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CYCLIC ANALYSIS AND BENDING PERFORMANCE OF SPLICE CONNECTION ASSEMBLY OF FRP COLUMNS IN MODULAR BUILDINGS

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Abstract *Extensive research has been carried out in recent years on the use of fibre-reinforced polymer (FRP) composites in the rehabilitation and strengthening of existing structures. This paper provides a concise review of Investigation on the bending performance of splice connection for modular buildings. Tubular FRP members having shapes square, hexagon and rectangle are considered. The aspect ratio of splicing having bond length 170mm, 150 mm and 190 mm has been investigated. Also investigation has been carried on the splice connection FRP column assembly under axial loading and eccentric loading and pushover analysis of FRP column assembly under full scale frame. The results also show that splice connection of tubular FRP member under axial loading and eccentric loading shows more moment capacity and strength*

Key Words: Fiber reinforced polymer (FRP); Tubular section member; Splice connection; Bolted flange joint; bonded sleeve joint; Ductilitys ; ANSYS WORKBENCH 19.0

1. INTRODUCTION

The past two decades have seen increasing application of fiber reinforced polymer (FRP) composites in civil engineering structures. The use of fibre-reinforced polymer (FRP) composites for strengthening reinforced concrete (RC) structures was first investigated as an alternative to steel plate bonding for beam strengthening at the Swiss Federal Laboratory for Materials Testing and Research (EMPA). These lightweight and corrosion-proof materials have gained recognition worldwide through applications in the rehabilitation and strengthening of existing structures. Due to the moderate cost of glass fibers and advances in the pultrusion manufacturing technique , FRP composites also have great potential as load-bearing members in new construction. Examples include bridge decks, beams, columns, and floor systems.

Connection designs for these members should consider the brittle and anisotropic nature of FRP materials provided major references for FRP composite connections, primarily for plates and I- section members. Additional studies may be needed for tubular section members which have the added advantage of efficient resistance against torsional and global buckling. Various types of bolted connections have been developed and compared for FRP beam-to-column assemblies with tubular sections. In a recent study, full adhesive FRP beam-column connections were shown to be more advantageous in stiffness and moment capacity than bolted connections. Splice connections consists of a steel bolted flange joint between two tubular steel-FRP bonded sleeve joints. These splice connection to be more advantageous in stiffness and moment capacity than bolted connections. This bonded sleeve connection was later adapted for all FRP beam-to-column assemblies and evaluated under static and cyclic loadings. The steel-FRP bonded sleeve joint (BSJ) can be adapted to provide a splicing solution that is needed to apply tubular section FRP members in building structures and in long-span scenarios.

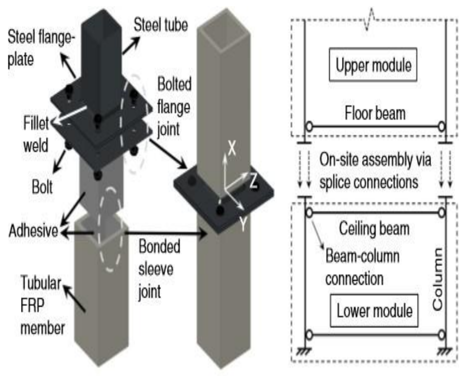

Fig 1.1: schematic representation of splice connection

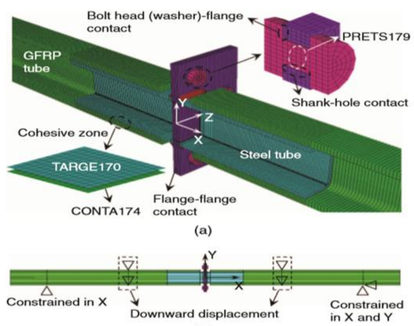

fig 1.2 : diagramatic representation of splice connection

2. SCOPE

The scope of this paper highlights the benefits of splice connection in modular buildings. We know, overall benefits of a fiber reinforced polymer includes high strength and stiffness, reduced mass, low thermal conductivity, high corrosion and weather resistance, durability, but also the implicit feature of offsite fabrication, etc. , thus the buildings become environmentally responsible, profitable and better place to live and work in.

Research on fiber reinforced polymers building materials is already firmly established. There are many global platforms that discusses on splice connection which aims to create a better and cost effective buildings when compared to conventional buildings.

Considering the relevance of this topic, splice connection in modular buildings is one of the most important and one of the most discussed topics worldwide. The goal of this research is to assess the moment carrying capacity and corresponding deformation of columns and frames. Here the investigation of bending performance and cyclic analysis of splice connection also investigate aspect ratio etc.. This work can also be used for future references; there is no codal provision for FRP.

