Experimental Investigations on Glass Fibre Reinforced Polymer Composite Pultruded Sections and Transmission Line Towers Modules

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ABSTRACT

The mechanical and environmental properties of Glass Fibre Reinforced Polymer (GFRP) composite pultruded members of angle, channel and box section with crush % under compression have been compared. Performance of various connections in GFRP composite pultruded members using adhesive, bolt and hybrid joints including crush % under compression have been evaluated. Fabrication of 3D tower module using different GFRP composite pultruded members have been done and tested for compression and investigation of connection behaviour including crush % have been carried out. Based on the investigations conducted, the performances of GFRP pultruded sections under different loading conditions and performance of various types of connections in GFRP composite pultruded sections have been discussed. The outcomes of 3D GFRP tower module made up of various sections have been presented and the best performing combination have been identified. A 110 kV Transmission Line Tower (TLT) model out of GFRP composite pultruded angle section have been fabricated for conducts load test.

Keywords : *Adhesive connection, Hybrid connection, Butt joint, Crush %, GFRP Pultruded Sections, Lap Joint, TLT*

INTRODUCTION

In our country, attempts to develop Transmission Line Tower using Fibre Reinforced Plastics pultruded sections are very few. To ensure the electric power transmission in the urban and rural areas, there is a need to technically develop compact 66 kV, 110/132 kV and 220/230 kV TLT structures and various factors like minimization of the tower footprint, its visual impact, utilization of restricted ROW and reduced land requirement along the TL route have to be ensured.

Under such circumstance in our country, need for conducting research in this vital area can't be ignored and hence an attempt has been made in the present research to

- Review the Literatures published which are dealing with the issues and challenges in construction of FRP based TLTs.
- Outline the need for investigating the mechanical and environmental properties of GFRP pultruded sections and connections.
- Suggest the step by step procedure for carrying out a comprehensive research in individual members, TLT modules and TLT models.

LITERATURE REVIEW

In order to identify the issues and challenges in construction GFRP based TLTs, published articles have been reviewed and the points identified are presented here under.

Selvaraj. M et al[1] have performed for technical, aesthetic and economic reasons, our next generation overhead transmission lines will be built with new materials and new design concepts in order to reduce the dimensions of the support structures. Selvaraj.et al[2] have conducted experimental studies on a X braced panel of TLT made from FRP pultruded sections and have indicated that building of TLT with FRP pultruded structural sections with suitable joining techniques is feasible. They have also performed an experimental analysis of a full scale 66 kV FRP tower under mechanical loading and demonstrated successful use of FRP sections.

Hernandez-corona et al[3] have checked the polymeric composite members, simulation of stresses along the TL were performed using COMSOL Multiphysics. Polyzois et al[4] have studied the structural behavior of a composite filament wound latticed tower under static and dynamic load conditions. The tower sections were fabricated without the

use of fasteners, thus eliminating the labour–intensive and fatigue prone bolted connections used in steel towers.

Prasad Rao. N et al[5] have studied the importance of design assumptions and connections detailing the overall performance of towers and highlighted the system behavior and prediction of failure pattern and ultimate load by Nonlinear finite-element analysis. Raghunathan M.D. et al[6] have discussed the development of the polymer composite known as Glass Fiber Reinforced Polymer (GFRP) material application in the civil/structural infrastructure.

The international council on large electrical system (CIGRE) has come up with a technical brochure on Transmission Line structures with FRP Composite under working group B2.61. It has elaborately discussed on various aspects of FRP material development, FRP structures manufacturing methods, FRP applications of lattice structures, FRP construction methods, Testing of FRP materials and structural components including FRP research and development needs in relation to overhead line components.

Need for the Present Research

From the Literature review carried out, it is observed that the investigation on the behaviour of GFRP pultruded section of different shapes and connections are very scarce and limited. Hence there is a need for investigating the behaviour of GFRP pultruded sections in a systematic way as outlined below.

1. Various shapes of GFRP pultruded members
2. Various joints and connections in the GFRP pultruded members
3. Development of GFRP TLT module and model
4. Experimental Investigation under load test.

Step by Step Procedure for Carrying out a Comprehensive Research

The step by step procedure followed for comprehensive research on this vital area is as below:

1. Visual inspection of FRP profiles
2. Testing for Mechanical and Environmental Properties
3. Testing for various connection
4. Fabrication and Testing of GFRP materials

(1) Visual Inspection of FRP Profiles

The common surface defects are identified as per the ASTM 4385-13 Standards. As of the present GFRP pultruded profiles are concerned following are the major defects noticed and such specimens were discarded.

