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USING FIBER-REINFORCED POLYMER COMPOSITE IN DOMES APPLICATIONS

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Abstract

This paper presents an introduction to the fiber-reinforced polymer materials and its component were presented, and the advantages of using the FRP were reviewed go through the adaptation of the FRP in international building codes (IBC). Meanwhile, explain the cause and resort to this material. Considering the FRP composites material has extraordinary mechanical and important in-service properties, a large improvement in the whole-life cost and lower environmental impact can be achieved. Moreover, better stiffness, strength, and durability can be obtained when combined the properties with other materials. The paper demonstrates the most advantageous way to use composites in architecture applications in the case studies of roofing systems- dome applications- that have been developed from the material. Comparing, the period from the final use of the product by industry to the fundamental innovation stage: this seems a very fast development in the process. The research end -up with the conclusion which briefly represents the key successes of advanced polymer composites in domes as a roofing system.

Keywords— FRP composites Materials, Roofing Systems, Durability, FRP Domes

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INTRODUCTION

This review paper, in this context, aims to provide a brief review of some applications of FRPs [Roofing systems and spatially domes applications. The research also gave attention to the novel design concepts through some recent case studies In Bahrain, which stand as evidence of current trends and possible research and industry developments of the FRP materials in Architecture application.

COMPOSITE MATERIALS AND ADAPTATIONS IN INTERNATIONAL BUILDING CODES

For years before 2009, “FRP has been used on buildings but has had limited uses without a uniform code recognition. AS FRPs materials become a viable product, the specifiers, building owners, and architects were able to understand the benefits of this material after the updated and effective in a new section of the 2009 International Building Code (IBC). The new Section 2612 of the code falls within Chapter 26, entitled "Plastics", in the (IBC) expands the proper uses of Fiberglass Reinforced Polymer (FRP) composites for building construction spatially it had been adopted again in 2012. This code change is a significant step toward the recognition of FRP composites by the prescriptive building codes.

The Architectural Division of the American Composites Manufacturers Association (ACMA) plays a role in preparing the introduction of the properties and uses of FRP to present to (ICC). The ICC is the organization that publishes the International Building Code (IBC) which is used as the primary model for building codes [7], these three parties' logos are shown in Figure 2".

'Two exceptions to the general Plastics code requirements were made by (IBC), to provide assurance that the materials being used in these applications are appropriate for use. The first considers the percentage of the FRP material on the building substrate considering the flame spread index requirements, in the case of using FRP as building ornamentation. Requirements of the Code stated that the FRP needed to be fire retardant. Additional requirements such as to be separated from the exterior wall by code-approved fire blocking material or installed directly to a non-combustible substrate. The second exception is considering the building height limitation as the FRP material can be used now in a manner consistent with noncombustible materials on buildings at a height above 40 feet".

Fig. 1. logs of International Building Code (IBC), the American Composites Manufacturers Association (ACMA)

THERMAL PERFORMANCE FRP COMPOSITES

"The temperature effects FRP composites can be dominated based on the original components such as the fiber type, epoxy-based vinyl ester, isophthalic unsaturated polyester, the polymer matrix, fillers, and curing process. Generally, excellent thermal performance can be achieved according to the exterior or typical interior exposure by using materials like the isophthalic unsaturated polyester, most epoxy, and epoxy-based vinyl ester, and most phenolic-based. A characteristic concerning the use of FRP composites is a gradual increase in stiffness or modulus, in lower temperatures, as compared to higher temperatures. There are two main terms involved with the temperature effect on the FRP composites. Frist is the Heat Distortion Temperature (HDT) of FRP composites which is mainly influenced by the fiber type and content (%), and is often reported in excess of 260°C. The second is called the glass transition temperature. When the resin matrix polymer reaches a point where it transitions from a glassy to a rubbery state this could the transition glass temperature, this happen in increased temperatures, where a gradual decrease in modulus is notable. When the working temperature of an FRP composite approaches or is above the Tg, mechanical properties generally will decrease [1] as shown in Figure 3. There are several options of matrix resins that can provide operating temperatures in the range of 90 to 400°C. Dynamic mechanical thermal analysis (DMTA) is one of the methods used to determine the value of Tg and differential scanning calorimetry (DSC) is the other method [8], [9]"

