Experimental Studies on Water Absorption Behaviour of Treated and Untreated Hybrid Bio-Composites

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Abstract

Various experimental works were successfully accomplished over the past years on the natural resources reinforced composites. This research work is focused on the water absorption behaviour of the treated and untreated banana fiber reinforced, used camellia sinensis particles filled along with the epoxy resin matrix bio-composites. Different weight percentages of reinforcement and filler materials were taken to prepare the hybrid composite specimens, whereas the epoxy resin matrix were keeping constant. Traditional hand layup technique was adopted and the boards of the hybrid composites were effectively fabricated by using the same technique. Hybrid bio-composite specimens for water absorption tests were prepared by using the portable wood cutting machine as per the ASTM standards for the efficient justification on experimental results. Water absorption tests on the hybrid bio-composite specimens were carried out as per the ASTM standards. Water absorption behaviour of the treated and untreated banana fiber reinforced, used camellia sinensis particles filled, epoxy resin matrix hybrid composite specimens were absorbed and compared with each other. Experimental results shows that the chemically treated banana fiber reinforced with narrow amount of used camellia sinensis particle filled hybrid composite specimens exhibits the better water absorption behaviour than that of untreated banana fiber reinforced with elevated amount of used camellia sinensis particle filled hybrid composite specimens.
1 Introduction

Use of bio-composites in engineering and other fields were significantly increased due to its availability. Most of the material science research focus is now turned on the bio-materials due to the scarcity of the synthetic and traditional materials. Several researchers are established their research outputs in the field of bio-composites. Superior hardness were obtained on the camellia sinensis particles filled with epoxy resin matrix/banana fiber composites [1]. Better mechanical properties were exposed on the used camellia sinensis powder and azadirachta indica seed powder filled bio-composites [2]. 50 wt% of resin matrix and 50 wt% of banana fiber reinforced bio-composites discovered the enhanced mechanical properties than other compositions [3]. Greater moisture absorption property is revealed by the 50 wt% of banana fiber addition into the jute fiber/resin matrix composites [4]. 50 wt% of sisal fiber into the banana fiber/resin matrix composites exposed the better moisture absorption property than other combinations [5]. Amount of fiber content is the key factor which is used to determine the water absorption capacity of the composites [6]. Compared to the hybrid banana composites, ability of the composites to absorb the water content is very lesser in woven banana fiber composites [7]. Increasing glass fiber content into the matrix material causes the lesser water droplet penetration on the composite specimen’s surface [8]. Enhanced water absorption properties of the composite specimens are found in ultrasonic waves treated fiber reinforcement [9]. Addition of banana fiber and glass fiber into the matrix causes the superior water absorption resistance [10]. Water absorption capability of the banana fiber reinforced composites were found good when the matrix is reinforced with limited quantity of reinforcement material [11]. Many experimental investigations were successfully conceded on the banana fiber reinforced resin matrix composites. In this experimental investigations, water absorption behaviour of epoxy resin matrix-banana fiber/camellia sinensis particles reinforced composites were established.

2 Materials and Methods

In this research work, epoxy resin was used as matrix material and it was purchased from Covai Seenu and Company limited and raw banana fibers were procured from Golden Fibres. Used camellia sinensis particles were congregated from local tea shops and bakeries in Erode city. Procured banana fibers length were in the range of 15 to 20 cm. The long raw banana fibers were then sliced into 1 to 3 cm in length using cutter. The sliced raw banana fiber was washed in well concentrated distilled water solution around 30 minutes. The washed raw banana fibers were then dried in atmospheric temperature for 48 hours. After the drying process, well cleaned banana fibers were immersed for one hour time period in 5.0 L plastic container which is filled with high concentrated Sodium Hydroxide (NaOH) and water solution. After the one hour time period the chemically treated banana fibers were dried in an oven at 110oC for 6 hours. Filler material which is used in this experimental work i.e. waste or used camellia sinensis particles were washed using the lower concentration distilled water solution around 45 minutes to remove the dust particles. After washing, the well washed camellia sinensis particles were dried at room temperature for 72 hours. Initially, epoxy resin is mixed with hardener in 2:1 ratio to enhance the epoxy resin strength using stirrer machine for 30 minutes. A rectangular moulding box (250 × 250 × 10 mm) is used to prepare the hybrid composite plates from the matrix, reinforcement and filler material. A normal hand layup technique is implemented to prepare the hybrid composite boards. Epoxy resin/hardener mixture (65 wt %) was formed as first layer in the moulding box for 2 mm thickness after that the mixture of chemically treated banana fibers (35 wt % was dispersed on the first layer i.e. Epoxy resin/hardener mixture up to 2 mm thickness. The same process is repeated up to 10 mm thickness accomplishment of the hybrid composite plate thickness. The same process is repeated again for the remaining three treated hybrid composite specimen boards preparation by keeping the weight percentage of epoxy resin/hardener mixture as constant (65 wt%) and changing the weight percentage of treated banana fibers (33, 31 and 29 wt%) and camellia sinensis particles (2, 4 and 6 wt%) correspondingly. Specimen description for both untreated and treated banana fiber reinforced hybrid composites were given in table.1 and table.2 correspondingly. The different characteristics of the water, which is used in this experimental study is given in table.3
### Table 1. Specimen description for untreated banana fiber reinforced hybrid composites

