



## Physical Characterization of Hybrid Fibre Reinforced Polymer Bars

S. Dhipanaravinda\*, R. Sivagamasundari<sup>a</sup>, G.Kumaran<sup>b</sup>

<sup>a</sup>\*Research scholar, <sup>a</sup>Assistant Professor, <sup>b</sup>Professor,

Department of Structural Engineering, Annamalai University, Tamil Nadu, India

**Abstract:** Fibre reinforced polymer (FRP) bars have been widely used in structural engineering applications due to their high strength, light weight and excellent corrosion resistance. HFRP bar is a new kind of FRP material manufactured by fusing GFRP (Glass FRP) and CFRP (Carbon FRP) in which physical properties are not yet fully described. They are also simple for execution which makes these materials as reinforcing elements of structural members. This paper presents a study on the important physical properties of HFRP rods of 10mm- diameter. In this study, the fibre content, density and water absorption properties were determined according to ASTM D3171- 15 (burn off test), ASTM D792-13(density test) and ASTM D570-10 (water absorption test) standards. The test results show that the hybrid FRP have 56.20 to 60.90% fibre content and density ranged between 1961 to 1980 Kg/m<sup>3</sup> and the percentage of water absorption were 0.56 to 0.62% respectively.

**Keywords:** ASTM standards, HFRP bars, Physical characterization

### I. Introduction

Fiber Reinforced Polymer (FRP) composite materials were originally developed for use in the automotive and aerospace sectors. In the last two decades, these advanced materials have seen a widespread use as an alternative reinforcement in structural engineering projects, to replace the internal steel reinforcement or as externally bonded materials to strengthen reinforced concrete structures. They are extremely light, excellent corrosion resistance, high tensile strength and good non-magnetization properties. Carbon fiber reinforced polymers (CFRP) and Glass fiber reinforced polymers (GFRP) are the most popular FRPs used in structural engineering components. In recent years, combinations of different materials like glass-steel have been developed to make the FRP elements more advantageous. In this regard, this paper presents the development of a new combination such as sand coated Carbon-Glass FRP bars and determination of their physical characteristics [1]. Only few studies have been conducted to analyze the physical properties of HFRP bars which can provide confidence to potential users of the material.

### II. Materials and Manufacturing Methods

The sand coated HFRP bars of 10mm- diameter supplied by Meena Fibre Glass Industries Puducherry were used in current study. These HFRP bars were manufactured by pultrusion process with the E-glass fibre volume approximately 60% and carbon fibres 40%. The glass fibers and carbon fibers are preferred as reinforcements and epoxy as matrix material. The epoxy resin, hardener Tri Ethylene Tetra Amine (TETA) and Catalyst (Methyl ethyl Kethone Peroxide) are used. The glass fiber of bi-directional woven mat with 200 gm and the density of 2.5 gm/cc are used. The carbon fiber of bi-directional woven mat with 200 gm and the density of 1.78 gm/cc are used. The raw glass fiber and carbon fiber which are used in the fabrication of HFRP bars are shown in fig .1



Figure 1. (a) Raw Carbon and (b) Glass fibres Rovings

Pultrusion process is the pulling of material such as any type of fibres and resin, through a shaped die having a constant cross section. The raw resin is always a thermosetting resin, and is sometimes combined with fillers, catalysts, and pigments. The resin impregnation system is left by the resin rich fiber, the un-cured composite material is guided through a series of tooling which aids to organize the fibre into the correct shape, and the excess resin squeezed out is called debulking. The die is heated to a constant temperature of about 145°, which will cure the thermosetting resin. The profile that exits the die is now a cured pultruded Hybrid Fiber Reinforced Plastic (HFRP) composite. The newly developed HFRP bar is shown in Figure 2.



**Figure 2.** Sand-coated Hybrid FRP bar

### III. Experimentation

According to ASTM standards, the manufactured hybrid rods are subjected to burn off test, density test, and water absorption test.

#### A. Burn off test

The fibre content of the HFRP bar was determined according to the ASTM D3171 guidelines. Between 3 to 5 samples at each composition were subjected to burn off tests. The specimens were used in the burn off test weighed around 0.5 g. Each specimen is weighed and placed into a desiccated crucible. Then, the crucible containing specimens are placed into a muffle furnace as shown in figure 3. The specimens are then to be heated up to 600°C that will burn off the matrix and leave the reinforcement (fibre). The maximum time for burn off should be 6 hours. At the completion of the heating process, the crucibles are removed from the muffle furnace, cooled to room temperature in a desiccators, and weighed to determine its mass. The fibre content by weight and volume was calculated according to the following equation (1) and (2),

$$W_r = (M_f/M_i) \times 100 \quad (1)$$

$$V_r = (M_f/M_i) \times (\rho_c/\rho_m) \times 100 \quad (2)$$

Where  $M_i$  is the initial mass of the specimen (g),  $M_f$  is the final mass of the specimen (g) after combustion,  $\rho_c$  is the density of the reinforcement or fibre (g/cm<sup>3</sup>) and  $\rho_m$  is the density of the specimen (g/cm<sup>3</sup>).



