Metallurgical and Materials Engineering *Research paper*
Association of Metallurgical Engineers of Serbia AMES *https://doi.org/10.30544/752*

WATER HYACINTH (EICHHORNIACRASSIPES) POLYMER COMPOSITES PROPERTIES – AQUATIC WASTE INTO SUCCESSFUL COMMERCIAL PRODUCT

Ajithram Arivendan[1], Winowlin Jappes[1], Siva Irulappasamy[2], Brintha Chris[3]*

[1,2] Department of Mechanical Engineering and Centre for composite materials, Kalasalingam Academy of Research and Education, Virudhunagar, Tamilnadu, India
[3] Department of Computer Science Engineering, Kalasalingam Academy of Research and Education, Virudhunagar, Tamilnadu, India

Received 20.10.2021
Accepted 07.12.2021

Abstract

In modern times, the demand for natural fibers is increased due to low density, low cost, recyclability, and biodegradable properties. Following work deals with the aquatic waste of water hyacinth plant fiber. The main intent of this work is to utilize the hyacinth plant into a successive manner and convert this plant into some commercial products. It is used as reinforcement material and epoxy polymer resin in matrix material with a suitable percentage of hardener (10:1). A new method such as a mechanical way of extraction process is introduced in this work. The different weight percentage of the hyacinth fiber is reinforced with matrix material like 15, 20, 25, 30, and 35%. With the help of a compression molding, machine water hyacinth reinforced fiber composite is produced by using 1500 PSI pressure and 110 °C, 100 °C of upper and lower plate temperature. A composite sample is cut into as per ASTM standards and the mechanical tests like tensile, flexural, impact test is conducted by using universal testing machine (UTM), and Charpy impact test machine. Based on the final mechanical test results, the 30% of hyacinth composite sample tensile 36.48 MPa, flexural 48.62 MPa, impact 0.5 J, and hardness 98 attained then, the hyacinth composite samples are adopted into water and chemical absorption test with 10 hours, 1week, 1month of continuous monitoring. Based on the final results, hyacinth fiber is strongly recommended to use an alternative of synthetic fibers and conventional natural fibers. The hyacinth composite is strongly recommended for the usage of commercial and household applications.

Keywords: water hyacinth natural fibers; mechanical properties; absorption properties; SEM; polymer composites.

[*]Corresponding author: Winowlin Jappes, *winowlinjappesjtw@gmail.com*

Introduction

Recent trends in environmental problems require a new novel solution method that holds natural material as an alternative. Countless researchers showed interest in natural material replacement. Previously, conventional synthetic fibers, like carbon, glass, and some others, are used as reinforcement material for polymer composites. But**, s**ynthetic fibers have some drawbacks such as higher cost, consuming higher energy, and being non-eco-friendly. Previous drawbacks are forcing to create new demand for bio-degradable materials to the researchers [1-4]. Thus, the natural fibers have received more attention compared to the betterment of environmental consideration aspects [5-7]. Water hyacinth is a free-floating aquatic plant, mainly available in tropical and subtropical regions. Normally, hyacinth plant leaves are very glossy and thick, with growth up to 2m in height above the water surface**.** The main reason for the free-floating of this hyacinth aquatic plant relies upon a bulbous air pocket. One of its special characteristics is fast growing which covers the entire small water body upper surfaces with a minimum of one to two weeks with the help of its daughter plants [8]. It produces a daughter plant **see**d through a vegetative system that withstands up to twenty-five years approximately. It forms a thick mat and fully occupies the water surfaces. Even the sun rays cannot penetrate below the water surface. Thus the main reason most of the aquatic animals and other plants in that water bodies are extinct except hyacinth because of thick mats.