| Epoxy resin (wt%) | Untreated banana fiber (wt%) | Camellia sinensis particles (wt%) | Specimen description |
|------------------|-----------------------------|----------------------------------|----------------------|
| 65               | 35                          | 0                                | UTHC-A               |
| 65               | 33                          | 2                                | UTHC-B               |
| 65               | 31                          | 4                                | UTHC-C               |
| 65               | 29                          | 6                                | UTHC-D               |

### Table 2. Specimen description for treated banana fiber reinforced hybrid composites

| Epoxy resin (wt%) | Treated banana fiber (wt%) | Camellia sinensis particles (wt%) | Specimen description |
|------------------|---------------------------|----------------------------------|----------------------|
| 65               | 35                        | 0                                | THC-A                |
| 65               | 33                        | 2                                | THC-B                |
| 65               | 31                        | 4                                | THC-C                |
| 65               | 29                        | 6                                | THC-D                |

### Table 3. Characteristics of the water used for Investigation

| Property       | Value  | Remarks       |
|----------------|--------|---------------|
| Color          | Na     | Colourless    |
| Turbidity      | Na     | Nil           |
| Taste          | Na     | Tasteless     |
| Odor           | Na     | Nil           |
| Temperature    | 36°C   | Room          |
| Solids         | Na     | Nil           |
| pH             | 7.5    | Slightly Alkaline |

Untreated banana fiber reinforced composite plates for all four samples were shown in figure.1 respectively. The above process is again followed to produce the untreated hybrid composite specimen boards using epoxy resin/hardener matrix, untreated banana fiber reinforced and camellia sinensis particles respectively. Treated banana fiber reinforced composite plates for all four samples were shown in figure.2 respectively. ASTM D-5229 standard was used to prepare the test specimens for water absorption test. The dimensions of the water absorption test was taken as $20 \times 20 \times 6$ mm based on the ASTM D-5229 standard. Water absorption test specimens for all samples of both treated and untreated banana fiber reinforced composite specimens were illustrated in figure.3 (a) and 3 (b) correspondingly. Pure water is used to conduct the typical water absorption test under the normal atmospheric conditions. Separate water containers were used to evaluate the water absorption behaviour of both untreated and treated banana fiber reinforced hybrid composite specimens. The five different time periods were taken into account like 24, 48, 72, 96 and 120 hours respectively. Effect of chemical treatment on water absorption behaviour of both chemically treated and untreated banana fiber reinforced with waste camellia sinensis particles filled hybrid composite specimens were discussed in results and discussions chapter.
Figure 1  Untreated banana fiber reinforced composite plates for (a) UTHC-A (b) UTHC-B (c) UTHC-C (d) UTHC-D samples

Figure 2  Treated banana fiber reinforced composite plates for (a) THC-A (b) THC-B (c) THC-C (d) THC-D samples

