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STUDY ON SPLICE CONNECTION FOR ASSEMBLY OF TUBULAR GFRP MEMBER UNDER FLEXURAL LOADING

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Abstract: This paper presents numerical investigations of the bending performance of innovative splice connections developed for tubular section FRP members. Each of the splice connections consists of a steel bolted flange joint between two tubular steel-FRP bonded sleeve joints. Specimens with different splice lengths are tested under finite element analysis. The FE modeling, moment-rotation behavior, and strain response, provides insight into the adhesive stress distribution and the yielding mechanism of the steel flange-plates.

***Index Terms* - Bolted Flange Joint, Bonded Sleeve Joint, Moment-Rotation Behavior, Strain Response.**

1. INTRODUCTION

Composite products made of fiber reinforced polymer or plastic (FRP) are increasingly used in civil engineering structures and poised as the modern day material owing to its superiority in terms of its adjustable characteristics such as high strength to weight ratio, commendable thermo-mechanical and corrosion resistant properties. It is composed of a polymer matrix reinforced with fibers. These fibers are usually glass (most widely used), carbon (premium cost), aramid (extremely sensitive to environmental conditions)or basalt and their polymer is usually an epoxy, vinyl ester, or polyester thermosetting plastic etc.

In particular, glass FRP (GFRP) composites are credited with sufficient strength and stiffness at moderate cost. Advances in the pultrusion manufacturing technique have enabled mass production of GFRP profiles at reduced cost with satisfactory quality control, motivating research into their application as bridge decks, reinforcement, roof structure, trusses and floor systems.

Several studies have been conducted to investigate the connection designs for FRP member as it is brittle and anisotropic in nature. Many authors have provided major references for FRP composite connections, specifically for open sections like plate, channel and I- section members. But compared to open section members, the closed section or tubular members have efficient resistance against torsional and global buckling, so it needed additional studies.

Many connection methods were proposed and studied by researchers to assemble tubular FRP members as it has added advantages than the open sections. In past studies, connection methods like standard connection, bolted through connection, steel connection, seated angle connection, wrapped angle connection, gusset plate connection, and cuff connection were developed and studied their behaviour under various loading conditions.

However, experimental results from those connections showed failures in a brittle manner, which were usually sudden without pre-warning. Failure of member were by stress concentration, separation of column flange, beam failure, cracking along the length of beam, failure on side plate and beam side wall, and some connections exhibit with fabrication difficulties. In practice for a closed section members, a connection system with ductile failure mode is favourable. To solve this problem, researchers proposed a connection system called bonded sleeve connection (BSC) which uses a sleeve connector formed by welding a steel endplate for joining tubular sections as beams and columns. Compared to other connections, BSC result in improved rotational stiffness, good moment capacity and ductility.

1.1 Objective of the project

- To investigate the effect of different splice lengths in proposed model.
- To evaluate moment rotation behaviour of each specimen.

2. MODEL DETAILS

The finite element modeling was performed using the ANSYS 16.0 software. A steel square tube of was joined to the steel flange plate by fillet weld.The cross-section of steel tube and steel flange plate were 80 × 80 × 6 mm and 190 × 190 × 6 mm, respectively. The other end of the steel tube were coaxially coupled and bonded to a pultruded glass fiber reinforced polymer (GFRP) square tube of length 890 mm by means of bonding agent - epoxy based adhesive. The cross-section of GFRP tube provided as 102 × 102 × 9.5 mm with adhesive layer of thickness 1.5 mm.

These two bonded assembles were fastened together at the steel flange plates with M12 grade 8.8 bolts (with washers and nuts). To accommodate the fillet weld and to remove rotational constraint, a gap of 15 mm provided between the GFRP tube and the steel flange plate. Fig.1 shows the proposed splice connection.

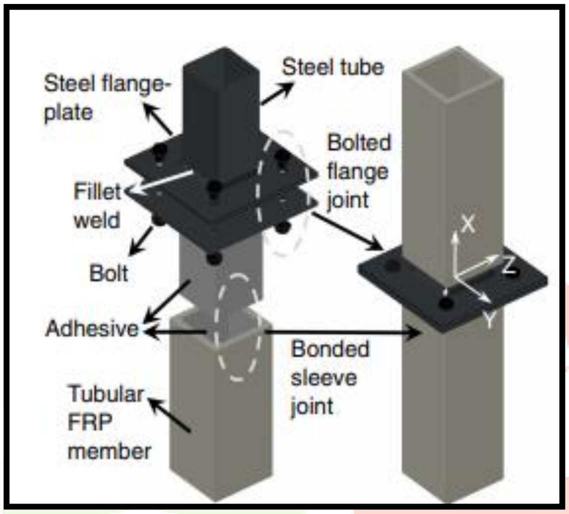

Fig.1 Proposed splice connection

3. Modelling And Analysis

ANSYS Workbench 16.0 was used to develop the three-dimensional model and non-linear simulations were done. Table 1 shows engineering properties of materials.

Table 1 Material Properties

Components	Yield strength (MPa)	Young's modulus (GPa)	Poisson's ratio
Steel square tube	420.1	209.5	0.28
Steel flange plate	311.8	201.2	0.28
GFRP square tube	330.6	25.2	0.3
Bolt	1043	235	0.28
Epoxy	32.2	4.25	0.28

In past studies, splice length of 120 mm and 170 mm bonded sleeve joints were studied and it was observed that increase in splice length from 120 to 170 mm, increased the moment capacity and also shifted the ultimate failure from GFRP web-flange cracking to fracturing of the steel flange plate. However, no studies were conducted to predict the effective length for the BSJ in a splice connection. So that studies needed to understand the effect of different splice length in splice connection and to enhance knowledge on the performance of tubular GFRP member.