The plant contains 60 percent of cellulose content with higher compared to the other aquatic natural fibers [9, 10]. Mainly, this plant is used for biomass production and used substrate for mushroom production. Water hyacinth plant roots absorb high pollutants, thus now researchers focus on this plant for making a successive product. This novel method of extraction and synthetic materials adopted in waste management and recycling concept Several kinds of literature noted that the hyacinth fiber reinforcement increases the mechanical properties compared to the other natural fibers. In recent years water hyacinth fibers have been used as a reinforcement material because of their huge availability and very cheap cost [11, 12]. All over the world, most of the countries implement some projects and tenders to remove hyacinth plants to mainly avoid environmental problems. It affects th**e** water departments, irrigation, tourism departments, and other local nearby peoples. Generally, water hyacinth plants have gained one of the beneficial properties, especially in invasive times. At that time, it clones itself and produced a similar group of daughter plants. This type of plant i**s** highly available in North America, Asia, Australia, Africa, and New Zealand. Its growth and life cycle improvement depends upon the temperature. Temperature plays a big role in water hyacinth plant growth life. Such as 15 °C is the minimum temperature and a maximum of 35 °C, where 15-35 °C is the optimum level of hyacinth plant growth [13-15]. In India most of the water bodies have this optimum temperature which is the main reason the hyacinth plant spreader in a maximum number of water bodies in India. Above 35°C, it cannot withstand the water bodies.

Normally, hyacinth plant seeds are spread by natural air, by humans, birds, and some other circumstances. When the hyacinth plant presents in the water bodies it reduces the physical and chemical properties like salinity, potential hydrogen, dissolved oxygen, and total dissolved solids. Once upon a time in Bangladesh, it fully occupied the water bodies and created an artificial fish scarcity. It is remembered in Bengal as the terror of Bengal [16-18].

In the present study, water hyacinth plant fibers were used as reinforcement materials and epoxy polymer matrix materials were used at varying weight percentages of 15, 20, 25, 30, and 35. Previously, studies were confined to identifying the chemical functional groups of water hyacinth plants and their inner molecules. The purpose of this study was to investigate the cellulose percentage fiber extraction process, and use the fibers as reinforcement materials to create a commercial item. Tests should be performed on mechanical, water, chemical absorption, and surface morphological characteristics. We strongly believe that only a little work has to be done on this water hyacinth plant in an effective approach [19, 20].

Materials and Methods

Extraction of The Water Hyacinth Plant Fiber

From the first step, the water hyacinth plant is identified at local water bodies nearby Trichy district, Tamil Nadu. After the collection of those plants roots and leaves are removed, only the stem part is taken to extract the fiber from the parent plant. Normally, all the natural fibers are extracted from the conventional retting process. But, in this plant, we cannot extract to the retting process [21]. By utilizing the hot water and chemical extraction method the minimum amount of fibers only derived as well as quality of fiber is highly affected. At last one mechanical way of extraction machine is fabricated with the help of 1/2 HP electrical motor, and finally, plant fiber is successfully extracted from the parent plant stem. Below figure 1 clearly explain the extraction process of hyacinth plant fiber from the parent plant stem with the help of a mechanical way of extraction machine [22, 23].

Fig. 1. Water Hyacinth Extraction Process.

Preparation of Composite Sample

Water hyacinth plant fiber is reinforced with the epoxy matrix material in the grade of LY556 and hardener HY951 in the mixing ratio of 10:1. Normally, the density of resin is 1.1 to 1.4g/cm^3, tensile strength is 28-35MPa, flexural strength is 44-65MPa, elongation 1.5%, tensile modulus 100MPa. Hyacinth fiber is reinforced to five different weight percentages such as 15, 20, 25, 30, and 35%, and the remaining percentage is epoxy matrix material. By utilizing the compression hot press molding machine with the temperature of 100°C of an upper, lower plate with 1500PSI pressure. After the pressure and temperature is applied for half an hour, hyacinth fiber-reinforced polymer composite is produced. Following the mechanical and absorption studies are done up to ASTM standards. With the help of below figure 2, it is clear to understand the different weight percentages of the hyacinth fiber-reinforced polymer composite samples.

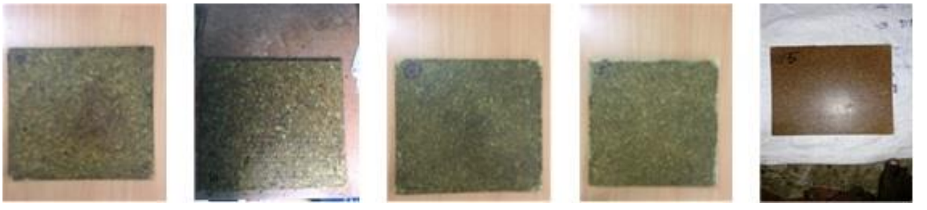


Fig. 2. Prepared Water Hyacinth Fiber Reinforced Polymer Composite.

