1.31 times more than the sharp edge prism. The stress-strain curve behaves bilinear and the stress-strain curve traces the same path as that of unconfined concrete until the jacket was activated. The FRP resists lateral deformation results in a confining stress to the concrete core thereby delaying the rupture and enhancing both the ultimate strength and stain of the concrete.*

Key words: *GFRP, Chamfered prism, compressive test, confinement, Woven Glass fiber, stress strain.*

1. INTRODUCTION

According to the ACI 440R-96 report, the term "composite" can be applied to any combination of two or more separate materials having a distinguishable interface between them. Often a surface treatment phase is introduced between the two combining materials, which improve the adhesion of the reinforcing component to the matrix phase. When composites are defined as polymeric matrix reinforced with fibers, they are called as fiber reinforced polymers (FRP). Advantages of FRP are High chemical resistance to acids and bases, reduction of corrosion related problems, practically no increase of dead weight of the structure, Economically use in many cases and Significant use in repair and rehabilitation of structural components. Composites are used as corrosion resistance. Composites serve as good seismic resistance materials. The confinement effectiveness of FRP Jackets in concrete prisms depends on several parameters, namely, concrete strength, types of fibers and resin, fiber volume and orientation in the jacket, jacket thickness, shape of the cross-section and the interface bond between the concrete core and the jacket (James M and Hurries, 2001). The external confinement with reinforced polymers composite can significantly increase the strength of the specimen under axial loading. The experimental results clearly demonstrate that composite wrapping can enhance the structural performance of concrete columns under axial loading (Omar Chaallal and Mohsen Shahawy, 2003). External confinement can significantly improve the ultimate strength and ductility of the specimens. The ultimate strength of the jacket and the concrete strength are the most influential factors affecting the ultimate strength and strain of the confined concrete (Berthet J.F and Ferrier E 2006). the confinement effectiveness of FRP Jackets in concrete prisms depends on concrete strength. The Concrete has a tendency to dilate under axial compression. FRP jackets confine the transverse dilation in concrete and create a state of tri-axial compression that increases the strength of the concrete (Mirmiran et al., 1998 and James et al, 2001). the confinement characteristics of FRP-jacketed rectangular reinforced concrete (RC) columns and studied the effects of the aspect ratio of the rectangular cross-section. They found that increasing the aspect ratio of the cross-section resulted in a lower ultimate strength for a CFRP-jacketed RC column (Cole C and Belarbi A, 2001). jacket delivers a uniform confining stress around the circular concrete core. The degree of enhancement was directly related to the corner radius. As the shape changes away from circular i.e. from the large corner radius to the small one, the applied stress start to decrease with the lowest Yousef (2007). square / rectangular sections are less effective than their circular counterparts Wu and Wei (2010). columns of square section and sharp corners evidenced no improvement of capacity, nor ductility from being confined with CFRP jackets. In the case of AFRP confinement there was improvement of load capacity, but no significant improvement on ductility. The improvement of axial load capacity gained, either from jackets of AFRP, or CFRP was almost equal for cylindrical columns Silva (2011). the Glass fiber wrapped specimens typically failed by a fracture of GFRP composite at or near the corner of the specimens due to the stress concentration in those regions Raid Benzaid and Nasr-Eddine Chikh (2008).

2. OBJECTIVE

Objective is to study Stress-strain relationship, Ultimate compressive strength and failure strain of FRP confined square concrete prisms by varying edges as corner radius, chamfered and sharp.

