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Research Paper

Innovative Materials in Modern Architecture

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ABSTRACT
This paper discusses the development of advanced polymer composite material applications in Architecture as a roofing system over the past three decades. Starting with illustrating the rapid growth in its utilization in comparison with the advantages of other construction materials, then the sequences in the adaptation of the FRP in the 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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I. INTRODUCTION

The abbreviation (FRPs) stands for Fiber Reinforced Polymers, this sort of composite material consists of a polymer matrix reinforced with fibers. This integration between the basic components results in a structural interaction that represents a composite material of high performance in a multitude of applications. The FRP Fiber Reinforced Plastics (FRP) is a different product that is applied in everything from chemical plant to luxury powerboats. That's why The FRP is the generic term for a uniquely versatile family of composites. An FRP structure typically consists of an unsaturated polyester (UP) resin applied to a mould in combination with reinforcement carbon, aramid, but glass fiber is most commonly, to form a part that is rigid, highly durable, and low in weight [1] as shown in Figure 1[2]. The mechanical and in-service properties of civil engineering polymers and fibre, and the techniques for the manufacture of fibers and composite materials have been discussed many times in a number of publications [3].

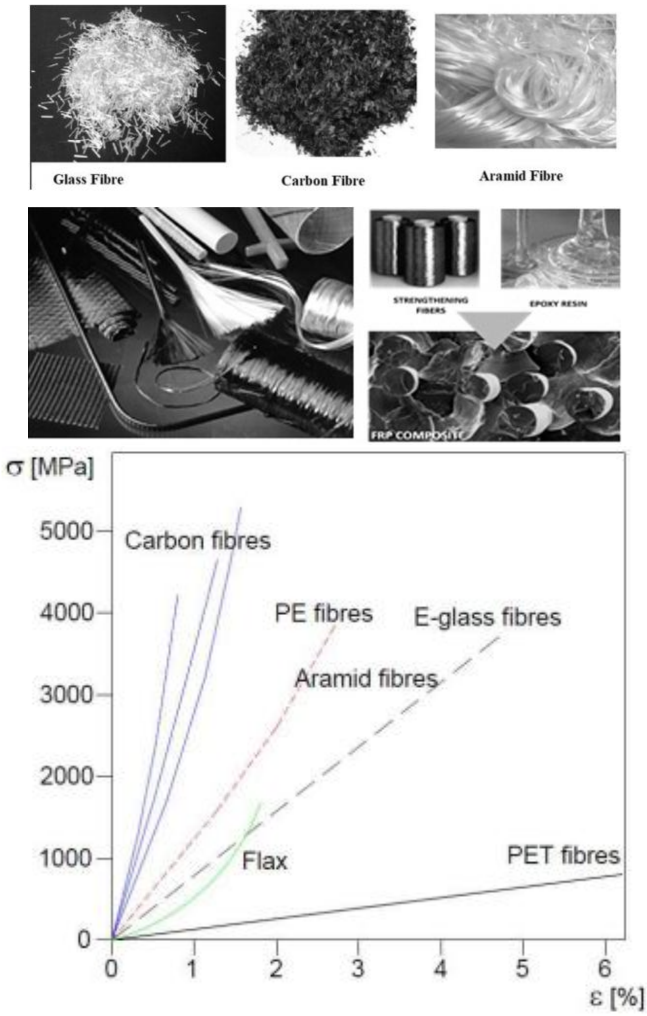

Fig. 1. Different types of fibers, and the diagram shows the comparison of stress-strain constitutive laws for each type of fibers for application in FRP composites [2]

