Advanced Materials Research Vols. 189-193 (2011) pp 4043-4048
© (2011) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMR.189-193.4043

Development of Basalt Fiber Reinforced Wood-plastic Composite Materials

Jinxiang Chen [1, a], Sujun Guan [2,b], Shunhua Zhang[2,c], Jingjing Zheng[2,d], Juan Xie[1, e] and Yun Lu [3,f]

[1]International Institute for Urban Systems Engineering & School of Civil Engineering, Southeast University, Nanjing, 210096, China

[2]Key Laboratory of Advanced Textile Materials and Manufacturing Technology of Ministry of Education, Zhejiang Sci-Tech University, Hang Zhou, 310018, China;

[3]Department of Mechanical Engineering, Graduate School & Faculty of Engineering, Chiba University, Chiba, 263-8522, Japan

[a] chenjinx@yahoo.com.cn, [b] guansujun1222@gmail.com, [c]zshhzj@163.com , [d]zjj_cecily@zstu.edu.cn , [e]xiejuanch@yahoo.com, [f]luyun@faculty.chiba-u.jp

Keywords: Wood Plastic Composite; Basalt Fiber; Composite Material

Abstract. The relationship between properties of BF-WPC and the content of BF were studied, when wood-plastics composite (WPC) was reinforced by 12 mm and 3 mm short basalt fiber (SBF). The results showed that there may have some uneven distributions of SBF in WPC, when the content of 12 mm BF exceeded 30%. Restricted to the uneven distribution and the quantity of "end weak'', it formed the close comprehensive property of BF-WPC by the length of 12mm and 3mm BF. The comprehensive property of BF-WPC has a maximum range of 15%-30% of the content of 12 mm BF. Compared to pure WPC, the tensile and bending strength of BF-WPC have improved. However, the reinforce effect of BF-WPC is different and is dependent on the index of each property. The BF-WPC plate can be developed with different properties and be a cost-effective material by choosing different length and content of BF.

Introduction

Presently, the research and development of ecological materials have become a major issue, due to the increasing consciousnes on environmental protection and the decreasing amount of forest resources [1]. Wood plastic composites (WPC) is made of plant fiber and thermoplastic materials by extrusion, injection molding, hot molding and other means [2]. WPC inherits the color and texture of the original wood [3-4], so it can be widely used in furniture, floor, pallet and automobile, et al [5]. The raw material of WPC could come from the waste plastic and scrap timber, thus using WPC could realize the conversion process of "turning the waste to be useful" [6] or recycling. However, compared to real wood, there are some deficiencies in applicating WPC, such as more energy consumption, higher production cost, higher density with lower strength ability, etc [7]. Until today, WPC could not be applied to structure materials and other similar field due to higher property requirements[8]. In order to overcome these shortcomings, a lot of studies had been carried out and had been proven to achieve gratifying resultson material formulation [9], reinforced by glass fiber [10], modification [11], and processing technology [12-14]. The aforementioned shortcomings of WPC are not well resolved, therefore, continues research and development should be carried out in order to find new break throughs in these deficiencies.

On the other hand, this paper would introduce basalt fiber (BF) which is known as "the 21st century non-pollutant green materials", which is a new kind of fiber prepared with natural ore and drawn through platinum rhodium alloy by melting at high temperature [15]. BF has wide raw material sources, low cost [16], and excellent property, such as high temperature resistance, corrosion resistance, thermal insulation, sound-absorbing and low moisture absorption, et al [17]. It is a cost-effective and high strength fiber [18], which had been widely used in road traffic [19], buildings and other reinforcement fields [20-21]. In view of this, through the cross-disciplinary advantage, on the basis of "wood" and "plastics" composite, it can effectively improve the tensile and bending strength by preliminary experiment using 3mm short BF reinforce WPC, but the growth of elongation is not ideal [22]. This article coincides to improve by increasing the length of short BF.

In order to determine the length interval of short BF of effectively reinforced WPC, the effect of longer BF reinforced WPC was discussed in this article. Futhermore, the relationship between the length and content of short BF, and the mechanical properties of BF-WPC was also investigated. It is clear that the BF-WPC could be developed by new technology-- using different length and content of short BF.

Experimental method

Material design and equipment In order to reduce the number of experiments, to improve the efficiency and to find out the best effect, select the length of 12mm and 3mm BF to reinforce WPC on experimental basis of 3mm BF reinforced WPC. Materials BF of diameter 17 μm which was made in 2010 provided by ZHEJIANG GBF BASALT FIBER Co., LTD; WPC of HDPE: Teak powder=3:7, (SHXINJIXIN Co., LTD). Experiment designs are divided into 6 groups in which the content of BF increases from 0% and each additional sample by 6%, and each group size is five. So, the total size is ten for 3mm BF including previous experiment results.