**Figure 3.** Muffle Furnace

#### B. Density test

The density of the HFRP bar was determined experimentally using ASTM D792-13. This standard requires the analytic scale to have 0.1 mg precision. The specimen is weighed in air is recorded. Then, the specimen is immersed in distilled water at 23°C using a sinker (holder) and wire to hold the specimen completely submerged (Fig4). Also, the totally immersed sinker in distilled water is weighed and noted. The specific gravity of the specimen was found using Eqn3. The specimen density is determined by multiplying the experimental specific gravity and density of the water (Eqn.4).



**Figure 4.** Density test setup

$$\text{Specific gravity } 23^{\circ}\text{C} = a / (a + w - b) \quad (3)$$

$$\text{Density } 23^{\circ}\text{C} = \text{specific gravity } 23^{\circ}\text{C} \times 997.5 \text{ Kg/m}^3 \quad (4)$$

Where  $a$  is the apparent mass of specimen, without wire or sinker, in air,  $b$  is the apparent mass of the specimen (and of sinker, if used) completely immersed and of the wire partially immersed in water,  $w$  is the apparent mass of the totally immersed sinker (if used) and of partially immersed in wire.

### C. Water absorption test

The specimens for water absorption test were prepared according to the ASTM D570 guidelines. This test was conducted using the HFRP bars with a diameter of 10mm. The length of each specimen was 25.4mm. The specimens were dried in an oven at specific time and temperature and then cooled the specimens in a desiccators (Figure 5). Immediately, the conditioned weight of the specimen was noted. After, the conditioned specimens were immersed in distilled water for 24 hours. At the end of 24 hours, the specimens were removed from the water one at a time, all surface water wiped off with a dry cloth, and then wet weight of the specimen was noted. The percentage increase in weight during the immersion was calculated by using the following eqn.5

$$\text{Increase in weight, \%} = \frac{\text{Wet weight} - \text{conditioned weight}}{\text{conditioned weight}} \times 100 \quad (5)$$



**Figure 5.** Specimens immersed in distilled water

## IV. Results and Discussion

### A. Burn off test

The ASTM test method shows the resin burn off as a way to resolve the essential content for composite materials. Table 1 depicts the measured fiber contents for all of the specimens. By the nature of the burnout test, probably always there will be some removal of carbon fibres. However, in a composite bar, most of the energy used goes into burning off the resin and sizing and the expected and measured values of the fiber volume of the carbon and glass fibers, were tend to be very close. The fibre content of the HFRP bar as measured by the burn off test was 56.20%. These results show that the complete fabricated composites are dominated by fibres in weight and volume composition.

**Table1. Burn off test results**

| Specimen ID | Fibre Content(%) |
|-------------|------------------|
| HFRP10-1    | 56.20            |
| HFRP10-2    | 58.51            |
| HFRP10-3    | 55.62            |
| HFRP10-4    | 60.78            |
| HFRP10-5    | 60.90            |

## B. Density test

The density test can also be used to indicate the degree of uniformity or variability among different samples units or different specimens, or to indicate the average density of a large item. The experimental values of density, obtained in this study are shown in Table 2. The experiments show that the density of the HFRP bars ranges from 2100.4 kg/m<sup>3</sup> to 2185.8 kg/m<sup>3</sup> respectively, which is slightly greater than that of previous results.

**Table 2. Density of HFRP bars obtained from the density test**

| Specimen ID | Density(kg/m <sup>3</sup> ) |
|-------------|-----------------------------|
| HFRP10-1    | 1961                        |
| HFRP10-2    | 1965                        |
| HFRP10-3    | 1972                        |
| HFRP10-4    | 1961                        |
| HFRP10-5    | 1980                        |

## C. Water absorption test

Table 3 shows the maximum water absorption obtained at H3 and H4 bars. The more water uptake may bring in severe degradation of HFRP rebars, since water uptake will plasticize the resin and may cause debonding between fibre and matrix.

**Table 3. Water absorption results of HFRP bars**

| Specimen ID | Water Uptake (%) |
|-------------|------------------|
| HFRP10-1    | 0.56             |
| HFRP10-2    | 0.58             |
| HFRP10-3    | 0.62             |
| HFRP10-4    | 0.60             |
| HFRP10-5    | 0.58             |

## V. Conclusion

The experimental test results show that the hybrid fiber content by weight of sand-coated HFRP bars were 56.20 to 60.90% respectively. These results of fiber content are adopted with ACI 440.6M-08 and CSA S-807-10(50% fiber content by weight or 55% as fiber content by volume). The unit weight of sand-coated HFRP bars ranges between 1961 to 1980 Kg/m<sup>3</sup>. The moisture uptake ratios at saturation for the sand -coated HFRP bars varies from 0.56 to 0.62% respectively.

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