Mechanical Testing

Water hyacinth different weight percent composite samples are tested to the mechanical testing like tensile, flexural, and impact tests are conducted by universal testing machine and charpy impact test machine. In these experiments, the cross head speed is maintained at 3mm/min for tensile test, and 2mm/min for a flexural test with the proper ASTM standards.

Hardness Test

The composite sample hardness is measured by utilizing a durometer to the ASTM D-2240 standard [24, 25]. Five to seven readings are taken for each sample and the average value is reported as the hardness value of the hyacinth composite material.

Water and Chemical Absorption Test

Water hyacinth natural plant fiber-reinforced composite samples are cut in to the proper ASTM standards for water and chemical absorption tests, with standard as ASTMD 570 and ASTM C413-18 [26, 27]. Initially, the plant composite samples are mixed 100ml of water and 100 ml of sodium hydroxide solutions. This test is carried out 10 hours, 1 week, 1-month time period. Every time period the hyacinth composite sample weight is measured and reported.

SEM Equipment

To identify the surface topology of the composite, primary, and secondary phase bonding, an external minute particles the scanning electron microscope is used 100x to 500x magnification, with 4.13 μ view field, 10 kV.

Result and Discussion

Mechanical Properties

Tensile Strength

The tensile strength of the composite sample is identified by using a universal testing machine. Below, figure 3 clearly explains the tensile strength of different weight percentage composite samples. Force is equally applied to the sample in the vertical direction, and the sample tensile strength is gradually increased like 15 to 30 weight percentage like 22.12 to 36.48MPa, and after the reinforcement, percentage is increased simultaneously composite strength is decreased. When the 35 weight percent of the composite sample is attained 23.46MPa because of higher reinforcement. At the end of the tensile strength test result, the optimal strength (36.48) is attained 30 weight percentage of the samples. This tensile strength of hyacinth fiber reinforced composite sample is higher than banana and coir composites [28].

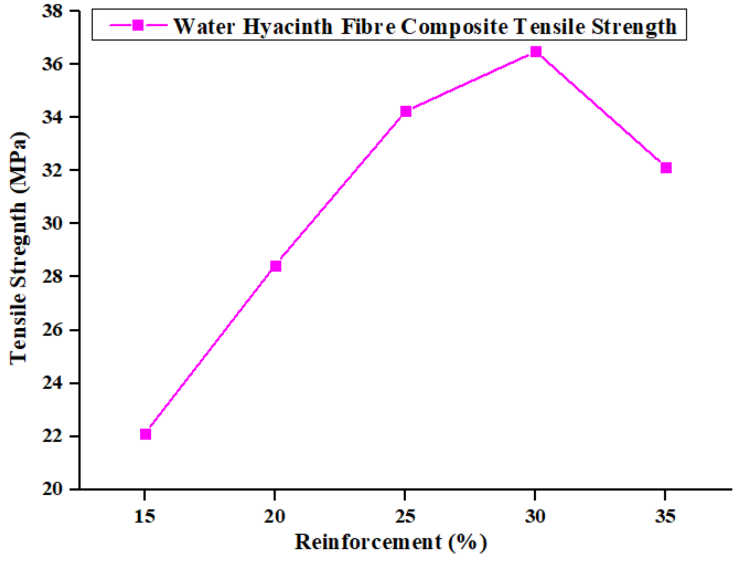


Fig. 3. Tensile Strength of Hyacinth Polymer Composite.

Flexural Strength

The flexural strength of the water hyacinth composite is evaluated with the help of a universal testing machine. The sample is tested as per ASTM standard ASTM D790 with 125x13x3 mm dimension. A horizontal force is gradually applied to the composite specimen until the specimen is broken. From this test, the weight different weight percentage of 15 to 30 samples attained 34.82 to 48.62 MPa. Same as the above tensile strength in this test also above 30 weight percent of the reinforcement content affects the secondary phase of the sample, which automatically decreases the flexural strength of the composite sample. At the end of the result, the 30 weight percentage achieves the nominal weight percentage of the flexural strength. Below figure 4 clearly explains the different weight percentages of fiber-reinforced polymer composite flexural strength. Flexural strength of hyacinth fiber composite is higher than coir and palm fiber reinforced composite material [29, 30].