The preparation process and property testing Mixing BF and WPC to the extruder by double roller mill to refine about 5-10minutes, and the front roll is at 160℃ and the back is at 170 ℃ respectively. After crushing the well mixed materials, mold it by the plate vulcanizing compression, molding temperature is at 180 ℃, preheating it for 5-10 minutes, pressurize it for 8min and at 8 MPa, then cold pressure 15 minutes after unloading mode.

According to GB/T 7-2005, GB/T 1449-2005 and GB/T 1043-1993 prepare the tensile, bending and impact samples, and test it by electronic all-powerful experiment on tensile (gauge is 80mm) and bending (span is 60mm), test speed is at 10mm/min Scan sample by SEM [22]. The detailed experimental conditions can be reffered to the reference [22].

Result and discussion

Mechanical properties Figure 1 shows the tensile strength of BF-WPC with the different contents of 12mm and 3 mm BF. From the graph, we can see that the tensile strength of BF-WPC is first increased and then gradually decreased, with the content of BF increased. When the length of BF is 12 mm, the elongation of BF-WPC had improved than the length of 3mm BF`s, while the content of BF amount 18%-30%.

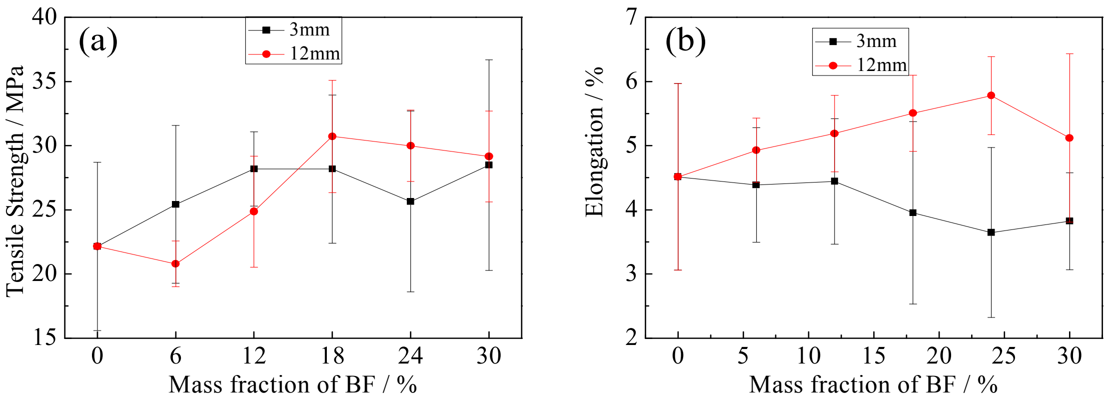

Fig.1 Relationship between the tensile properties of BF-WPC and BF content.
(a) Tensile strength and (b) Elongation.

Fig. 2 is the bending strength of BF-WPC with different content of BF respectively. The graph shows that with the increasing content of BF, the bending strength of BF-WPC haveincreased during the process, and when reached its maximum it bagan to decline. These changes varies depending on the content of BF. The bnding strength reaches its maximum when the content of 12 mm BF is about 24%. The amount of changes varies after it reaches its maximum, in which the largest was more than 50%, while the smallest about one third, which maybe related to the propery index and the length of short fiber.

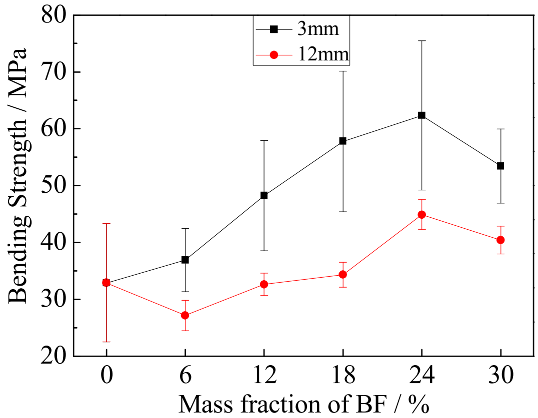

Fig. 2 Relationship between bending strength of BF-WPC and BF content.

Fracture fractography of BF-WPC Figure 3 shows the cross-section fractography of BF-WPC by bending broke, with the length of BF is 3mm and 12mm and the content of 18% and 24%. Figure 3 shows that WPC mixed density is uniform; while from the cross-section in Figure 3, no matter what length of BF is used, they all showed the overhanging BF (as shown with general arrow mark), also some hollow holes after BF had been polled out (as shown with wide arrow mark). However, the overhanging section of the length of 12mm BF is longer than that of 3 mm. Moreover, from the Fig. 3(d), the length of 12 mm of BF and its content of 24%, the distribution part of the overhanging section of BF is more dense, and almost formed a wispy. In other words, the uniformity of distribution of BF in WPC had decreased if content of BF is more than 30%.