3. OBJECTIVES

- Investigation of splice connection assembly for various sections using ANSYS by considering the beams connecting which are, both square , both hexagon and both rectangle
- Investigate aspect ratio of splicing and corresponding variations in moment-deformation curve has been analyzed
- Investigate splice connection by providing additional stiffeners to the flange for the square section. Then we can compare it with S-170-8 section
- Investigate the changes in eccentric loading on eccentrically loaded column with 100mm offset and eccentrically loaded column with stiffened plate having eccentricity 50%, 25% and 75%
- Conduct a push over analysis having beam and column were GFRP square hollow section

4. METHODOLOGY

4.1 MODELLING

Three-dimensional models were developed in ANSYS WORKBENCH 19.0 to demonstrate the behaviour properly. The models include tubular FRP beam having sections square, rectangular and hexagon. With splice length 170mm and 8 number of bolts. Here of all section is same and weight of FRP member in each section is same.

Inoder to check aspect ratio of splicing with various bond lengths considered for the study; that are 170mm, 150mm and 190mm. The sections are represented as S-170-8, HEX -170-8, REC-170-8, S-150-8, HEX-150-8, REC-150-8, S-190-8, HEX-190-8, REC-190-8 which is in the form of B-x-y where B is the beam section, x is the splice length and y is the number of bolts.

In the square section of S-170-8 an additional stiffeners are provided. Stiffeners (15 × 10 × 25 mm) are provided at the flanges.

Consider an eccentrically loaded column S-170-8 having both ends pinned condition. Column with stiffeners and column having 100mm offset from the center of the connection are taken. Size of the FRP column 990 × 102 × 102 mm having eccentricity 25%, 50% and 75% Conduct a push over analysis having beam and column were GFRP square hollow section having size 102 × 102 × 9.5 mm. A steel tube with dimensions of 80 × 80 × 6 mm was welded to an 8-mm-thick steel endplate (front endplate) to form the sleeve connector. The 6-mm-thick back endplate was slightly thinner than the front endplate. Here we are using cuff connection; a single monolithic unit for the entire column section as a load-carrying element, without the use of bolts, Because of the fabrication difficulty at that time. Pultruded angles wrapping around beam and column, developed the highest ultimate moment capacity compared to the others.

A grade 355 steel square tube (80 × 80 × 6 mm) was joined to a 6-mm-thick grade 250 steel flange-plate by fillet welds with a leg length of approximately 6 mm. The other end of the steel tube was coaxially coupled into and bonded to a pultruded glass fiber reinforced polymer (GFRP) square tube. The steel flange-plates with M12 grade 8.8 bolts (with washers and nuts), each of which was pretensioned to approximately 65 kN by a torque wrench to qualify as tensiontight according to AS1998 (Standards Australia 1998). The M12 bolt had a yield strength of 1,043 MPa and a Young's modulus of 235 GPa. Element solid 186 is used and shape of mesh is hexahedron

4.2 MATERIAL PROPERTIES

Table -1: Strengths and moduli of the GFRP material

Orientation and component	Strength (MPa)	Modulus (GPa)
Longitudinal tensile	330.6	25.2
Longitudinal compressive	330.6	-
Transverse flexural	88.5	6.2
Transverse tensile	88.5	-
Transverse compressive	103.0	-
Interlaminar shear	31.2	-
In-plane shear	27.6	3.0

Table -2: Strengths and moduli of the steel materials

Steel componenent	Yield strength (Mpa)	Ultimate strength (Mpa)	Young's modulus (Gpa)	Poisson's ratio
80 × 80 × 6 mm SHS	420.1	519.4	209.5	0.28
6-mm-thick flange	311.8	455.2	201.2	0.28

5. RESULTS AND DISCUSSION

From the analysis moment carrying capacity and corresponding deformations of square , rectangle and hexagon are checked. Fig 5.1 , 5.2, shows deformations of all sections

