บทความวิจัย/วิชาการ

FIBER REINFORCED POLYMER CROSSARMS : A NEW DIMENSION IN COMMUNICATION CABLES MANAGEMENT

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บทคัดย่อ

การศึกษานี้แบ่งออกเป็นสองส่วน ได้แก่ การทบทวนวรรณกรรมเรื่องวัสดุเส้นใยเสริมแรงโพลิเมอร์เพื่อผลิตคอนฉนวนแทนวัสดุดั้งเดิม และการทดสอบคอนฉนวนที่ขายเชิงพาณิชย์ของผู้ประกอบการในไทยรายหนึ่ง การทบทวนวรรณกรรมมีวัตถุประสงค์เพื่อศึกษาความเป็นไปได้ในการใช้วัสดุเส้นใยเสริมแรงโพลิเมอร์แทนวัสดุดั้งเดิมในการผลิตคอนฉนวน จากการศึกษาพบว่า วัสดุเส้นใยเสริมแรงโพลิเมอร์สามารถที่จะนำมาทดแทนวัสดุดั้งเดิมได้ เนื่องจากสมบัติทางวิศวกรรมที่ดีเยี่ยม และอายุการใช้งานที่ยาวนาน นอกจากนี้ราคารวมทั้งค่าติดตั้งและการดูแลคอนฉนวนจากวัสดุเส้นใยเสริมแรงโพลิเมอร์ยังถูกกว่าวัสดุดั้งเดิม ทำให้คอนฉนวนจากวัสดุเส้นใยเสริมแรงโพลิเมอร์มีความได้เปรียบในการแข่งขันกับวัสดุอื่นๆ ในอนาคต กรมวิทยาศาสตร์บริการในฐานะหน่วยงานที่รับทดสอบและรับรองมาตรฐาน ได้ทดสอบคอนฉนวนจากวัสดุเส้นใยเสริมแรงโพลิเมอร์ของผู้ประกอบการไทยรายหนึ่ง ตามมาตรฐานของการไฟฟ้าส่วนภูมิภาคและมาตรฐานสากล พบว่าคอนฉนวนของผู้ประกอบการไทยผ่านเกณฑ์มาตรฐานทั้งหมดได้ เราหวังว่างานศึกษานี้จะเป็นประโยชน์กับผู้ที่เกี่ยวข้องที่จะนำข้อมูลไปใช้ประกอบการตัดสินใจในการเลือกใช้วัสดุเส้นใยเสริมแรงโพลิเมอร์ในงานคอนฉนวนต่อไป

คำสำคัญ : เส้นใยเสริมแรงโพลิเมอร์ คอนฉนวน สายสื่อสาร

Abstract

This study can be divided into two parts: the review of fiber reinforced polymer comparing to other traditional materials in the crossarms, and the test of the commercialized crossarms supplied by a Thai company. The review aims to examine fiber reinforced polymers

(FRP) as the replacement for the traditional and conventional materials in crossarms. It was shown that the FRP can certainly replace the traditional materials in the future due to its superior engineering properties and its long expected service life. In addition, the overall cost of the FRP crossarms was shown to be cheaper than other materials'. Hence, this will provide a competitive edge for the FRP crossarms. As the testing, inspection, and certification agency, the Department of Science Service has performed the tests of the crossarms supplied by a Thai company. The crossarms was thoroughly tested and investigated according to the domestic (PEA) and international (ASTM) standard. It was found that the crossarms supplied by a Thai company can pass all the required standards. The study may be useful to the interested parties to utilize the information as the support to adopt the use of the FRP materials in related fields.

Keywords : fiber reinforced polymer, crossarm, communication cable

Introduction

Figure 1. Typical view of a sidewalk in Thailand (A). The communication cable connected to the electrical power with hooks (B).The entanglement of communication cables (C).The communication cables/lines arrangement near the high voltage transformer (D).