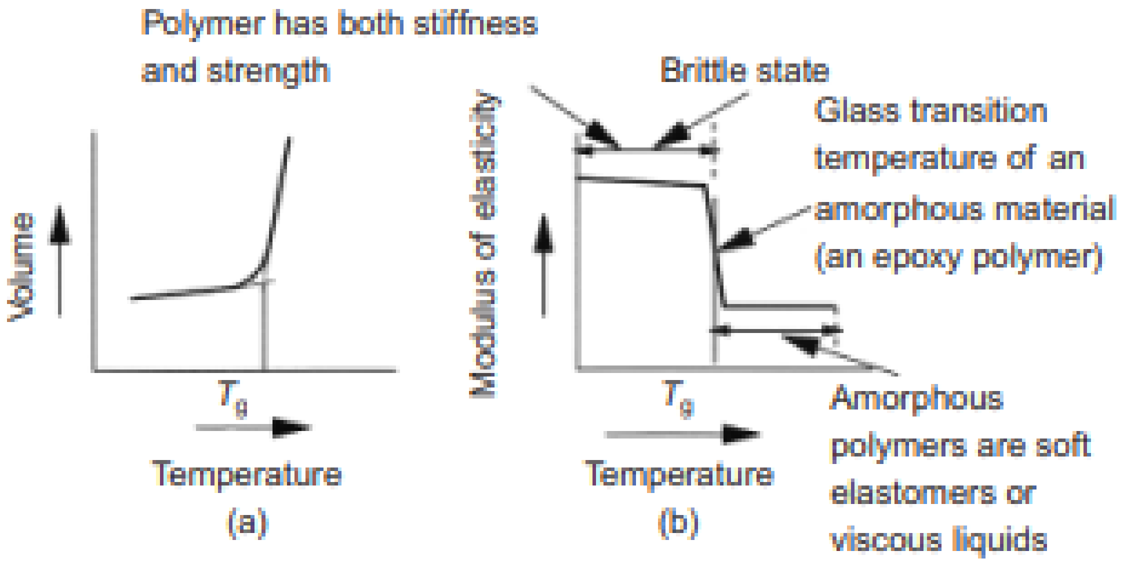

Fig. 2. Relationship between properties of polymer and temperature at the glass transition temperature [1]

Long-Term Performance Durability Of The Composite Materials

"Since the late 1940s under a variety of conditions and in numerous applications various, the FRP materials have been use. As a building material, the durability of FRP composites is much considered superior compared to the durability of structural materials such as typical steel-reinforced concrete, mild steel, aluminum alloys, or stainless steel. Due to the physical properties of the FRP products, they became in well-distributed and use in severe environmental conditions, such as seawater, air with high salinity and chemical processing plants, semiconductor facilities, coal-fired power plants, and sewage treatment plants. Moreover, some applications such as pole and the tropics were able to resist moisture levels temperature in extreme climatic regions as successful innovative systems, components, and solutions developed by the FRP designers. structural applications that are constructed in Large-scale like domes and pressure vessels show the capability of FRP composites as safely withstand sustained loads over long periods. Previous creep research on FRP materials found that the matrix material plays a dominant role in controlling the material's properties. Creep-related strains and deformations can occur in long-term, axial-loaded columns and beams at significantly high applied load levels. Another parameter is that the FRP has proven superior service lives under cyclic loading conditions as implemented in automotive leaf springs, boat hulls, aircraft structures, helicopter rotor blades, and pressure vessels".

"One of the most advantages also of the E-glass polyester or vinylester FRP parts is that they can resist harsh environmental conditions such as temperature and moisture with the moisture absorption percentage is typically less than 1%. This characteristic is recommended for service-load to ultimate-load ratios and surface finishes which is applicable to installed architectural panels for Example. When it comes to external exposure Ultraviolet (UV) is one of the most direct concerns visual appearance in selecting building material, since gloss changes and yellowing and color shifts can occur due to UV exposure. Different techniques can be used during the manufacturing of the FRP material to avoid such effects such as painting the exposed surfaces or an opaque gel coat surface. The structural layers of FRP composites are protected from UV by an opaque gel coat surface or by painting the exposed surfaces. Incorporating UV screens into the matrix is also commonly done in modern resins. Among these techniques, gel coating is the most common since it adds a deep 0.25-0.51mm thick protective layer and gives desired surface finish and a deep 0.25-0.51mm thick protective layer. Gel coating had used to provide a durable, long-life finish on boat hulls mostly by the marine industry [10] The FRP has different specifications as dome application and final finishing.