Impact Strength

The impact strength of the hyacinth composite sample is investigated by using an IZOD impact test machine with ASTM D256 standard and a dimension of 65x13x3 mm. As on following previous test results this impact test 30 weight percentage composite sample achieved high impact strength 0.5 J compared to the remaining composite samples. Below, figure 5 explains the above 30 weight percentage sample attained the low strength compared to the previous one. From the results of mechanical strength, it is clearly explained the 30 weight percent of the sample obtained the highest mechanical strength on tensile, flexural, and impact tests [31]. Based on the final mechanical strength results the water hyacinth composite sample is strongly recommended to commercial house holding applications.

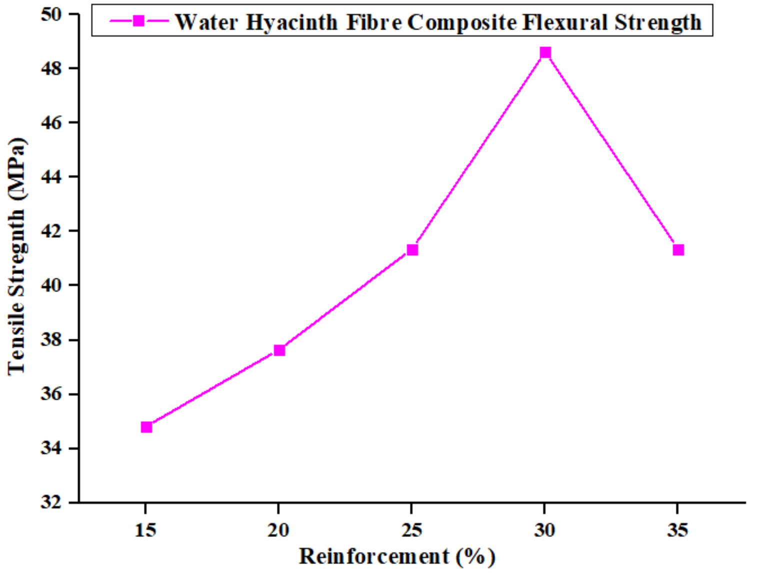


Fig. 4. Flexural Strength of Hyacinth Polymer Composite.

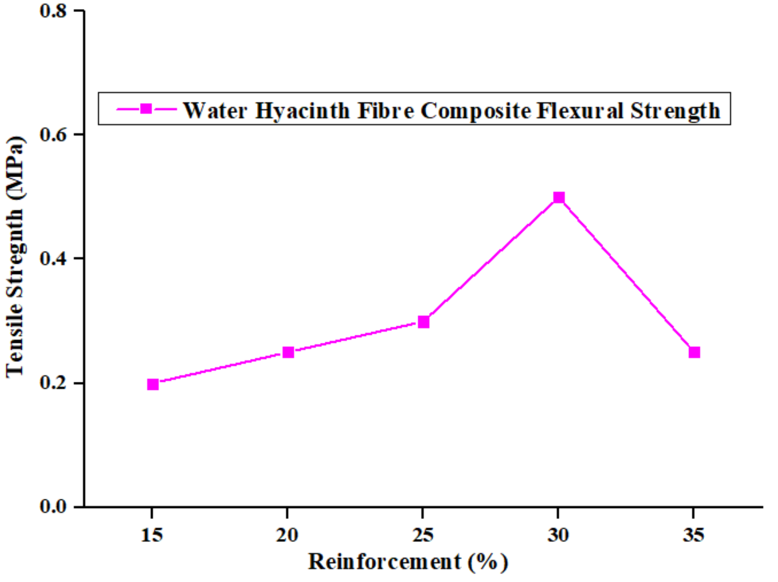


Fig. 5. Impact Strength of Hyacinth Polymer Composite.

Hardness Test

The different weight percentage of the water hyacinth fiber-reinforced composite sample is tested with the help of a durometer as per the ASTM D-2240 standard. Normally, the hardness of the material measured the material resistance to the elastic and permanent deformation. It is the main factor influencing the mechanical properties. Hyacinth fiber reinforcement and epoxy matrix material bonding determine the hardness of the material.

