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# Evaluation of polyester/glass fiber waterproof composite subjected to temperature and acid environment

B. C. Gary[a], *, G. Marinnucci[b], P. M. Munhoz[c], L. G. A. Silva[d]

(a) 0000-0001-6486-2310 (Nuclear and Energy Research Institute – Brazil).
(b) 0000-0001-9035-8791 (Nuclear and Energy Research Institute – Brazil).
(c) 0000-0002-0072-7299 (Nuclear and Energy Research Institute – Brazil).
(d) 0000-0002-7968-2117 (Nuclear and Energy Research Institute – Brazil).
* Corresponding author: bruno.caravelas@usp.br

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**Abstract**: Polymer composites have a wide range of chemical applications, with strong performance in the paper and cellulose and sugar-alcohol industry due to the chemical resistance such materials offer because of the presence of the polymer matrix. The literature shows that vinyl ester resins offer chemical resistance for these applications, however at a higher price than commercial resins, such as unsaturated polyesters. The aim of this research was to evaluate the chemical resistance of glass fiber reinforced waterproof polyester resin composites (GFPO). Composite was manufactured by hand lay-up and the waterproof polyester specimens were kept immersed in a buffer solution with pH 3 at 70 °C for 150 days. To evaluate the behavior of waterproof polyester composites, flexural tests were performed and compared with properties of the vinyl ester composites. After the chemical resistance test, the GFPO composite presented a Young's modulus of 6 GPa with a maximum flexural of 100.6 N. In conclusion, a waterproof polyester resin composite can be a good option for applications in corrosive environments where a vinyl ester resin composite would be applied.

## 1. Introduction

Composite materials offer numerous benefits covering a wide range of applications, with emphasis on the automobile industry, civil construction, aeronautics, sugar and alcohol, pulp and paper, wind energy, laser equipment and chemical industries, being an excellent choice for manufacturing components subjected to static and dynamic stresses [1] because of its high specific mechanical strength and fatigue resistance. Boeing 787 and Airbus A350 airplanes show the benefits of using composite materials, which, according to the respective manufacturers, present 50% and 53% in mass, providing a reduction of 11% and 14% in mass compared to conventional airplanes of the same class, which allows a significant reduction in fuel consumption and also contributing to the reduction of $CO_2$ emissions, thus definitively paving the way for using composites in all aeronautical segments.

However, polymeric composite structures can be compromised when used where the polymer matrix can be damaged by the loading or environment condition. As it is rigid, it may present brittle failure when subjected, for example, to cyclical stresses or impact. There are numerous structural components made of composite materials that constituent materials can fail when subjected to the condition of an aggressive environment, if they are not properly designed for this specific use.

For applications in aggressive media, vinyl ester resins have experienced a large number of applications in acidic or alkaline media, for example in storage tanks for organic raw materials, such as aqueous polymeric emulsions, lubricants and surfactants. However, some resins, such as polyester, for example, which have a high demand and offer an attractive price, can seriously compromise a composite in aggressive environments [2] if used inappropriately and even affect the production of a company.

In general, the degradation of materials represents a high expense for the industry, either due to an early stop for maintenance or even by reducing the lifespan of the component or structure [3]. Studies that propose the evaluation of materials in aggressive media are particularly important in marine environments, oil and gas production, sugar and alcohol industries, chemical plants, pulp and paper and energy conversion and generation systems, including fossil and nuclear.

Some authors [4] [5] have developed new methodologies to perform accelerated physical degradation tests on pultruded profiles of glass fiber reinforced vinyl ester matrix composites [6], others have studied, in a short period of time, the durability of a reinforced vinyl ester matrix composite with fiberglass exposed to six different environmental conditions [7]. It is also found in the literature that applications of composite materials that interact with corrosive fluids work with a temperature of 70 °C [8].

The aim of this research was to evaluate the chemical resistance of glass fiber reinforced waterproof polyester composites (W-GFPO) and compare with the behavior of glass fiber reinforced polyester composites (GFPO). Both composites were manufactured by hand lay-up polyester specimens and waterproofed with epoxy resin were kept immersed in a buffer solution with pH 3 at 70 °C for 150 days.