If you look above your head when walking along the street of Thailand, two things that you can easily observe are the disorder of installed communication cables and their close proximity to electrical power wires above you as seen in Figure 1. Most of the electrical power structures are mainly consisted of two important parts: crossarms and the pole. The crossarm (Figure 2) is defined as the bar attached to the main pole which can be used to house either the electrical power wires or the communication cables. Therefore, a single power pole can have multiple crossarms attached to it such as the one shown in Figure 1 A. Furthermore, the top crossarm is always reserved for the high voltage power wires, while the lower one will be used for transmission wires. Additionally, some poles can have additional crossarms at an even lower level to accommodate the attachment of the communication cables for the purpose of the line management and distribution.

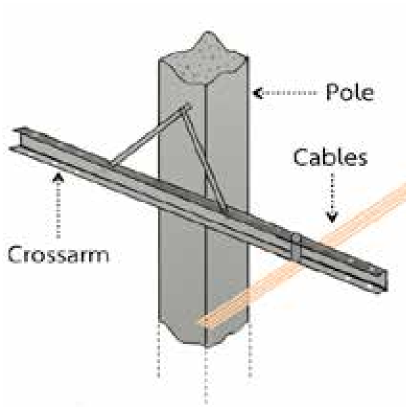

Figure 2. The crossarm attached to the electrical power pole

However, if there are only a few communication cables to attach to the pole, they can be directly attached to the pole with just a simple hook as seen in Figure 1 B. However, the increasing number of inhabitants in the area will usually result in higher demand for additional utilities, including the communication service. Thailand does not enforce the regulation on the installment of the additional lines as much as it should do. Hence, the increasing number of the cables will usually result in the disorder and entanglement as observed in Figure 1 C. The risk is then raised when the installment of the communication cables is in the proximity of the electrical power wires (Figure 1 C) or the high voltage transformer (Figure 1 D). The rising risk is due to the fact that most of the communication lines, except the fiber optics, are still using copper and aluminum as a mean of data transfer (Wittenberg, n.d.). Hence, it will be very hazardous if the damaged communication cables contact with the electrical power wires or the high voltage transformer. This would result in a very deadly accident such as the recent event when the cable installation technician got electrocuted on September, 10th 2017 (Khaosod, 2017)

Traditionally, electrical power structures are mainly manufactured from one of the three materials, including wood, concrete and steel. Each of materials has its own advantages and also its own drawbacks. A briefly summary of each material is shown below.

1. Wood is a versatile material and a popular choice for the electrical power structure because of its relatively low upfront cost (Toth & Lockhart, 2014, p. 14). Moreover, wood is also a good natural electrical insulator. Usually, wood will be treated to prevent fire, rotting, and termites. Hence, many chemicals and preservatives will need to be used to do the treatment such as Pentachlorophenol and Creosote. Both of the chemicals are toxic, one is a biocidal agent and the other is a carcinogen respectively (FRP Transmission Innovations Inc., 2013).

2. Steel is lightweight and does not biodegrade. However, steel is prone to corrosion from environments, chemicals and pollutions, which can shorten the lifespan of the steel structure. Due to this fact, regular inspection and maintenance are needed to be performed to ensure the safety of the structures (FRP Transmission Innovations Inc., 2013). This will increase the maintenance cost and also associated cost. However, steel is also a very good electrical conductor so it's not ideal to build electrical power structures from steel since a minor mistake can cause a catastrophic accident (Toth & Lockhart, 2014, p. 15).

3. Concrete is usually used in the form of the pole due to its durability and resilience, but sometimes a small one can be used as the crossarm. Concrete is also a very good electrical insulator similar to wood. However, due to its weight the concrete poles and structures will be required heavy machinery to install (FRP Transmission Innovations Inc., 2013). Therefore, the installment of the structures in the remote area or the dense neighborhood will be very hard and expensive to install. Moreover, the damaged one will need to be replaced instead of repaired since cracks could affect the concrete structures in numerous ways such as lower the durability and weaken the mechanical properties (Herbert & Li, 2013, p. 2831).