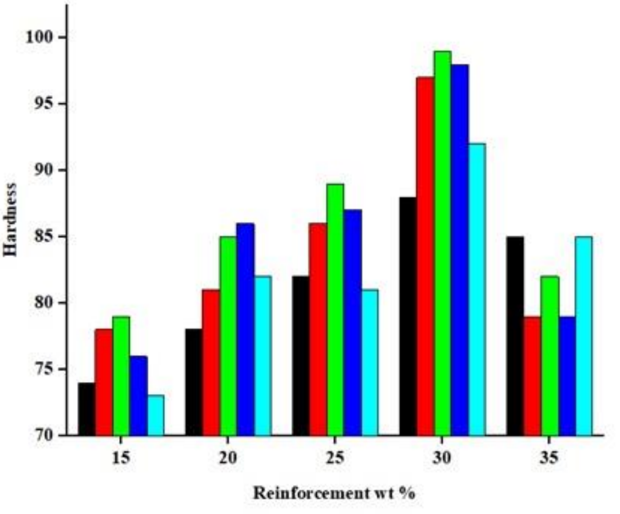


Fig. 6. Hardness of Test of Different Weight Percentage Composite Sample

The above figure 6 clearly explained the different weight percentage fiber-reinforced composite sample hardness values. Based on the above hardness values diagram the 30 weight percent of the sample is attained high hardness strength compared to the remaining weight percentages [32]. This 30 weight percentage sample fiber reinforcement is properly mixed with a second matrix material. This is the main reason it attained more hardness values compared to the others.

Water Absorption Test

Water hyacinth fiber-reinforced composite sample water absorption test is investigated with the help of ASTMD 570 standard. Normally hyacinth fibers have hydrophilic nature, and the epoxy matrix material have hydrophobic nature. It is necessary to check the water absorption properties of the composite sample to recommend a hyacinth composite on commercial aspects. This test is carried out every two hours of monitoring up to 10 hours, every 10 hours up to 50 hours, and every 1 week of monitoring up to one month. Based on the three different test results are increased because of hyacinth fiber hydrophilic nature. At the end of a month 4th week onwards, the absorption values of the hyacinth fiber composite samples become constant. As an earlier stage, the composite sample has cut into 50x20x3mm dimension then the initial weight of the different weight percentage composite sample is tested by using an electrical weighing machine then it is poured into 100 ml of water solution [33]. After a two, ten, one-week time period, the sample is cleaned with the help of dried cloth then the new weight is measured. This absorption process is continually taken up to one month. From the final absorption results the below figure 7 is drawn by using origin pro software.