## 2. Methodology

### 2.1. Materials

The GFPO panels were manufactured by Afinko Polímeros with a plain weave fabric of 330 $gm^{-2}$, both in a hand-lay up process, and a fiber ratio of 55% in volume. The resins used in this study were unsaturated polyester (PO).

To waterproof the GFPO, now called W-GFPO, a bisphenol-F epoxy resin-based coating was used, which was supplied by Masterpol Adhesives, under the trade name of M-CR500. The waterproofing membrane is composed by an epoxy resin and a cycloaliphatic amine, with the latter being responsible for curing the polyester resin.

Compared to aliphatic amines, cycloaliphatic amines offer less volatility, greater light stability, less reactivity, less toxicity and better color retention. In pure state, they find great difficulty in curing at room temperature, due to their low reactivity [9].

A pH 3 buffer solution was used to evaluate the chemical resistance of W-GFPO composites. Buffered solutions are solutions that resist changes in pH when small amounts of strong acid or strong base are added to them. The pH variations that occur in the buffered solutions are insignificant when compared to the variations in the unbuffered solutions, therefore these solutions are used to keep the pH constant to prepare solutions of defined pH.

### 2.2. Temperature and acid environment

The specimens were immersed in a buffer solution and kept in a temperature-controlled oven at 70 ºC, as shown in Figure 1, and isolated to avoid evaporation of the solution. Thickness and mass measurements were performed daily for 150 days and no significant changes were identified compared to specimens before the test, indicating that the chemical attack was preserved by the waterproofing agent.

**Fig. 1**. Oven with controlled temperature for specimens storage.

### 2.3. Characterization methods

In order to characterize the GFPO specimens were kept under temperature and acid environment and flexural tests were performed.

A glass mold with rubber seals was used to manufacture the composite plates and a Macrotop saw, model SFM-750, a Manrod milling machine model ZX-40HC/PC (MR-205-B) and a mask with the oriented geometries for machining the specimens.

The flexural properties of the composites were determined by testing guided by ASTM D790, with geometry of 3.5 x 12.7 x 127 mm³. A ratio between the distance of the supports and the thickness (span-to-depth ratio) of 16:1 is recommended, when the relationship between the tensile strength with fibers oriented in the direction parallel to the supports and the shear strength in the plane is equal or less than 8; a ratio of 32:1 may be required. For tests that need to determine the tangent bending modulus in order to reduce effects caused by shear, a ratio of 60:1 is suggested [10]. The flexural test was carried out in the Instron EMIC equipment, model 23-30, calibrated in 2021, with a load cell of 5 kN and a speed of 1.50 mm/min.

## 3. Results and Discussions

Table 1 shows the results of the composite flexural tests. A small drop around 9% in the maximum flexural property can be seen, when comparing GFPO and W-GFPO specimens, which should be associated with the post-curing effects. With longer chemical test times, 12 and 24 months, the literature shows [11] that this property tends to increase after an initial decrease. The specimen for chemical testing had the waterproofing agent, however the authors do not offer any reinforcing properties to the composite.

**Table 1**. Flexural test results of GFPO and W-GFPO composites before and after chemical testing.

| Composite | GFBO | W-GFBO |
|---|---|---|
| Elasticity Module (GPa) | 6.1 | 5.9 |
| Max Flexural (MPa) | 58.6 | 53.5 |
| Max Deformation (%) | 2.2 | 2.1 |
| Max Load (N) | 99.1 | 100.6 |

## 4. Conclusions

A waterproof polyester resin composite can be a good choice for applications in corrosive environments where a vinyl ester resin composite would be applied, providing cost savings where a more expensive option would be used to obtain similar results. The study with a temperature of 70 °C proved to be effective in use in important fields, such as sugar and alcohol industries, chemical plants, pulp and paper.

## Declaration of Competing Interest

The authors declare no conflict of interest.

## Credit author statement

**Bruno Caravelas Gary:** Conceptualization; Methodology; Formal Analysis; Writing – original draft. **Gerson Marinucci:** Resources; Writing – review. **Pedro Munhoz:** Resources; Writing – review. **Leonardo Gondim A. Silva:** Resources; Supervision; Writing – review.

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