3. PROPERTIES OF MATERIAL

Cement used for making prisms is OPC 53 grade (Bharathi cement) was used for the entire experimental investigations. The physical properties of the above tested according to standard procedure, conforms to the requirements of IS 12269-1989. The properties are as follow: fineness of 0.8%, specific gravity 3.85, consistency 34% of weight of cement. The fine aggregate used in this study are clean river sand, passing through 4.75mm sieve Fine aggregate have fineness of 3.12, specific gravity 2.86, bulk density 1608 kg/m^3, water absorption 1% and grading for zone II. Machine crushed stone with angular shape was used as coarse aggregate. The minimum and maximum size of aggregate is 12.5mm and 20mm respectively Coarse aggregate have fineness of 8.08, specific gravity 3.1, bulk density 1616 kg/m^3, water absorption 0.5%, maximum size of 20 mm and angular in shape. Ordinary clean potable water free from suspended particles was both for mixing of concrete and curing. E-Glass FRP (Woven Mat) is used in the experiment. E-glass is the most common type of glass fiber used in resin matrix composite structures and was used in this investigation. The principal advantages of E-glass are low cost, high tensile and impact strength and high chemical resistance. The disadvantages of E-glass, compared to other structural fibers are lower modulus, lower fatigue resistance and higher fiber self- abrasion characteristics. In general, fiber composites behave linearly elastics to failure. GFRP and resin used have tensile strength of 1750 and 2500 N/mm^2, Elastic modulus 65 and 74 x10^3 N/mm^2, thickness 2.6 and 1.8 mm, poison ratio 0.23 and 0.29 respectively.

4. SPECIMEN DETAILS AND CASTING

In the present investigation, total 15 no. which were divided into two sets as with and without wrapping of roved with E-Glass FRP of Woven Mat (3 in each category). of concrete prisms will be casted and be tested under compressive loading; the types of the specimen are square prism 150 x 150 x 300 mm with sharp edges, square prism with corner radius of 19 mm and 13 mm and square prism with chamfered edge of 19 mm and 13 mm as shown in figure 1. M30 mix design is adopted for the study. Ratio is 1:2:3.7 with 0.45 w/c ratio and 380kg/m^3 of cement. The specimen preparation work can be divided into two stages: making concrete prisms and hand-apply the GFRP around these prisms. The prisms were cast in vertical position. First mould was filled to about the half height and then compacted using damping rod. The mould was filled in three layers in the same manner. The FRP bonding procedure was done in accordance to ACI 440.2R-02. The entire installation procedure consists of three major phases. They are Surface preparation, Fabric preparation and Fabric installation. The process flow chart is shown in figure 2.

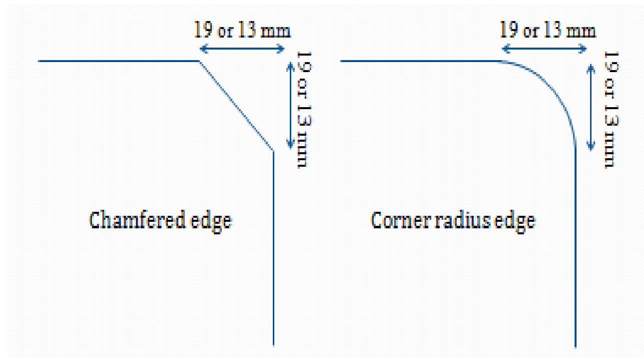

Fig - 1. Chamfer and Corner Radius detailing

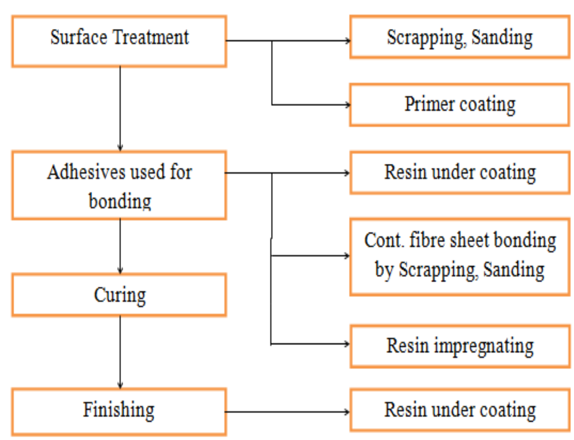

Fig - 2. Steps of FRP wrapping over prism

5. TESTING OF SPECIMEN

Specimens are tested in compression testing machine of capacity 2000kN shown in figure 3. Specifically fabricated steel square frames of 170 x 170mm were used to measure strain in compression zone. Each frame can be fixed to the prisms by means of two screws on either side of the prisms, leaving clearance on each side as shown in figure 4. Dial gauge of 0.01 mm of least count was fixed between two square frames at top of the prism. The deformation indicated by the dial gauge divided by the gauge length of 150 mm gives strain at that level. From the load, corresponding stresses were calculated. The test was continued until specimens fails completely and from recorded reading, stress-strain values were plotted.