Stella C. et el in 2017 [4] “evaluate the contribution of the new FRP materials on energy-saving and found it is great. Specifically, it is specified a reduction of 34.1% and 22.8% and also, up to 13.9% for heating and up to 5% for cooling and also were recorded respectively, on the underlying floor. In this research, the effect of the increase of the insulation thickness on the reduction of thermal losses was evaluated. Relevant reductions on the inside Summer temperature levels were reported, in correlation to the respective measurements before the application of the materials and during the winter. Moreover, results showed also a great performance of the extruded polystyrene board with the cool ceramic tile as a new composite material specifically the ones used at the roof floor. A reduction was reported on the surface temperature by 21% in the case of the roof floor with a final coating of an asphalt membrane and 15% in contrast to the conventional roof floor. The basic idea and key concept behind all-in-one FRP unitized façade elements were discussed by Rietbroek in (2013). The research showed that they can be fully produced and assembled off-site. After transportation, on the building bearing structure these elements are mounted, so will provide an instantly finished façade [5]. In the Building and Construction industry, the applications of the FRP product is not limited to structure and infrastructure projects, but are also used in building as different surfaces for kitchens and bathrooms, and roof tiles. This is due to its characteristic of low weight and low maintenance requirements, which results of mix resins with glass fiber and fillers to cast synthetic marble and solid surfaces and tiles. Moreover, FRP considers an ideal alternative to conventional materials for large projects like wind generators and bridges, low weight for easier installation combined with low maintenance and durability [6]

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.

Fig. 2. The different types of natural final finishing and coloring of the FRP composite materials for architecture use[10] (http://www.bfgarchitecture.com/building_envelopes)

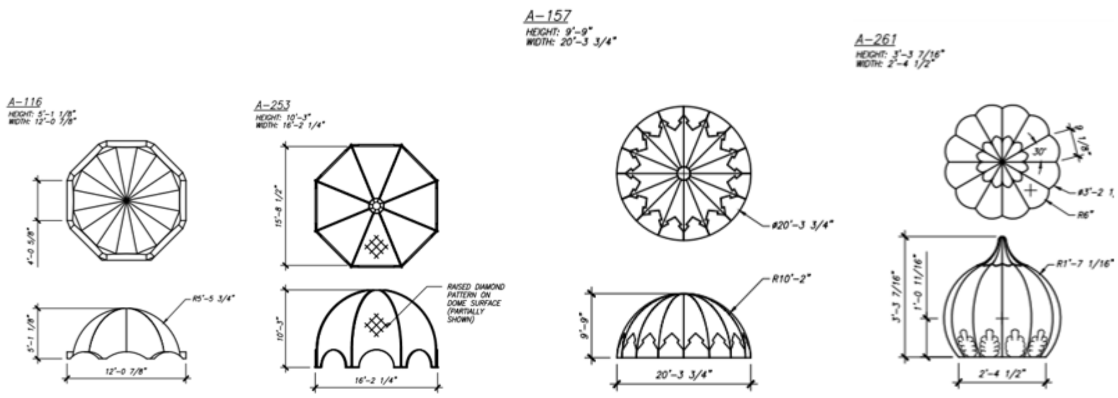

Fig. 3. Example of the different dome models of the FRP materials used in roofing systems as architecture applications. [12]

II. FRP COMPOSITES APPLICATION IN BUILDING ROOFING - A BRIEF SUMMARY OF RECENT CASE STUDIES

A. AL FATEH GRAND MOSQUE, BAHRAIN

As one of the largest in the world Mosque Al-Fateh Grand Mosque in Bahrain’s capital Manama, with a capacity of over 7,000 worshippers, the mosque can comprise 6,500m2. In the mid-1980s, BFG was selected to develop the mosque’s signature dome on a scale that has yet to be a required area.

Fig. 4. Composite dome, Location: Al Fateh Grand Mosque, Manama, Bahrain, Client: Al Fateh Grand Mosque, Architect: Dar Al Handasah, Engineering Consultants: Dar Al Handasah, Main Contractor: Consolidated Contractors Company, Handover: 1986

Over Forty years it remains in authentic condition. As a landmark and traditional Centrale state-of-art, the architect's vision demonstrated a huge central dome with a 26-meter diameter. "Bahrain's Grand Mosque was not without its challenges. THE most challenging in this project was that the site is near the sea therefore deep piles were required to solve the soft soil meant issues. Additional structural complexity was the heavy chandelier needed to be suspended below the main. To meet the contractor's timeline other technical solutions had to be followed fast scheduling regarding the short project window. As a fraction of the concrete alternative, which weighed about 30 tonnes, BFG's lightweight composite dome structure was able to eliminate the need for the heaviest foundations. A total of 24 external segments,