(2) Testing for Mechanical and Environmental Properties

In order to examine the mechanical and environmental properties of GFRP pultruded section, 3 no of sample specimen have been prepared and various tests have been conducted as per ASTM standards and the tests is furnished in Table 2

Table 1 : Defect Identified in GFRP Specimens

S.No	Common Defects	Photos	S.No	Common Defects	Photos
1	Blister		4	Delamination	
2	Blooming, Undercure		5	Fiber Bridging	
3	Chips		6	Fiber Prominance	

Table 2 : Various Property Tests with ASTM code

S. No	Test	ASTM	Category
1	Compression test	D695	Mechanical
2	Tensile test	D3039	
3	Flexural test	D790	
4	Abrasion test	D4060	
5	Moisture Absorption test	D570	Environment
6	Fire test	D635-14	

The comparative results of maximum compressive strength and crush percentage, maximum tensile strength and tensile extension percentage, maximum flexural strength and deformation percentage and abrasion weight loss in percentage of various GFRP pultruded sections are furnished in Table 3.

- It is observed that GFRP pultruded box section withstanding 5% more crushing ability when compared to GFRP pultruded channel section and 30% more crushing ability when compared to GFRP pultruded angle section.

Table 3 : Comparison of Mechanical properties test results

S. No	Specimen	Compression		Tensile		Flexural		Abrasion (Max Wt Loss %)
		Max. Crush %	Max Strength (MPa)	Max. Ext. %	Max Force (kN)	Max. Deformation %	Max Force (kN)	
1	GFRP Channel	78.32	395.27	1.1	16.3	3.1	734.2	7.27
2	GFRP Angle	50.10	449.76	2.5	38.2	2.1	1776	3.22
3	GFRP Box	81.63	1202.5	2.5	38.2	2.1	1776	3.22

- It is observed that GFRP pultruded box section exhibits compressive strength 3 times higher than the GFRP pultruded channel section and 2.5 times higher than the GFRP pultruded angle section.
- While considering the tensile elongation, flexural deformation and abrasion loss, GFRP pultruded box section is in advantageous side. But GFRP pultruded angle section is more effective in the fabrication and connection when compared to box sections.
- From the abrasion test results, the observation of the channel specimen has been abraded more than angle and box specimen.

Table 4 : Comparison of Environmental Properties test results

S. No.	Specimen	Moisture Absorption Test (Weight Gain %)	Fire Test (Ignition time in seconds)
1	GFRP Channel	1.75	7
2	GFRP Angle	2.50	9
3	GFRP Box	2.50	9

- It is noted that in the moisture absorption test, GFRP pultruded angle & box sections weight gain of 43% higher than GFRP Channel section.
- It is noted that the GFRP pultruded channel sections withstands only 7 seconds for ignite which is 22 % lesser than GFRP angle and box sections.

(3) Testing for Various Connections

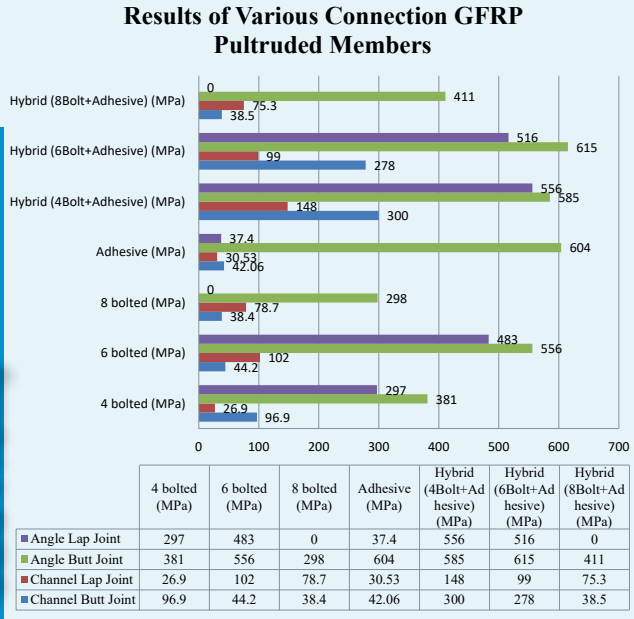
Experimental Setup:

In order to verify the efficiency of connection in the GFRP pultruded member for TLT fabrication is carried out may test have been conducted and the table 5 furnished the details.