Figure 3  Water absorption test specimens (a) Treated banana fiber reinforced composite specimen (b) Untreated banana fiber reinforced composite specimen
3 Results and Discussions
The following results have been obtained through the experimental studies, which was carried out on the epoxy resin matrix, waste camellia sinensis particles filled, chemically treated and untreated banana fiber reinforced hybrid composites by varying the weight percentage of the both filler and reinforcement materials with epoxy resin matrix. Water absorption tests were performed on the treated and untreated banana fiber reinforced composite specimens to explore its water absorption behaviour. Percentage of water absorbed by the untreated banana fiber reinforced hybrid composite (UTHC) specimens after the time interval of 24, 48, 72, 96 and 120 hours were represented in figure.4. It was absorbed from the experimental results, all untreated banana fiber reinforced hybrid composite specimen’s water intake percentages are in the range of 21.8, 24, 17.9 and 24.4 for UTHC-A, UTHC-B, UTHC-C and UTHC-D specimens after 24 hours respectively. After 48 hours, water absorption percentage of the all untreated banana fiber reinforced hybrid composite specimens were noticed in the range of 21.8, 24, 17.9 and 24.4 for UTHC-A, UTHC-B, UTHC-C and UTHC-D specimens accordingly. Water absorption percentage of the all untreated banana fiber reinforced hybrid composite specimens after 72 hours are found in the range of 25.12, 27.55, 20.61 and 28.06 for UTHC-A, UTHC-B, UTHC-C and UTHC-D specimens correspondingly. Percentage of water absorption by the all untreated banana fiber reinforced hybrid composite specimens after 96 hours are observed in the range of 25.78, 28.27, 21.14 and 28.79 for UTHC-A, UTHC-B, UTHC-C and UTHC-D specimens accordingly. Water absorption percentage of the all untreated banana fiber reinforced hybrid composite specimens after 120 hours were noticed in the range of 26.43, 29.98, 21.68 and 29.52 for UTHC-A, UTHC-B, UTHC-C and UTHC-D specimens correspondingly. It was noticed that, hybrid composite specimen consists of 65 wt% of epoxy resin, 31 wt% of untreated banana fiber and 4 wt% of waste camellia sinensis particle (UTHC-C) absorbs very minimal water during the water absorption test than that of other three untreated banana fiber reinforced hybrid composite specimens in all time intervals. The two important kinetic parameters like n and k was considered to understand the water absorption kinetics between the fiber and epoxy resin. The following equation shows the relationship between the two essential kinetic parameters.

\[
\log\left(\frac{Q_t}{Q_e}\right) = \log k + n \log t
\]

In the above equation (1), mole percentage of water absorbed by the fiber at a particular time t is noted as Q_t. Mole percentage of water absorbed by the fiber at equilibrium condition at time t is noted as Q_e. The constant for epoxy resin water absorption characteristics is denoted as k. If the diffusion values between the water and fiber is less than 0.5, it obeys the Fick’s law and it is said to be Fickian. If the diffusion value is less than 1, the diffusion is said to be anomalous. If the diffusion value is lies between 0.5 and 1 then the diffusion is said to be nonfickian. Water kinetics between the fiber and water is indicated by the k. The mode of diffusion between the fiber and water is indicated by n. In this experimental study, the value of n is observed as less than 0.5. Due to the penetration of water molecules through the interfacial regions and presence of void contents in the composites, the n value is very less. Diffusion coefficient exemplifies the capability of water molecule to diffuse through the fiber. Percentage of water absorbed by the treated banana fiber reinforced hybrid composite (THC) specimens after the time interval of 24, 48, 72, 96 and 120 hours were represented in figure.5. It was absorbed from the experimental results, all treated banana fiber reinforced hybrid composite specimen’s water intake percentages are in the range of 19.41, 21.47, 15.56 and 21.91 for THC-A, THC-B, THC-C and THC-D specimens after 24 hours respectively. After 48 hours, water absorption percentage of the all treated banana fiber reinforced hybrid composite specimens were noticed in the range of 21.35, 23.62, 17.12 and 24.10 for THC-A, THC-B, THC-C and THC-D specimens accordingly. Water absorption percentage of the all treated banana fiber reinforced hybrid composite specimens after 72 hours are found in the range of 22.90, 25.34, 18.36 and 25.85 for THC-A, THC-B, THC-C and THC-D specimens accordingly. Water absorption percentage of the all treated banana fiber reinforced hybrid composite specimens after 120 hours were noticed in the range of 23.48, 25.98, 18.83 and 26.51 for THC-A, THC-B, THC-C and
THC-D specimens correspondingly. It was noticed that, hybrid composite specimen consists of 65 wt% of epoxy resin, 31 wt% of treated banana fiber and 4 wt% of waste camellia sinensis particle (THC-C) absorbs very minimal water during the water absorption test than that of other three untreated and treated banana fiber reinforced hybrid composite specimens in all time intervals.