DIYAR AL MUHARAQ MOSQUE, BAHRAIN

"A strategic site on a distinguished 19,000 m2 on the island of Muharraq, is located Bahrain's new Grand Mosque, which is visualized as the unifying core of the community. The mosque is distinguished by its unique architecture and rich Arabian Islamic design, the mosque is a regional architecture recognized with a composite dome in the center. The domes consist of different FRP from 12 separate panels, ornamental elements in three-layer, and a spectacular view of 45 meters minaret. Designed to work together in a series of intricate layers, BFG built each of the three different FRP domes from 12 separate panels. The unique 3D geometry of the domes had been fabricated in three layers by using a process, rubber molds, and traditional contact molding. They are Installed in sequence on-site by BFG, built to last for decades, as they can withstand winds of up to 120km/h. The third inner dome was designed with a smooth gel-coat, the second dome boasts a high gloss external finish, while, the first dome, seen on the first exterior layer and has a spectacular see-through design with an inlaid Islamic pattern. as shown in Figure 3.

Fig. 3. Project: Ornamental dome, Location: Diyar Al Muharaq, Bahrain,

Rashid Al Zayani Mosque, Bahrain

"In a large-scale Bahrain's imposing new Rashid Al Zayani mosque takes a traditional form as an Islamic religious building. The mosque is visualized as a community hub with residential units, and shops included in the master plan. The total site area is 2810m2, the mosque has a capacity for up to 1230 worshippers. On the main prayer hall, a magnificent 16 meters diameter composite dome as a roofing system with a to a secondary eight meters three domes. The final fishes of the dome appear as bronze. Another series of small domes, a suite of five eight-meter diameter half domes arranged in sequence around the base of the main structures also used to cover the prayer place for women, a courtyard, a Majlis for special occasions, and six classrooms. The constructed company- BFG - was chosen to design, manufacture, and install a series of structural domes for the project. The domes are finished with a double-sided finish and gel-coated FRP. The domes comply with ASTM84 and are extremely fire retardant and, Class A and can withstand a wind load of up to 120km/h. as shown in Figure4."

Fig. 4. Project: Composite domes, Location: Rashid Al Zayani Mosque, Qalali, Bahrain, Client: Al Zayani Investment, Architect: Gulf House Engineering, Engineering Consultant: Gulf House Engineering, Main Contractor: Skyline Contracting Handover: 2014

CONCLUSIONS

This paper presents an introduction to the fiber-reinforced polymer materials and its component were presented, and the advantages of using the FRP were reviewed go through the adaptation of the FRP in international building codes (IBC). The research review as well the details of the effective legalization of FRP materials in the international building code (IBC) which started after 2009. FRP composites are largely used in the automotive, marine, industrial or ballistic sectors for several decades, but only since the late 1990s, FRPs materials applications shown a noticeable increase in civil buildings engineering and infrastructures. Major applications of FRP composites in buildings can be found especially in retrofitting existing buildings in the form of jackets, strips, or wraps composed of traditional materials. The presented case studies concluded in evidence about the successful integration of FRP composite and traditional building materials such as masonry, reinforced concrete, timber or steel. The current trends of architectural design are discussed, moreover, the recent marked that increased the use of FRP applications in building components such as roofs, façades, and skins, both in the form of all-in-one cladding panels, domes, load-bearing pultruded members or adaptive solar protection panels and movable shading systems.

The current design trends are also emphasized, via a short summary of some case studies as well as ongoing research projects. Finally, the research findings are a step forward toward informing and educating contractors, architects, and developers about the benefits and appropriate uses of fiberglass.

The outcomes of the research show that the success of the FRP composite as a new material depends mainly on Innovation, which dominates the essential role to ensure that it will have even more success in the construction future.

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