Fig. 5. Convention center 12 m GRP Dome Location: Bahrain Client: Private Engineering Consultants: Gulf House Engineering Main Contractor: NASS Contracting Handover: 2012

The dome was fabricated complete with insulation and fixed to a space frame of lightweight aluminum. In a range of colours with design elements in relief, the frame of aluminum secured a series of 293 internal decorative composite panels." Painstakingly hand-made utilizing conventional plywood and MDF for the tooling, the dome's single skin FRP panels were produced locally in Bahrain and designed to be fire retardant to Class 1 BS476 Part 6. BFG was able to achieve a simulated cement texture on the dome segments, designed perfectly to match the matt, sandy exterior of the main building below. Below the internal dome, a beautiful ring of 3-meter high calligraphy covers the circumference of the ring beam, beneath which four stone arches reach down to the floor to form the main square. The dome was installed in less than a month in-site, which is a big time saving comparing the concrete. Until now, although its coastal location, it remains in its original condition resisting the high corrosion potential and the high airborne salinity, as shown in Figure 4." In the following are some additional examples of the FRP composite material applications in roofing systems as shown in Figures 5, 6 and 7 for Private Palace, Sakhir palace dome and Convention center consequently.

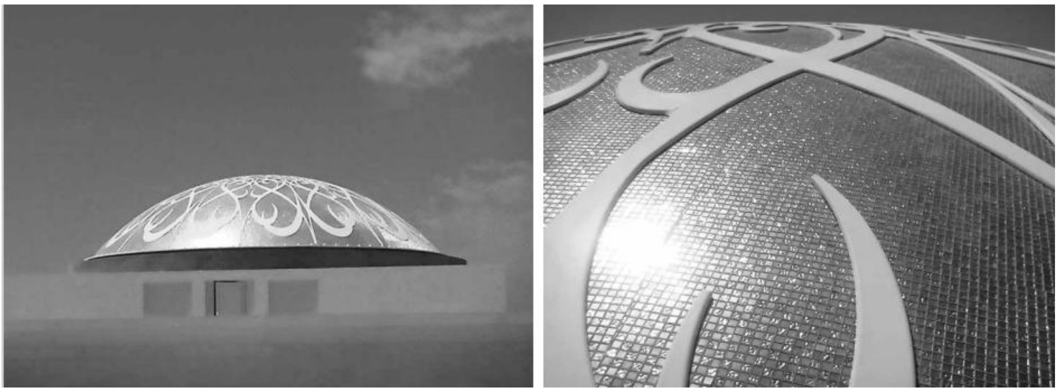

Fig. 6. GRP Structural dome bonded with 18k gold-plated tiles and GRP Calligraphy Location: Bahrain Client: Royal Court Engineering Consultants: Gulf House Engineering Main Contractor: NASS Contracting, Bahrain Handover: 2011

Fig. 7. Convention center GRP Dome, Location: Bahrain, Client: Confidential, Engineering Consultants: Gulf House Engineering, Main Contractor: G P Zachariades, Handover: 2016

III. CONCLUSIONS

In this review paper, a summary of the most recent applications of FRP composites in roofing systems as domes gives evidence of the variability of applications as well as of the intrinsic advantages of such materials, compared to traditional materials for buildings. The current design trends are also emphasized, via a short summary of some case studies as well as ongoing research projects.

As has been reviewed in this paper the FRP composite materials are an unparalleled system and should be proposed in design like this specific implantation way in order to take full benefit of its remarkable properties. It was concluded that the particular components' materials along with their durability in the short and long-term are the key reasons for success in construction and architectural applications.

Based on the analyzed case studies it was found that considering the whole-life cost of a building, it is more expected that the manufactured FRP composite system welling to be more economical than that made by conventional construction materials. However, the recommendation for future implementation is to integrate both conventional and FRP composite materials for a more successful construction system.

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