In this article, we will look through other alternative, namely fiber reinforced polymer (FRP), and its properties. The new material will be needed to solve all the drawbacks of other materials such as the flammability in wood, the corrosion in steel, the heavy weight and costly resources used to install a structure in concrete, and the high maintenance cost from all three materials. Additionally, we will examine one of the commercialized FRP crossarm supplied by Thai company, Kij Sangthong Trading Co., LTD. and its properties.

Methods

In this article, two studies will be investigated: the review of FRP comparing to other traditional materials and the test result of the commercialized FRP crossarms.

The review of FRP comparing to other traditional materials

In this study, the authors will compile and discuss the benefits of FRP materials comparing to other traditional materials from both the engineering and economic points of view. Most of the data will be reproduced and compiled from previous studies.

The test result of the commercialized FRP crossarms

The Department of Science Service (DSS), which is the leading government agency providing the product testing, inspection, and certification services with MSTQ standard. DSS can help as the evaluation, inspection, and certification agency for the products in order for them to be able to join the bidding of tenders form Provincial Electricity Authority (PEA). According to Terms of Reference "RHDW-027/2559: the Fiberglass Reinforced Polymer (FRP) crossarm 1,000 mm," the products wished to join this bidding have to meet certain standards (Provincial Electricity Authority, 2017).

Different test methods according to domestic and international standards such as ASTM can be performed to determine the competency of crossarms. The list of the test methods are as follows:

1. Water Absorption according to PEA specification (Provincial Electricity Authority, 2017)
2. Dielectric strength according to PEA specification (Provincial Electricity Authority, 2017)
3. Dimension testing according to PEA specification (Provincial Electricity Authority, 2017)
4. Accelerate Weathering according to ASTM G154-12 and ASTM D790-10 (ASTM International, 2010; ASTM International, 2012)
5. Thermal Aging according to ASTM D3045-10 (ASTM International, 2010)

6. Flammability Test according to UL-94 (UL, 2013)
7. Bending Test according to PEA specification (Provincial Electricity Authority, 2017)
8. Fiberglass content according to ASTM D2584-11 (ASTM International, 2011)
9. Hardness Barcol according to ASTM D2583-13 (ASTM International, 2013)
10. Volume resistance according to ASTM D257-14 (ASTM International, 2014)
11. Bolt-hole torque strength according to PEA specification (Provincial Electricity Authority, 2017)

Results and Discussion

The review of FRP comparing to other traditional materials

Over the past decade, FRP has emerged as an alternative to traditional and conventional materials in numerous fields. FRP or Fibre Reinforced Polymers is a multiphase composite made of a polymer matrix reinforced with fibers. According to the principle of combined actions, a better combination of properties can be achieved. By using low density fiber materials to mechanically enhance the strength and elasticity of polymers, the relatively weak polymers can become stronger with high strength, high stiffness, and light weight (Callister & Rethwisch, 2011, p. 627-628).

The properties of FRP, wood, steel and concrete are summarized in Table 1. Due to its superior properties, FRP become new alternative materials to build electrical power structures in many developed countries.

