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An Examination on Torsional Loading and Environmental Effect on Glass Fibre Reinforced Polymer Cross Arm in Transmission Line Tower

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Abstract:
Transmission Line Towers have crossarm which is from Glass-Fibre Reinforced Polymer (GFRP), where the insulator assembly and bare line conductor are located at a safe distance from the tower structure. Crossarm structures normally subjected to various load combination. Therefore this paper will provide a review on the previous researches on GFRP due to the torsional loading and torsional behaviour of GFRP structures, where it was revealed that the mechanical strengths. In addition, the GFRP alone has others advantageous which generally more robust compared to other conventional materials on strength which regard to high strength and stiffness-to-weight ratio, corrosion resistance, chemical stability. It has the capability to sustain various loads, longer serviceability and perform as a good insulator in lightning impulse strength.

Keywords: *Torsional behaviour, GFRP structures, Crossarm, Transmission Line Towers, Environmental*

I. Introduction

The Fibre-reinforced polymer (FRP) is used to build crossarm members in the design of the transmission line (TL) towers [1-3]. The failure mechanisms of FRP are more complex under multiracial loading than under uniaxial loading. Evaluation of the behavior of FRP under multiracial loading is important for designing composite structures [1]. Glass FRP (GFRP) composites are the common FRP materials compared to the other FRP materials, cause of its lower cost and high quality and consistency in their production [4]. Therefore, the uses of the GFRP composite is becoming attractive and more popular due to their lightweight, high strength, and

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its corrosion in resistance at transmission line tower components [5]. If the FRP composites were exposed to the environmental loading and mechanical properties, it may degrade during their service life. The value of the degradation rate for the GFRP composites may increase, due to the simultaneous action of mechanical and the environment loading [6].

Generally, when it has high strength material it will have low dumping capacities. When it has high damping material, it will have low strength and poor mechanical properties. Composite materials, however, offer the possibility of both high strength (from the fibre) and high damping (from the matrix and from matrix/fibre interaction), a combination of the strength and damping may well prove valuable for structural purpose, but very little quantitative work has been carried out concerning the damping properties of fibre reinforced plastics.

The GFRP crossarm is a surplus component to the basic insulator where combined insulation significantly, in order to improves the lightning impulse voltage performance of the electrical power line distribution and transmission line structure, shown in Fig. 1, view of the transmission fiberglass crossarms installed on the pole structure, combine with fiberglass strain rod. Flashover will be occur if the insulation length of a strain rod, L", is not proportional with the insulation length of fiberglass crossarms, L'[7].

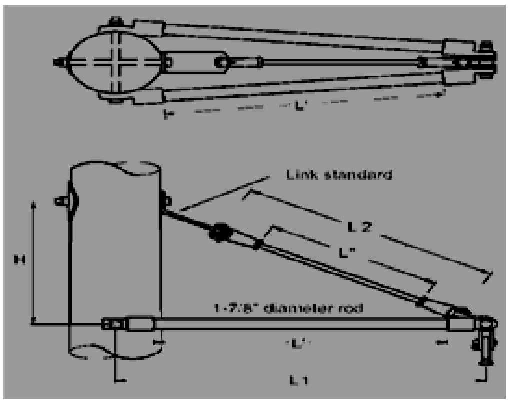

Fig. 1 Transmission fiberglass crossarm system. [7].

The GFRP properties depend on the characteristics of their constituent materials (a type of polymer and matrix and reinforcing fibre), fibre orientation, fibre content and also the interaction between fibre and matrix. Due to the internal structure of the GFRP laminates profiles, the behaviour of the material is isotropic, with higher mechanical properties in the direction of the rovings. For example, the mechanical properties of the crossarm structure are higher in the longitudinal fibre direction in pultrusion process compare with any other direction. Otherwise, the real effect of main nature arrangements on transmission line structures into the application is dynamic, such as wind forces, vibration, elevate nature temperature and mechanical defect (cable rupture) would break all the tower line assemblies [8]. This continuous and multitude action/forces effect (longitudinal or transverse) will result in a catastrophic collapse if the insufficient relative strength of FRP was not supported by the strength of assemblies in the mechanical load and forces reflection.

Additionally, another effect from environmental degradations of FRP in many applications structural is also very crucial in generally. Specifically ageing of GFRP composites component or structures caused by a climate and temperature gradient in Malaysia [9]. Actually, the available information on the torsional behaviour and the load-carrying mechanism of this GFRP crossarm are very limited. Therefore, this review on the previous study which related to the composite structures will be considered as a factor for unique torsional response and load-carrying mechanism for crossarm application.