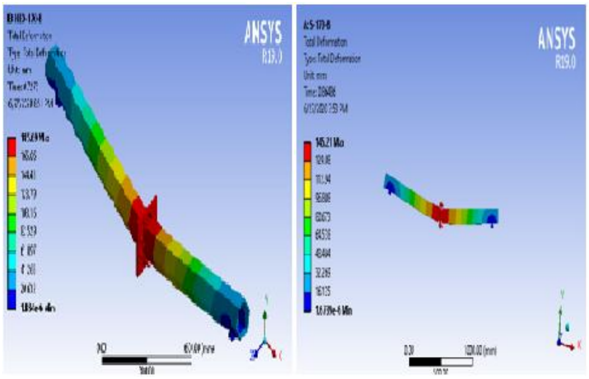

Fig 5.1:deformations of square and hexagon

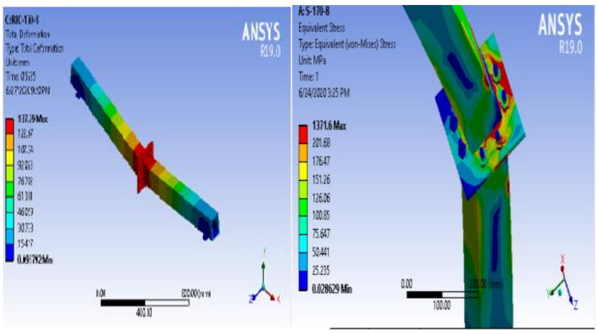

Fig 5.2 : deformations rectangle

In fig 5.1 red colour shows maximum deformation. That means maximum deformation can be shown at the flanges of the connection.

Table-3: moment and deformations of all sections

Shape	Moment (kn-m)	Deformation (mm)
Square	15.887	154.99
Hexagon	15.685	179.21
Rectangle	21.919	137.99

Analysis shows that rectangle has more moment capacity and also stiffness as compared to other sections. Also deformations are comparatively less.

In the above analysis shows maximum deformations can be seen at flange of the connection. In the next section provide an additional stiffeners (15 × 10 × 25 mm) to the flanges .

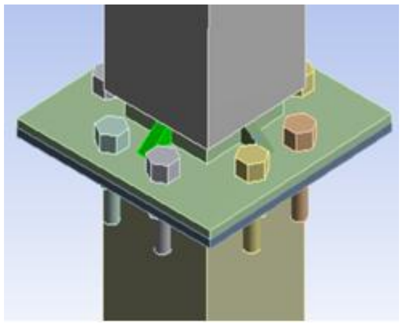

Fig -5.3: connection with stiffeners

Table 4: moment and deformation of the S-170-8 with stiffener and without stiffener

Section	Moment (KN-M)	Deformation (mm)
S-170-8		
Square	15.887	154.99
Stiffened S-170-8		
Stiffened S-170-8	17.726	146.18

Analysis shows by providing additional stiffeners can make more strength and stiffness.

Inoder to check the aspect ratio of splicing, with splice length 170mm, 150 mm, 190 mm following results are obtained

Table -5 : moment and deformations of 170mm, 150 mm,190mm bond length

Shape	Moment (KN-M)	Deformation (mm)
Bond length -170-8		
Square	15.887	154.99
Hexagon	15.685	179.21
Rectangle	21.919	137.99
Bond length -150-8		
Square	15.283	157.93
Hexagon	15.549	172.58
Rectangle	21.659	120.72
Bond length -190-8		

Square	16.085	157.51
Hexagon	15.784	172.58
Rectangle	22.323	136.89

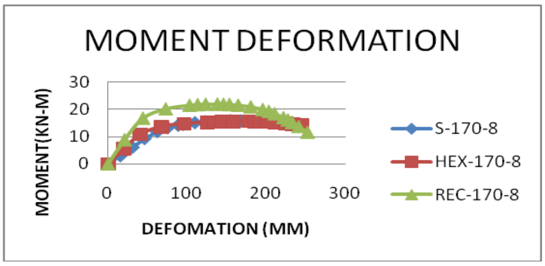

Chart -1 : moment – deformation of 170mm bond length

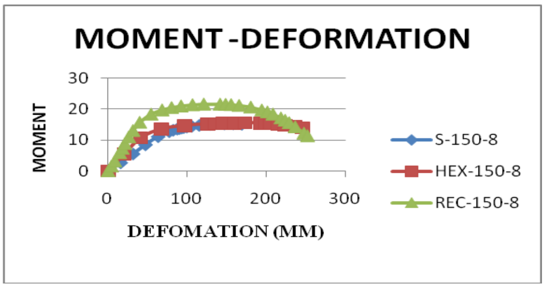

Chart -2 : moment – deformation of 150mm bond length

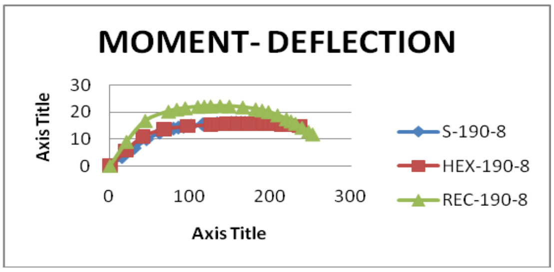

Chart -3 : moment – deformation of 190mm bond length

Analysis When the bond length was decreased by 20mm , it was observed that the deformation increases with no change in moment carrying capacity. Thus reducing bond length below 170mm is not much effective.