Properties	FRP	Wood	Steel	Concrete
Corrosion, rot, and insect resistance	Resisted to a board range of chemicals /unaffected by moisture/ Resisted to insect damage	Prone to rotting and decaying when exposed to moisture/ susceptible to attack from insects	Prone to oxidation and corrosion (require painting/galvanizing)	When moisture penetrates the concrete, rebar corrosion can occur.
Strength	High strength	Low strength	High strength	High strength (with rebar)
Density (g/cm^3)	1.5-2.1 depending on types of fiber	0.4-0.7 depending on moisture	7.85	2.40
Electrical conductivity	Nonconductive	Can be conductive when wet	Conducts electricity	Nonconductive
Thermal properties	Good insulator	Good insulator	Bad insulator	Moderate insulator
Modulus of Elasticity (E) (GPa) (Stiffness)	140-150 (High stiffness, rigid and hard to deform under load)	12-13 (Low stiffness, rigid, but easy to deform under load)	200 (High stiffness, rigid and hard to deform under load)	20-40 (Low stiffness, rigid and easy to deform under load)
Impact resistance	Will not permanently deform under impact	Can permanent deform under impact and break	Can permanent deform under impact	Can permanent deform under impact and break
Expected Service Life (year)	70-100	45 (treated)	60 (galvanized)	50
Cost of Materials	High	Low	Medium	Low
Cost of Installation and Maintenance	Low installation cost and Low maintenance cost	Low installation cost, but High maintenance cost	High installation cost and High maintenance cost	High installation cost and High maintenance cost

Table 1. Comparison of FRP versus traditional materials (Bedford Reinforced Plastics, 2017; Callister & Rethwisch, 2011; FRP Transmission Innovations Inc., 2013; Kalaga, 2013; Mishra, 2010)

Some reasons why FRP structures are widely used, specifically the crossarm, are as follows (FRP Transmission Innovations Inc., 2014a; "Use of Composites Increases in the Utility and Telecommunication Industries," 2004)

1. The weight of FRP is light; it can be lifted by one or two persons and easily lifted from the ground to install without heavy machinery like crane lift or helicopter lift.
2. FRP crossarms are electrically nonconductive. When it's installed on the live energized pole, the risk of electrocute is low.
3. The surface of crossarms is smooth but not slippery, and there are no splitters or other surface items to harm installation technicians.
4. The ease of field drilling and field cutting when needed.
5. The high strength-to-weight ratio of FRP allows it to be convenient and cost-effective to transport and install in many remote locations where the use of heave machinery is not possible.

6. The expected life span of the FRP crossarm is over 70 years. Hence it can reduce the number of replacements comparing to other materials.

From the economic point of view, FRP crossarms will reduce the cost of the replacement as well as the maintenance cost. For example, wood crossarms would need to be replaced in about 25-40 years depending upon environmental conditions and the quality of timber. With this fact, the FRP crossarms can skip 2 cycles of replacement. The analysis performed by FRP transmission Innovations Inc. in 2014 shows that at 75 years period when the first FRP crossarm needed to be replaced, the overall cost (material, installation, maintenance and replacement cost) of FRP crossarms will be only half of the overall cost of wood crossarms (FRP Transmission Innovations Inc., 2014a). All of these factors will be greatly amplified in Thailand setting due to the humid climate, where it could rain all year round.

The other point from the economic standpoints is the cost of recycle or disposal of the worn-out structures, especially for the wood crossarms. Most of wood crossarms will be needed to have surface treatments in order to prevent the natural corrosion, rotting, and the attack from insects (FRP Transmission Innovations Inc., 2013). The treating chemicals and preservatives are toxic and very hard to safely dispose. Hence, the cost of disposal the product will be high as well as the recycling of the product will be nigh impossible. While, in the case of FRP crossarms, there is no leaching of chemicals into the environment and it can be safely recycled and disposed in the general landfill without any environmental contamination (FRP Transmission Innovations Inc., 2014b)

The test result of the commercialized FRP crossarms

Figure 3. Installed FRP crossarm the front with NBTC logo (A) and the rear (B). FRP crossarm (glass fiber) supplied by Kij Sangthong Trading Co., LTD. (C)

With the increasing uses of FRP materials in numerous applications nowadays, most of the FRP materials used in Thailand are still relied on importing from overseas manufacturers. Hence, the many advantages of FRP can be easily offset by the cost and price of the FRP materials. Therefore, if Thai companies can supply the products locally, it would be beneficial for Thailand. One of such example is the company name Kij Sangthong Trading Co., LTD., which have co-developed and co-researched in partner with Office of The National Broadcasting and Telecommunications Commission (NBTC), to develop the FRP crossarms as shown in Figure 3A and 3B.