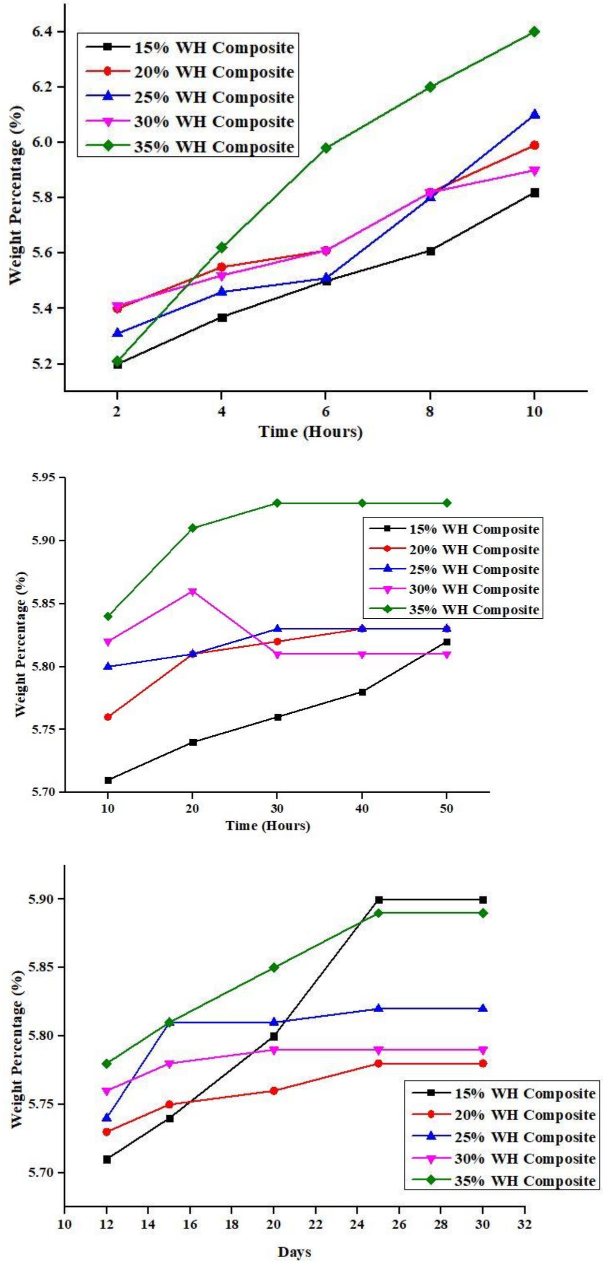


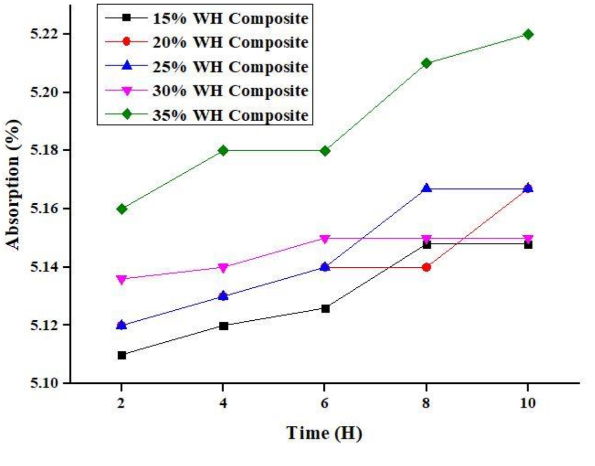
Fig. 7. Water Absorption Test of Hyacinth Fiber Reinforced Polymer Sample.

Table. 1. Comparison Chart of Hyacinth Composite With Other Natural Composites.

Serial Number	Testing	Present Hyacinth Plant Composite	Existing Natural Fibers based Composites
1	Mechanical (Tensile) Testing	32-36 MPa	28-34 MPa
2	Mechanical (Flexural) Testing	44-58 MPa	36-52 MPa
3	Mechanical (Impact) Testing	0.3-0.5 J	0.10-0.25 J
4	Absorption Studies (Water)	Increasing 2.8 wt.%	Increasing 4 wt.%
5	Absorption Studies (Chemical)	Decreasing 2 wt.%	Decreasing 2.4 wt.%
6	Hardness Test	80-115	66-98

Chemical Absorption Test

Water hyacinth fiber-reinforced composite sample chemical absorption test is conducted as per ASTM C 413-18 standard. Normally hyacinth fibers have hydrophilic nature, and the epoxy matrix materials have hydrophobic nature. Consideration of commercial product purpose the chemical absorption test is necessary to the hyacinth composite samples. This test is carried out the same as the previous water absorption test, such as every two hours of monitoring up to 10 hours, every 10 hours up to 50 hours, and every 1 week of monitoring up to one month. Based on the final results the sodium hydroxide solutions slightly affect the hyacinth composite sample those the here format of testing. From the earlier stage, the sample is cut to be 50x20x3mm dimension, and the initial weight is measured by using a digital weighing balance machine. The different weight percentage of the hyacinth composite sample is adopted to the 100 ml of sodium hydroxide solutions. Then the monitoring tests are conducted. Based on the final results this hyacinth composite is strongly recommended for commercial usage and householding product purposes.