Among the above conditions best model should be considered as column. Beam with stiffeners and beam with 100mm offset shows more moment carrying capacity and stiffness. So these can be column sections. Here considering column with eccentricity 50%, 25%, 75% are considered . column having support condition both end pinned. The analysis result as follows

Table-6 : force and deformations of eccentrically loaded column

Section	Force	Deformation
Eccentricity-50%		
EL column 100 offset	242.38	35.082
EL column with stiffened	251.09	35.849
Eccentricity-25%		
EL column 100 offset	302.53	22.513
EL column with stiffened	305.83	24.9
Eccentricity-75%		
EL column 100 offset	207.69	34.084
EL column with stiffened	208.47	49.758

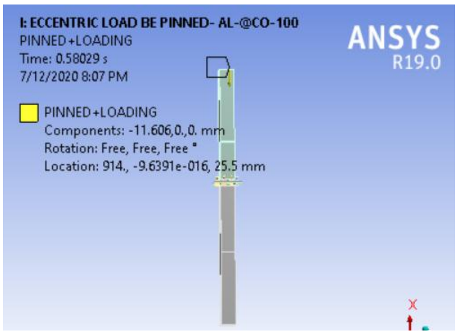

Fig -5.4 : column with eccentric load

25% Eccentricity at both cases shows almost same capacity of force and deformation.

Consider a frame with tubular FRP column and beam connected using cuff connection. Frame loaded statically ; maximum load carrying capacity and lateral displacement are checked.

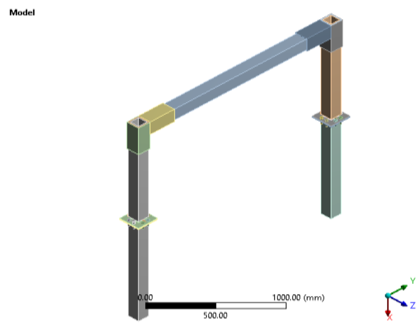

Fig -5.5: geomtry of tubular FRP frame

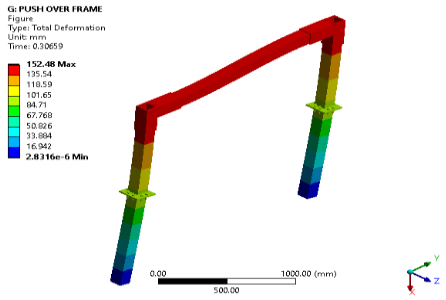

Fig -5.6 :deformation in frame

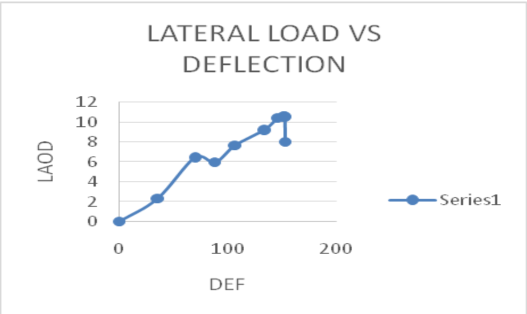

Chart-4 : load- deflection of frame

- stresses at
  - Steel tube :313 Mpa
  - Flange :303 Mpa
- Failure on load-Deflection :10.6
- Maximum lateral displacement :150.15mm

- Based FEMA CYCLIC PROTOCOL

drift =8% (corresponding to 150 mm drift displacement)

6. CONCLUSIONS

Analysis shows that rectangle has more moment capacity and also stiffness as compared to other sections. Rectangle has unequal stiffness in other sides. Square and Hexagon shows almost same moment carrying capacity. Hexagon has less stiffness than others. We can conclude that square shape is the more effective for the construction. When the bond length was decreased by 20mm, it was observed that the deformation increases with no change in moment carrying capacity. Thus reducing bond length below 170mm is not much effective. When the bond length was increased by 20 mm, it shows that a small change in moment carrying capacity but deformation is almost same. So we can conclude that increasing and decreasing of bond length is not applicable. When additional stiffeners are added to the flange makes 11.575% increase in moment carrying capacity and 6% decrease in the deformation with respect to normal S-170-8 sections. 25% Eccentricity at both cases shows almost same capacity of force and deformation. 25% eccentricity on stiffened eccentrically loaded column are more applicable. Tubular FRP frame have better load carrying capacity and less deformation. Based on FEMA CYCLIC PROTOCOL, drift of the frame is 8% ,that means the frame is seismically susceptible

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