Table 5 : Details of Various Connection and Joints of GFRP Pultruded Member

S. No	Joint	Member	No of Specimens	ASTM
1	Bolt (Butt & Lap Joint)	4 bolted Connection 6 bolted Connection 8 bolted Connection	3 No's (50mm x 5mm x 6mm)	D695
2	Adhesive	Butt & Lap Joint		
3	Combined (Butt & Lap Joint)	4 bolted Connection & Adhesive 6 bolted Connection & Adhesive 8 bolted Connection & Adhesive		

Result and Discussions



	4 bolted (MPa)	6 bolted (MPa)	8 bolted (MPa)	Adhesive (MPa)	Hybrid (4Bolt+Adhesive) (MPa)	Hybrid (6Bolt+Adhesive) (MPa)	Hybrid (8Bolt+Adhesive) (MPa)
Angle Lap Joint	297	483	0	37.4	556	516	0
Angle Butt Joint	381	556	298	604	585	615	411
Channel Lap Joint	26.9	102	78.7	30.53	148	99	75.3
Channel Butt Joint	96.9	44.2	38.4	42.06	300	278	38.5

Fig. 1 : Comparison of Compression Test on Various Connection Joints of GFRP pultruded members

- While considering the joints, butt joint exhibits better performance when compared to all other joints.
- As of connection investigations are concerned, the results are compared in Figure 11 and it is observed that 6 bolted with adhesives butt joint possess higher compressive strength value when compared to all other joint types.

(4) Fabrication and Testing of GFRP Materials

Experimental Setup

In the next step a comprehensive arrangements have been made for evaluating the performance of TLT module fabricated out of various GFRP pultruded profiles. Table 6 shows the details of the TLT modules and dimensions.

Table 6 : TLT Modules Details and Dimensions

S. No	TLT Modules	Description	No of Specimens	Dimensions
1	Channel (C)	Vertical member : Channel and Bracing : Channel	1	40 cm x 40 cm x 50 cm
2	Angle (B)	Vertical member : Angle and Bracing : Angle	1	40 cm x 40 cm x 50 cm
3	Box (A)	Vertical member: Box and Bracing: Angle	1	40 cm x 40 cm x 50 cm

(a) GFRP TLT Channel (b) GFRP TLT Angle (c) GFRP TLT Box

Fig 2 : GFRP TLT Modules Test setup

In order to investigate the behaviour of various shapes of GFRP pultruded modules such as channel, angle and box sections against the maximum load, the test have been conducted in the universal testing machine as shown in Fig 2.

Result and Discussions

A comparison on compression behaviour of GFRP pultruded TLT module is furnished in Figure 3 and it is noted that TLT module A category shows more compressive strength when compared to C module which is nearly 4 times the compressive strength and compared to B module which is 1.7 times the compressive strength.

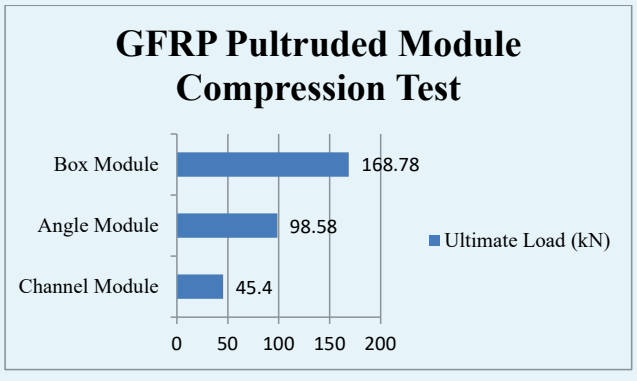


Fig. 3 : Comparison result of GFRP pultruded TLT Modules

CONCLUSION

In the experimental investigation, the following studies have been concluded

- Visual inspection of FRP profiles have been carried out and discarded.
- Testing for Mechanical and Environmental Properties have been carried out and the behavior of GFRP profiles have been investigated.
- Testing for various connection have been carried out identified the best connection and joints suitable for TLT
- Fabrication and test of GFRP modules have been carried out and compared the ultimate load carrying capacity of compression.

Future Work

- A 110 kV Transmission Line Tower (TLT) model out of GFRP composite pultruded angle section have been fabricated for conducts load test.
- GFRP Transmission Line Tower (TLT) model will be analysed by software.

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