As the government agency, the Department of Science Service could provide the test result to manufacturers and suppliers to certify the product according the PEA requirement and other relevant agencies/organizations. Kij Sangthong Trading Co., LTD. had submitted such request to DSS in 2016. The submitted samples are shown above in Figure 3C. The rationale for each test will be covered and discussed prior to showing the results. The rationales are as follows:

1. Water absorption test is tested to show that the product will not absorb too much water and become electrical conductive.
2. Dielectric strength is tested to demonstrate that the structure can withstand the damage in case of short circuit or external electric field.
3. Dimension testing is performed to show that the product following the dimensional specification of the PEA.
4. Accelerated weathering is tested to gauge the product's properties after placing in the simulated environment by using intense UV radiation cycles.
5. Thermal aging is tested to see the effect of heat from environment on the product.
6. Flammability test is performed to confirm that the products will not be burnt or ignited from external source, which can damage the overall structure.
7. Bending test is performed to show that the product can withstand assigned loads.
8. Fiberglass contents are tested to confirm that product is met with the required amount.
9. Hardness Barcol is tested to show that the product can withstand enough of external force that can accidentally strike the structure.
10. Volume resistance is tested to show that the product is an insulator and will not conduct electricity

11. Bolt-hole torque strength is tested to show that the product can be safely attached to main electrical power pole by bolts and wrench without any damage.

The detailed test results are shown in Table 2. The product passed all the criteria of the minimum PEA requirements. Moreover, the products even excel in some criteria, including the water absorption, fiberglass content, hardness Barcol and electrical volume resistance.

Test methods	Result	Minimum Requirement	Comment (measurement unit and other)
Water Absorption	0.10%	Less than 0.25%	%
Dielectric Strength	Passed	Passed	No breakdown/flashover at 20 kV for 1 minute
Dimensions	Passed	Passed	According to spec sheet
Accelerated Weathering	92.3%	90%	The specimen after treating with UVA-340 for 2,250 hrs. has the flexural strength more than x % of the untreated specimen's.
Thermal Aging	Passed	Passed	No cracking test at 70°C for 3 weeks
Flammability UL-94	Class V-0	Class V-0	Class V-0
Bending Test Vertical – 2,000 kg Horizontal – 1,100 kg	Passed	Passed	No dent, bent, chip, crack, or other deformation
Fiberglass content	66.1	More than 55	%
Hardness Barcol	77.8	More than 40	No unit
Volume Resistance	$1.61*10^{14}$	More than $1*10^{10}$	Ohm-cm / test at 500 V (DC)
Bolt-hole torques strength	Passed	Passed	No crack/deformation

Table 2. Test results of the fiberglass reinforced polymer crossarm

Conclusion and Suggestion

An alternative material, fiber reinforced polymers (FRP), for using as the material for the electrical power structures has been presented. The structure, such as a crossarm, can be greatly beneficial from the use of FRP. The high environmental resistance, high strength, high stiffness, high electrical resistivity, light weight, good impact resistance, and long expected service life are the ideal properties of good electrical power structures. With the use of FRP, crossarms can have all of these properties without sacrifice any of them unlike other conventional and traditional materials. Moreover, the low combining cost from both installment and maintenance of the FRP crossarms could make them to be economically competitive to other traditional materials. Hence, the possibility of installment of FRP crossarm into every electrical power structure is possible. The capabilities of Thai companies are also another important factor in bringing the FRP crossarms to more area in Thailand into reality, by manufacturing and supplying cheaper than imported products from overseas.

The authors want to urge the PEA and other relevant agencies to adopt the use of FRP materials as the replacement for the traditional materials' crossarms and also favor the use of the products manufactured or supplied by Thai companies, which have been proven and tested that their products meet the standards and required specifications.

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