Fig - 3. Speciment in compression testing machine

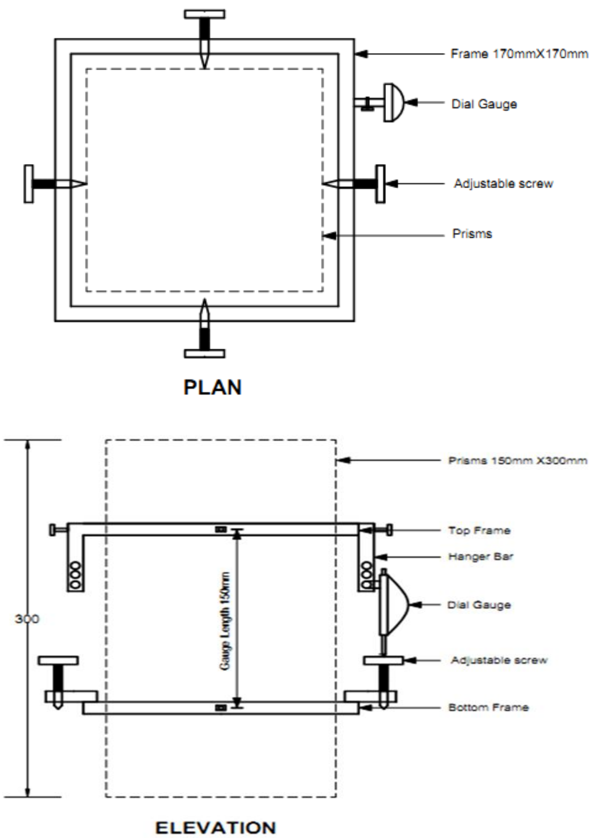

Fig - 4. Straing gauge with steel frame setup

6. RESULTS AND DISCUSSIONS

Results show a significant improvement of load carrying capacity and failure strain with the use of FRP confinement. Stress–strain curves, which characterize the confined concrete, are bilinear whatever the strength of the concrete core. This study reveals a significant change of behaviour when the concrete is confined. The tests proved that the benefits of confinement could be enhanced by the use of FRP confinement, which can be seen from the results of testing the compressive loading prisms. The failure mode for FRP-confined concrete is the rupture of the FRP jacket due to hoop tension and FRP delaminating. The breakage line was generally perpendicular to the fibers. For whatever sharp edge, chamfered edge, corner radius, the breakage line appeared at a corner, specifically in corner radius exactly at the end of the rounding. The failure of all of the confined square columns took place at one of the corners within the mid-height of the specimen as shown in figure 5. The stress strain graph of comparing sharp edge with all other prisms are shown in chart 1, 2, 3 and 4 correspondingly.