Table 2 Geometric specifications of model

Model	Components	Dimensions
Square	GFRP tube	102 x 102 x 9.5 mm
	Steel tube	80 x 80 x 6 mm
	Steel flange plate	190 x 190 x 6 mm

For this investigation splice length of 150 mm and 190 mm was considered and it was conducted on the model of square cross-section . The models were named as S-150 and S-190. Here the bolt configuration was eight numbers of bolts. The finite element analysis was done and results were obtained in terms of deformation and equivalent stress. The values of moment and rotation were also compared and moment-rotation curve was developed.

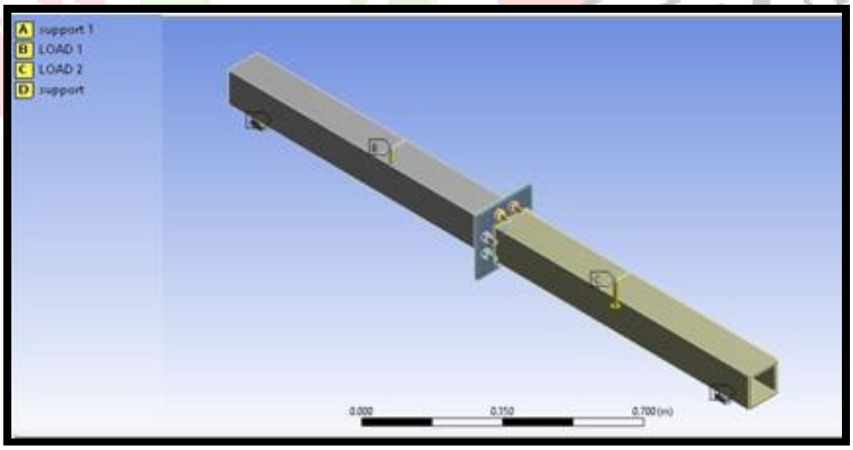

Fig.2 Model of the specimen with boundary conditions

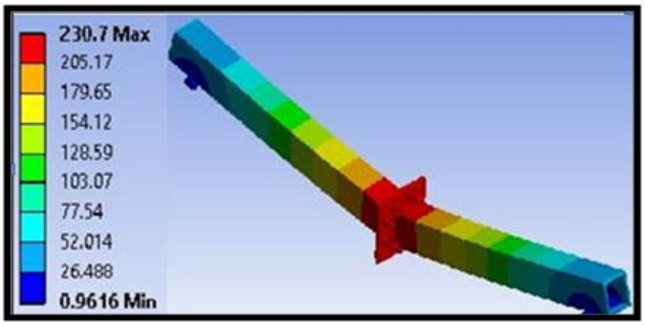

Fig.3 Total deformation of model S-150

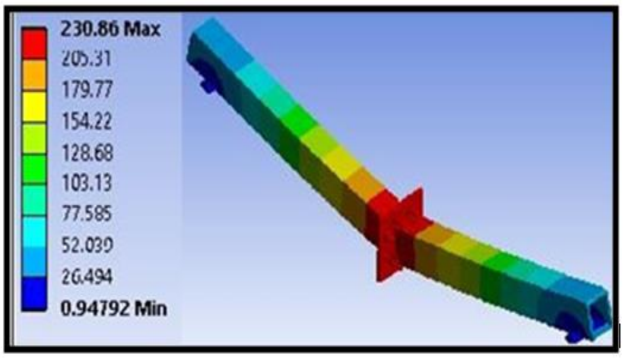

Fig.4 Total deformation of model S-190

4. Results and Discussion

After the study on effect of splice connection tubular member with different splice length was done, it was found that by increasing the splice length from 150 mm to 190 mm, made only a slight difference in moment capacity. When comparing these results with splice length of 170 mm model the effective splice length for the splice connection will be 170 mm and increase in splice length does not change the behavior of the splice connection under flexural loading in significant manner. Fig.5 shows the comparison of moment and rotation values for the splice lengths of 150 mm, 170 mm and 190 mm.

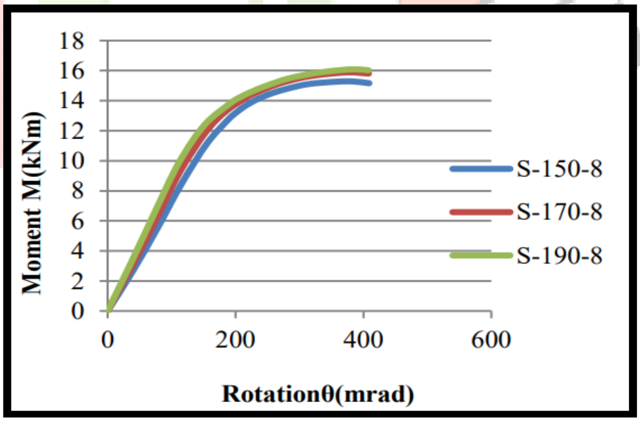

Fig.5 Moment-rotation curve

5. Conclusions

It was evident that there is no drastic change in deformation value. Under flexural loading the debonding of steel tube from flange plate was observed. Due to the debonding of GFRP tube from steel tube, stress distribution was observed maximum in the connection and also in the GFRP tube. The failure was observed by debonding of steel tube from flange plate and a loss of full composite action between the steel and GFRP tube in the later stage of the loading process. The observation suggested that increasing the bond length beyond 120 mm was not efficient in reducing the softening of the adhesive bond and FE modeling predicts the occurrence of bond softening only at larger load levels.

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