II. Effect of Torsional Behaviour of Load-Carrying Mechanism

To extend the description of the loading mechanism in the torsional effect of FRP in such application, the numerous study has focused and emphasis in varies of the application of structures study and experiments to investigate the torsional behaviour in terms of strength, rotational ductility, and failure mode. Torsional analysis and effect of composite structures is a topic of major interest both from the theoretical and applicative point of view. Therefore, in this review, the previous study from the experimental responses are highlighted to composite structure give a clear picture in term of strength and torsional collapse behaviour.

Meanwhile from the theoretical, there are a few are address is using which contributed to the solution. Structural members in crossarm structure are one of the examples of the structural elements subjected to the torsional moment where the torsion cannot be ignored while designing these members structural subjected to multi-load or multi-forces exist with are of diverse profile such as T-shape, inverted L-shape, double T-Shapes and box sections. Besides, the consequence of torsion, the cracks follow the spiral crack pattern and failure of the structural member occurs [10]. Therefore, different strengthening and upgrading procedures are available, out of which, application of FRP is the best solution for torsional strengthening.

III. Torsional Behaviour and Investigation

Tibhe and Rathi [10] found that GFRP bonded beam with control specimen with respect to torsional moment, angle of twist and ductility factor has found out for the specimen have characterized of reinforced torsional strength for RC beam.

From the study of Raffaele Barretta et al. [11] stated the torsional in terms of warping function of two-phase random composite beams by a FEM approach.

Meanwhile Potluri et al. [12] is an investigation of flexural and torsional properties of biaxial and triaxial braided composites, with the results found from the predicted of computed with modified laminate theory and laminate analysis experimental results were in good agreement with the values.

The torsional behaviour of unidirectional GFRP materials with the same resin matrix has been investigated by Ogasawara et al. [13] where the Lekhnitskii's equations has been used to calculate the torsional rigidities while compared with experimental results, thus from the data achieve Ogaswara et al has found that the equation was agreed with the experimental results, and they are mainly determined by the shear stiffness of the materials.

The study by Zhang et al [14] of torsional behaviour of a novel lightweight hybrid fiber-reinforced polymer (FRP) – aluminum space truss structure that consists of two triangular deck-truss beams has found that the torsional calculation from the experiments was appropriate with numerical analyses results.

Meanwhile, Vijaya Ramnath et al. [15] has study the torsional behaviour of polymer composite golf shaft has found that the composite shaft will perform better than steel shaft which the GFRP gives a better result for the flexibility, strength and torsional breaking strength behaviour.

Ogasawara, Onta, et al. [16] studied regarding the torsion behaviours of unidirectional GFRP with the same matrix resin, found that in the nonlinear torsional behaviour was observed above 0.5 % of the shear strain, and it is due to visco-plastic and plastic deformation of the matrix resin.

IV. Flexural Torsional Buckling

For the last 20 years, there were various authors have been addressed about the performance and strength of pultruded GFRP members due to concentric compression. Most of the works have focused on I-shaped sections, with little attention devoted to tubular sections (see Fig. 2).

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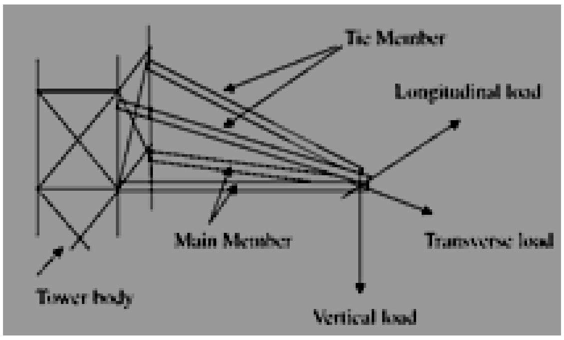

Fig. 2. Schematic of multi loading mechanism at the composite cross is attached at lattice transmission and distribution line tower [3].

Meanwhile structure of pultruded GFRP tube applies in many applications. Thus, the square tube of glass-fiber reinforced polymers (GFRP) crossarm has produced by the pultruded technique, and most of the advantages of pultruded GFRP have made the material attractive in the applications at transmission tower with low self-weight and corrosion resistances capabilities. Therefore, the preferred cross-section in geometry selected is preferred because of its ease of connection and maintenance factor, however the cross-section geometry in the crossarm application could exhibit complex behaviour when subject to multi-axis compression forces.

Buckling modes mainly characterized due to reducing torsional stiffness, plus it occurs with flexure during buckling, affecting significantly the member capacity. From the study Cardoso and Togashi [17] of the flexural-torsional buckling behaviour of pultruded glass-fiber reinforced polymer (GFRP) indicate that the result of load-deflection curves which presented with the influences of post-buckling reserve of strength, damage and differential rotation has significant characterization with generalized beam theory (GBT) predictions (see Fig. 3).