Fig - 5. Failure crack of concrete prisms

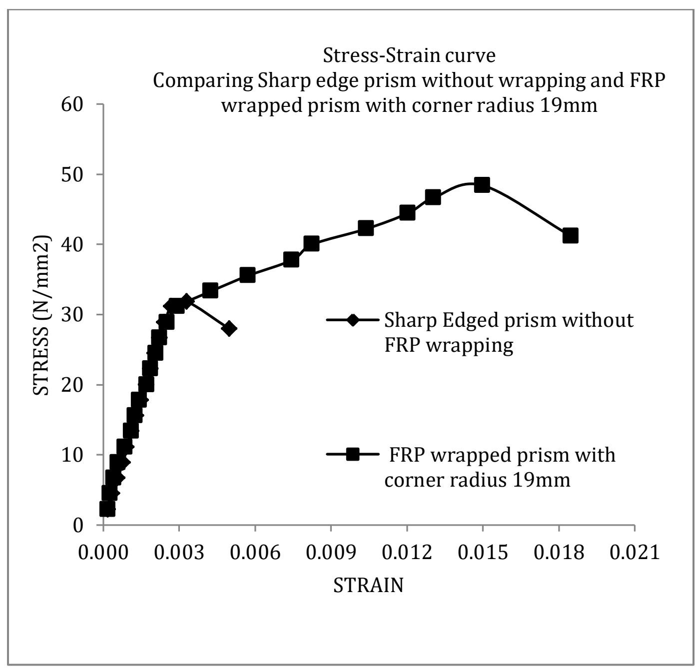

Chart - 1. Stress-Strain curve Comparing Sharp edge prism without wrapping and FRP wrapped prism with corner radius 19mm

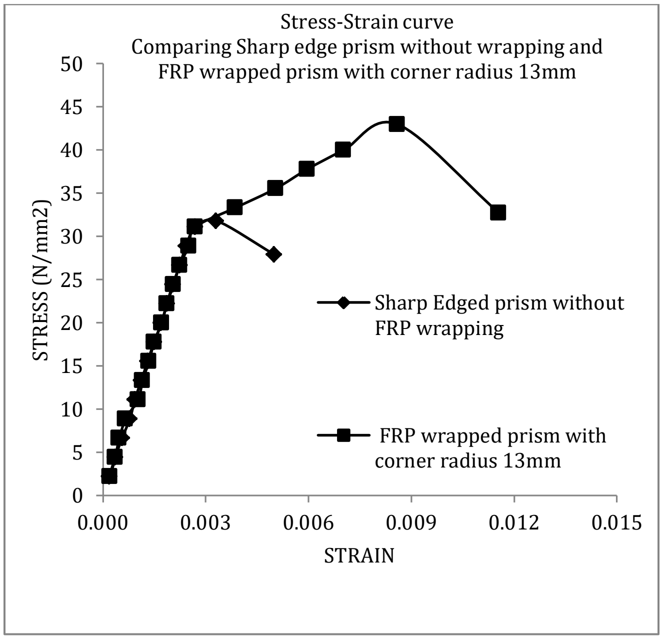

Chart - 2. Stress-Strain curve Comparing Sharp edge prism without wrapping and FRP wrapped prism with corner radius 13mm

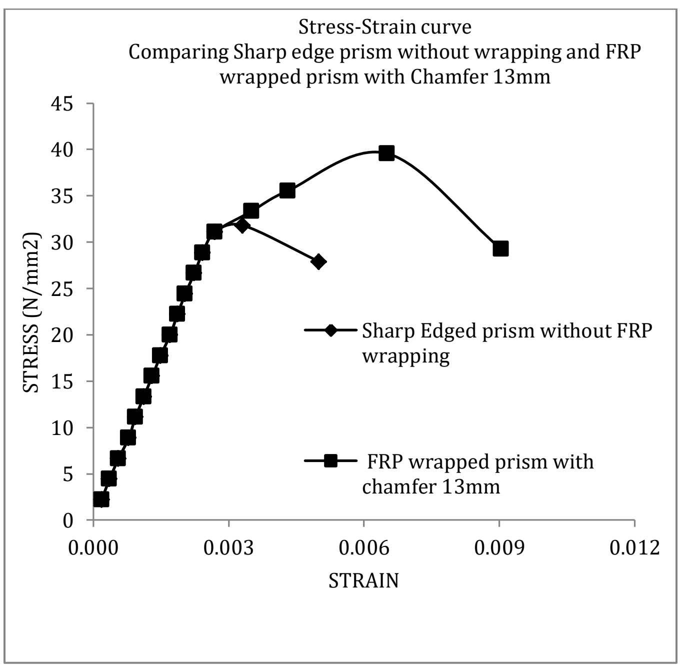

Chart - 3: Stress-Strain curve Comparing Sharp edge prism without wrapping and FRP wrapped prism with Chamfer 13mm