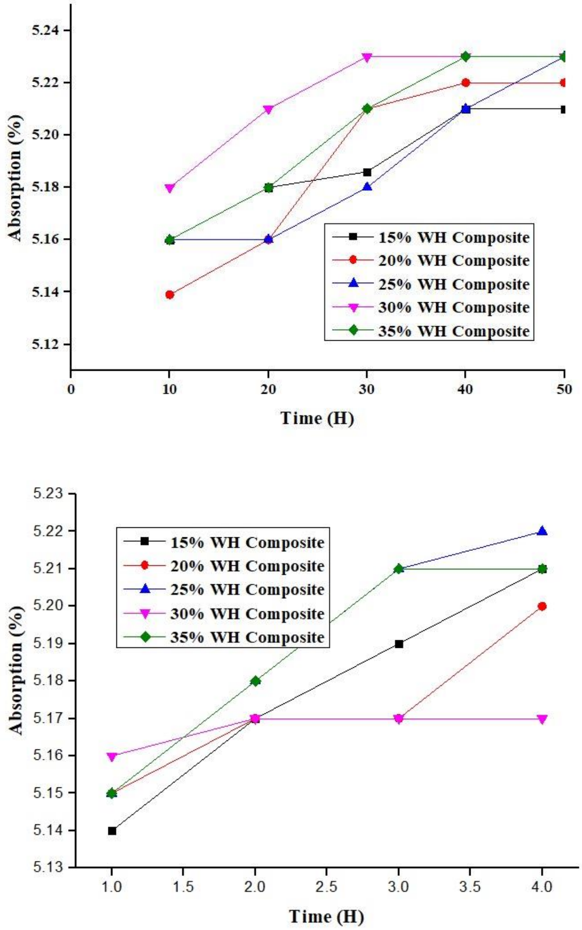


Fig. 8. Chemical Absorption Test of Hyacinth Fiber Reinforced Polymer Sample.

<u>Morphological Analysis</u>

The water hyacinth fiber reinforced composite surfaces are analyzed by using a scanning electron microscope. The SEM image of water hyacinth powder composite is shown in below figure 9(a). The direct view of the electron images shows the good interfacial bonding to the reinforcement and matrix materials, and figure 9(b) shows the fibers pulled out to the secondary phase material. The figure 9(c) shows the proper bonding of hyacinth fiber and epoxy matrix materials.

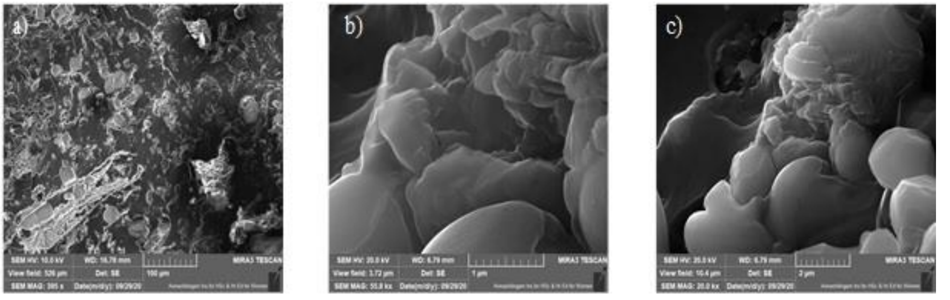


Fig. 9. SEM images: (a) water hyacinth powder and ash composites, (b) fibers pulled out to the secondary phase material, and (c) proper bonding of hyacinth fiber and epoxy matrix materials.

Conclusion

This work briefly investigates the water hyacinth natural fiber as a reinforcement, and it is mixed with an epoxy matrix material which produced to hyacinth fibre reinforced polymer composite sample.

- In this work, the different weight percentage of the hyacinth composite sample is investigated, such as 15, 20, 25, 30, and 35%.
- Compared to the different weight percentages of the composite sample, 30% of hyacinth composite has attained higher mechanical strength compared to the remaining samples.
- The results of the hardness test clearly explained the 30% of hyacinth fibre reinforced composite samples have a higher hardness value compared to the remaining composite samples.
- From the results of the water absorption test, all the samples are increased initially with respective weight percentages up to 30 hours. After that, it comes to the constant. This behaviour is repeated to the same on chemical absorption test also.
- SEM images are clearly shown the nature of bonding and elaborately explain the primary phase behaviour compared to the secondary phase (epoxy matrix phase).
- Based on the final results of this work water hyacinth fibre reinforced composite sample has a better alternative to synthetic fibre composites, and it is highly recommended for the usage of commercial application and house holding product purposes.

References

[1] H. Abral, D. Kadriadi, A. Rodianus, P. Mastariyanto, S. Arief, S. M. Sapuan, M. R. Ishak: Materials and Design, 58 (2014) 125-129.

[2] A. Ajithram, J. T. Winowlin Jappes, N. C. Brintha: Materials Today: Proceedings, 45 (2020) 1626-1632.

[3] M. Asrofi, H. Abral, A. Kasim, A. Pratoto: Materials Science and Engineering, 204 (2017).

[4] M. Asrofi, H. Abral, A. Kasim, A. Pratoto, M. Mahardika, F. Hafizulhaq: Fibers, 6 (2018).

[5] M. Karina, H. Onggo, A. Syampurwadi: Journal of Biological Sciences, 7 (2007) 393-396.

[6] Y. Gao, H. Chen, J. Wang, T. Shi, H. Yang, X. Wang, X: Journal of Fuel Chemistry and Technology, 39 (2011) 893-900.