![Figure 4](image)

**Figure 4** Percentage of water absorbed by the untreated banana fiber reinforced hybrid composite (UTHC) specimens

Weight of all untreated banana fiber reinforced hybrid composite (UTHC) specimens after the time interval of 24, 48, 72, 96 and 120 hours were represented in figure 6. It was perceived from the experimental results, all untreated banana fiber reinforced hybrid composite specimens weight are in the range of 2.86, 2.86, 2.72 and 2.92 grams for UTHC-A, UTHC-B, UTHC-C and UTHC-D specimens after 24 hours respectively. After 48 hours, weight of the all untreated banana fiber reinforced hybrid composite specimens were noticed in the range of 3.15, 3.15, 2.99 and 3.22 grams for UTHC-A, UTHC-B, UTHC-C and UTHC-D specimens accordingly. Weight of the all untreated banana fiber reinforced hybrid composite specimens after 72 hours are found in the range of 3.29, 3.29, 3.13 and 3.36 grams for UTHC-A, UTHC-B, UTHC-C and UTHC-D specimens correspondingly.

![Figure 5](image)

**Figure 5** Percentage of water absorbed by the treated banana fiber reinforced hybrid composite (THC) specimens

Weight of the all untreated banana fiber reinforced hybrid composite specimens after 96 hours water test are observed in the range of 3.36, 3.36, 3.20 and 3.43 grams for UTHC-A, UTHC-B, UTHC-C and UTHC-D specimens accordingly. Weight of the all untreated banana fiber reinforced hybrid composite specimens after 120 hours were noticed in the range of 3.44, 3.44, 3.26 and 3.51 for UTHC-A, UTHC-B, UTHC-C and UTHC-D specimens correspondingly. It was noticed that, weight of the hybrid composite specimen consists of 65 wt% of epoxy resin, 31 wt% of untreated banana fiber and 4 wt% of waste camellia sinensis particle (UTHC-C) possess very minimum than that of other three untreated banana fiber reinforced hybrid composite specimens in all time intervals.
Weight of the untreated banana fiber reinforced hybrid composite (UTHC) specimens after test

Weight of all treated banana fiber reinforced hybrid composite (THC) specimens after the time interval of 24, 48, 72, 96 and 120 hours were represented in figure 7. It was perceived from the experimental results, all untreated banana fiber reinforced hybrid composite specimens weight are in the range of 2.36, 2.47, 2.21 and 2.39 grams for THC-A, THC-B, THC-C and THC-D specimens after 24 hours respectively. After 48 hours, weight of the all untreated banana fiber reinforced hybrid composite specimens were noticed in the range of 2.60, 2.72, 2.43 and 2.63 grams for THC-A, THC-B, THC-C and THC-D specimens accordingly. Weight of the all untreated banana fiber reinforced hybrid composite specimens after 72 hours are found in the range of 2.71, 2.84, 2.54 and 2.75 grams for THC-A, THC-B, THC-C and THC-D specimens correspondingly. Weight of the all untreated banana fiber reinforced hybrid composite specimens after 96 hours water test are observed in the range of 2.77, 2.90, 2.60 and 2.81 grams for THC-A, THC-B, THC-C and THC-D specimens accordingly. Weight of the all untreated banana fiber reinforced hybrid composite specimens after 120 hours were noticed in the range of 2.83, 2.96, 2.65 and 2.87 for THC-A, THC-B, THC-C and THC-D specimens correspondingly. It was noticed that, hybrid composite specimen consists of 65 wt% of epoxy resin, 31 wt% of treated banana fiber and 4 wt% of waste camellia sinensis particle (THC-C) possess very minimal weight after the water absorption test than that of other three untreated and treated banana fiber reinforced hybrid composite specimens in all time intervals. Superior water absorption behaviour was found in Sodium Hydroxide (NaOH) treated banana fiber reinforced composite specimens, due to the elimination of lignin, cellulose and hemicelluloses contents on the alkali-treated banana fiber and it might made spaces in the banana fiber molecules. Addition of limited quantity (4 wt %) of filler contents i.e. waste camellia sinensis particle were filled up in the voids in the banana fiber and it enriches the good amount of interfacial consociate between banana fiber and epoxy resin matrix.

Figure 6 Weight of the untreated banana fiber reinforced hyrid composite (UTHC) specimens after test

4. Conclusion

The following conclusions have been made based on the experimental results that are obtained from the water absorption test on the different weight percentage of untreated and treated banana fiber reinforced, different weight percentage of used camellia sinensis powder filled, constant weight percentage of epoxy resin matrix bio-composites. Chemically treated banana fiber reinforced composite specimens were exhibited the better water absorption behaviour than that of untreated banana fiber reinforced composite specimens. The percentage of water absorption was found very
minimum in 4 wt% of used camellia sinensis powder and 31 wt% of treated banana fiber composite specimens due to the enhanced compatibility of alkali-treated banana fiber with the epoxy resin matrix.

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