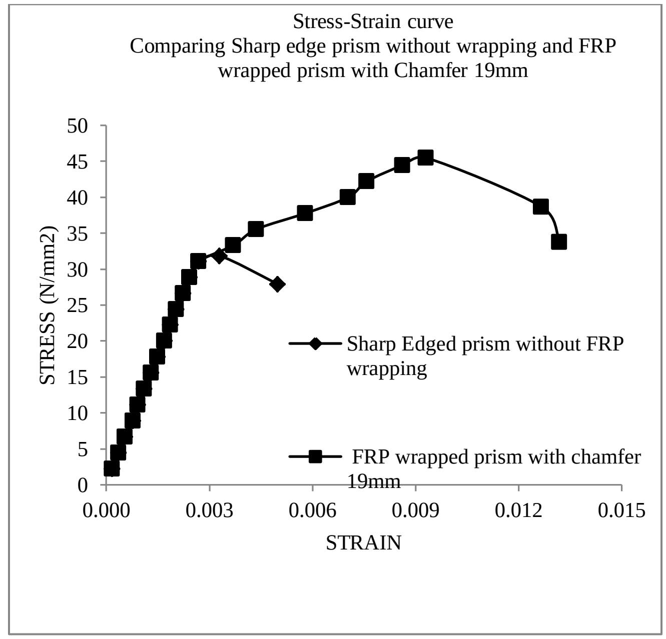

Chart - 4: Stress-Strain curve Comparing Sharp edge prism without wrapping and FRP wrapped prism with Chamfer 19mm

7. CONCLUSION

The provision of FRP is an effective way of providing additional confinement of concrete. The external confinement with Fiber reinforced polymer composites can significantly increase the strength of the specimen under compressive loading. From the experimental results, while comparing the ultimate stress between sharp edge and corner radius of 13mm wrapped with Woven Roving Mat G-FRP, the ultimate stress in corner radius increases 1.06 times than the sharp edge prism. Similarly while comparing the failure strain, corner radius prism increases 3.6 times than the sharp edge prism For the ultimate stress between sharp edge and corner radius of 19mm wrapped with Woven Roving Mat G-FRP, the ultimate stress in corner radius increases 1.12 times than the sharp edge prism. Similarly the failure strain in the corner radius increases 1.31 times than the sharp edge prism. For the ultimate stress between sharp edge and chamfered edge of 13mm wrapped with Woven Roving Mat G-FRP, the ultimate stress in corner radius increases 1.12 times than the sharp edge prism. Similarly the failure strain in the corner radius increases 1.31 times than the sharp edge prism. For the ultimate stress between sharp edge and chamfered edge of 19mm wrapped with Woven Roving Mat G-FRP, the ultimate stress in corner radius increases 1.12 times than the sharp edge prism. Similarly the failure strain in the corner radius increases 1.31 times than the sharp edge prism. The stress-strain curve for concrete confined by FRP composites behaves bilinear and the stress-strain curve traces the same path as that of unconfined concrete until the jacket was activated. The failure of the square columns always starts at one of the corners proving that the stress concentration occurs at the corners The FRP resists lateral deformation due to the compressive load and results in a confining stress to the concrete core thereby delaying the rupture of concrete and enhancing both the ultimate compressive strength and the ultimate compressive stain of the concrete.

8. SCOPE OF FUTURE STUDY

The stress-strain behaviour of plain concrete prisms with different types of laterals should be studied. The stress-strain behaviour of FRP confined concrete externally strengthened with high strength fibre composite wraps of CFRP and epoxy resin should be studied. A systematic study is required to understand the effects of adverse environmental condition (humidity, freezing and thawing) on the deflection and ultimate load carrying capacity of the FRP confined concrete. The effectiveness of various types of corner radius of reinforced columns externally strengthened with CFRP and GFRP should be studied. Case study on the lateral and axial strain behaviour of FRP confined concrete for eccentric and cyclic loading may also be attempted. An analytical model can be made to determine the maximum bearing capacity of concrete members with different cross sections for different configurations.

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