[7] U. Hajar, A. Wardoyo: Applied Ecology and Environmental Research, 17 (2019) 1959-1965.

[8] V. P. Indulekha, C. George Thomas, K. S. Anil: Indian Journal of Weed Science, 51 (2019).

[9] J. Liu, Z. Tang, C. Wang, K. Wu, Y. Song, X. Wang, Z. Zhang: Renewable Energy, 163 (2021) 1701-1710.

[10] L. Xin, L. Liu, R. Fan, J. Luo, S. Yan, Z. Rengel, Z. Zhang: Environmental Science and Pollution Research, 24 (2017) 23584-23597.

[11] S. Farahat, A. Banna, A. Mohamed, E. Esawi, M. Mohamed, A. Daim, A. Mosa, A. Khaled: Sustainability (Switzerland), 12 (2020) 1-16.

[12] E. Wakil, A. E. Elbasseer: Polymer Composies, 42 (2021), 3732-3745.

[13] M. A. Rahman: Waste Management, 80 (2018) 310-.3180.

[14] A. G. Supri, H. Ismail: Polymer - Plastics Technology and Engineering, 50 (2011) 113-120.

[15] A. Ramirez, S. Pérez, E. Flórez, N. Acelas: Journal of Environmental Chemical Engineering, 9 (2021).

[16] S. Ruiz,M. Adela, M. Barbero-Barrera, T. Téllez: Materials,12 (2019).

[17] S. Saputra, A. Handaya, M. Hapsari, A. Pitaloka, A: Contemporary Engineering Sciences, 8 (2015) 33-36.

[18] P. Silva, P. Rui, M. R. Marcelo, D. Melo, J. D. Armando, M. Carlos: Industrial Crops and Products, (2015) 1033-1038.

[19] P. Sindhu, G. Raveendran, P. Binod, A. Pandey, A. Madhavan, J. Alphonsa, N. Vivek, E. Gnansounou, E. Castro, V. Faraco: Bioresource Technology, 230 (2017) 152-162.

[20] D. Soeprijanto, I. Soeprijanto, D. Warmadewanthi, M. Muntini, A. Anzip: International Journal of Renewable Energy Development, International Journal of Environmental Science and Development, 10 (2020) 27-35.

[21] N. Supatata, J. Buates, P. Hariyanont: International Journal of Environmental Science and Development, 4 (2013) 179-181.

[22] A. G. Supri, S. J. Tan, H. Ismail: Journal of Vinyl & Additive Technology, 19 (2013) 47-57.

[23] S. Tanpichai, S. K. Biswas, S. Witayakran, H. Yano: ACS Sustainable Chemistry & Engineering, 7 (2019) 18884-18893.

[24] W. Ting, I. Tan, S. F. Salleh, N. A. Wahab: Journal of Water Process Engineering, 22 (2018) 239-249.

[25] P. Tran, T. Khanh, N. Kim, H. Leu, M. P. Pham, M, N. A. Luong, H. Khiem: International Journal of Hydrogen Energy, 46 (2020) 13976-13984.
[26] J. Shing, T. Chieh, H. Chien, Y. J. Wu, S. M. Lin, R. Juang, R: Journal of Agricultural and Food Chemistry, 56 (2008) 5806-5812.
[27] F. T. Yani, R. Ulhaqi, W. P. Pratiwi, K. Pontas, H. Husin: Journal of Physics: Conference Series, 1402 (2019).
[28] M. Chaoyue, T. Huang, Y. Zhou, Y. Tian: Bioresource Technology, 314 (2020) 123-676.
[29] M. Chaoyue, T. Huang, Y. Zhou, Y. Tian: Energy and Fuels, 34 (2020) 14147-14158.
[30] A. Hakim, A. Awad, E. Nemr, T. M. Basheer: Radiation Physics and Chemistry, 189 (2021), 1-14.
[31] S. Alix, E. Philippe, A. Bessadok, L. Lebrun, C. Morvan, S. Marais: Bioresource Technology, 100 (2009) 4742-4749.
[32] H. N. Dhakal, Z. Y. Zhang, M. O. Richardson: Composites Science and Technology, 67 (2007) 1674-1683.
[33] R. Mahadev, B. Adaveesh, T. S. Mohan Kumar: Matellurgical and Materials Engineering, 10 (2021) 1-15.