Furthermore, in the study of Cardoso, Harries, and Batista [18] were regarding the development of a rational and comprehensive equation in order to determine the strength of GFRP pultruded square tube columns under the concentric compression. In the study the material properties, critical loads, compressive strengths and failure modes are reported. Post-buckling has been observed on the behaviour and interaction between crushing, local and global buckling (see Fig.4). From the above-mentioned, result from the equation can be calibrated for this or any lateral deflection criterion and testing of columns exhibiting large lateral deflection which both data showing good agreement.

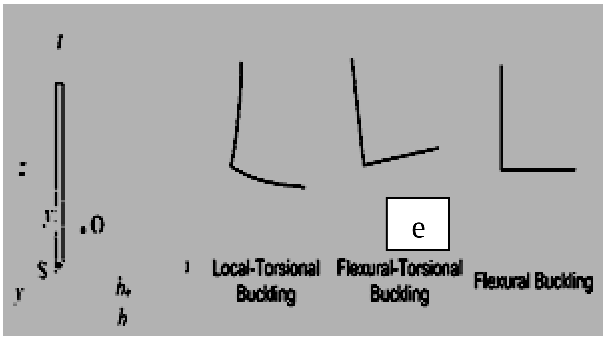

Fig. 3. L shape column parameters with buckling modes observed in angle members subject to compression [17].

Fig. 4 Failure modes observed of pultruded GFRP square tube (local buckling and slenderness mode) [18].

Meanwhile Swanson [19] on his study review an existing solution for the problem of torsion of orthotropic laminated rectangular bars section. Results are also given to show convergence of different forms of the solution, as well as to assess the error when the thin cross-section formulas are used for intermediate aspect ratio geometries (see Fig. 5).

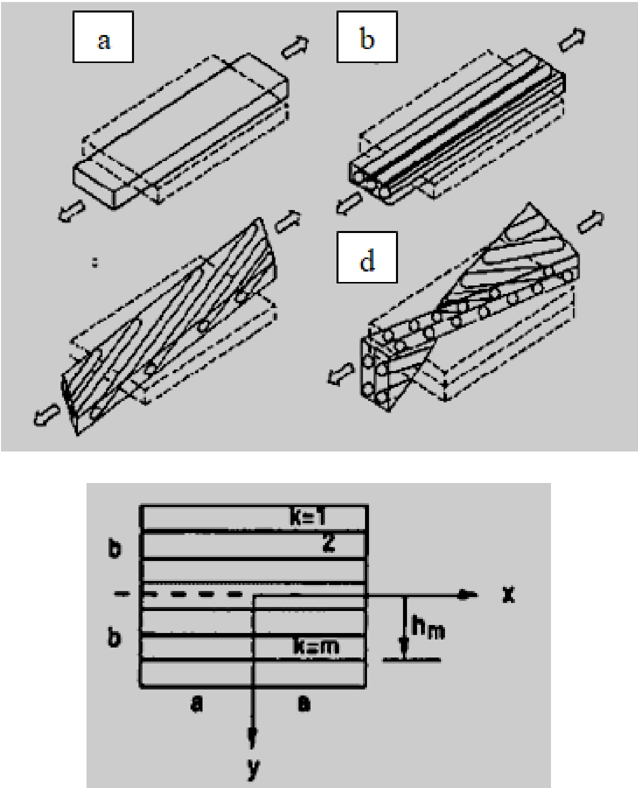

Fig. 5. (a) Deformation of isotropic material, (b) Orthotropic composite under uniaxial tension - coaxial, (c) Orthotropic composite under uniaxial tension – off-axial, (d) Orthotropic composite under uniaxial tension – general laminate, (e) Cross-section of layered loading about the z-axis. [20] [19].

V. Conclusions

The wooden crossarm was used in the early introduction of transmission lines in Malaysia. Later in 1963 fiberglass crossarm was suggested to exchange wooden cross arm on transmission towers in Peninsular Malaysia.

The purpose of this paper was to evaluate the torsional effect and torsional behavior and load carrying mechanism of GFRP composites crossarm in the transmission line. Understanding the previous torsional behavior study which benefits to identifying and predicting in-term of service-life and the influence in deformation measure of composites corresponding to the serviceability of crossarm transmission line structures application in Malaysia.

Hence, it is vital to acknowledge the torsional effect of GFRP cross arm performance and awareness factor as a function of time or lifespan will attribute to serviceability high-performance composite crossarm.

However, research on load mechanism characteristics of FRP composite for crossarm transmission line tower in pultruded composites is relatively limited, furthermore the development in general technique fabrication/manufacturing the FRP composite crossarm is also less presence in study where the particular fiber arrangement and certain fiber matrix system/composition will be a potential factor to enhancing and prolong the life-span and capability/serviceability of crossarm in transmission line in Malaysia application.

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