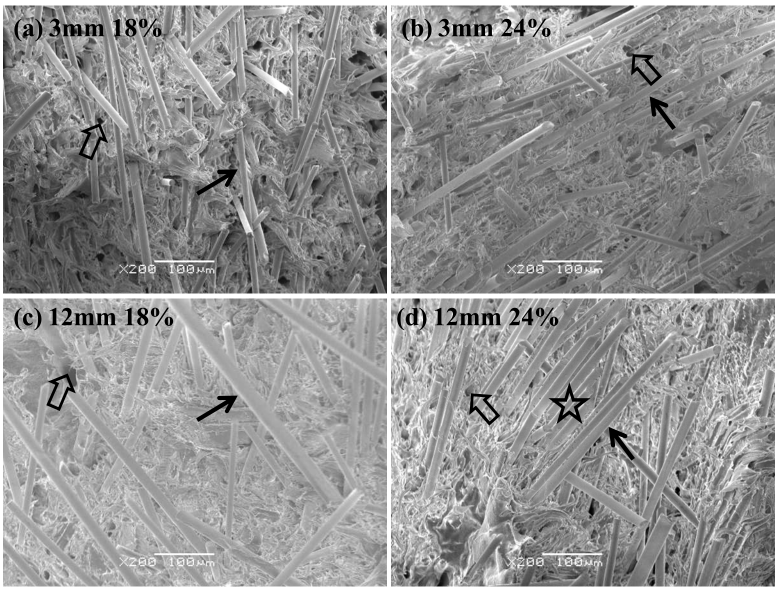

Fig.3 Fractography of bending fracture surfaces of composite.

Property analysis of BF-WPC and its strengthening mechanisms Figs 1 and 2 show that, whether the length of BF length is 3 mm or 12 mm, except that the elongation has no largely change, other mechanical property index of BF-WPC both show a rising progress, then all began to decline after reaching its maximum, along with the increase of the content of BF. Bending strength reaches its maximum when the content of BF is about 20%-30%, while the tensile strength is about 15%-25%. With the similar report about the glass fiber reinforced WPC [10]: the percentage of wood powder in WPC is not more than 30%, the best content of additive glass fiber is 15%, and the tensile and bending strength increased 23-40% and 10% respectively [10, 23]. Compared with that of the glass fiber, it is visible that the content of added BF to reinforce WPC could substantially increase, at the same time, substantially increasing its mechanical properties,

For the strength mechanism and the mentioned maximum phenomenon, it can be explained that when composites under external load is put in place, the shear force will load the matrix transfer to enhance the fiber [24], and the mutual snare deformation between BF and matrix would be interfaced, thus the enhancement between the two worked [25-26]. When the content of reinforced fiber reached a certain value, these excessive fibers affect the even combination between matrix and fiber, which will cause the transferefficiency of stress to decline between the interface. Thereby the maximum phenomenon will show the properties index of materials.

According to current mechanism of "shear stress transmission", if the BF and WPC are mixed well, and squeezed evenly, then the effect will be better. From Figure3, WPC dense wrapped around BF, and the mechanical properties such as tensile strength of BF confirmed to be much larger than WPC. Therefore, the tensile and bending strength had been significant reinforced, which can be demonstrated that when the materials was mixed fully in the experiment, the result of the molding process is ideal. In this experiment, the content of wood powder in WPC is up to 70%, and the best content range of BF is about 15%-30%, which is much larger than that 15% of glass fiber. In this regard, as reported [22], when the length of BF is 3mm even if the content of BF is up to 30%, Figure 3 shows that the mainly is WPC, while BF should have enough space. Therefore, as long as the content is not too much, BF may not become phenomenon of "difficult to be evenly combined" (referred to as "uneven"). With the qualitative hypothesis of "weak end", it could explain that the phenomenon of the maximum content of BF is less than 30% [22].

By this hypothesis, the quantity of "weak end" of the length of 12mm BF is only 1/4 to 3mm, with the same content of BF, compared to 3mm BF, if the fiber diameter is the same. Therefore, mechanical properties of each index and the maximum content of BF should be better and bigger. Although Fig. 1 shows the changes of trends of the tensile experiments, the effect is not very apparent. While Figure 3 shows that the length of overhanging BF (Fig. 3c, d) is much longer than that of 3mm (Fig. 3a, b), and the mentioned part section of overhanging BF will be fastened together(Fig. 3d), when the length of BF is 12mm. So it could be presumed that the content of 12mm BF is 24%, which may have begun to affect the uniformity of fiber distribution. In other words, the length of reinforced BF is not longer the better, the effect is also related with the content and distributation of BF. The relationship between the two will be more detailed and studied on the other coverage.

Development of the BF-WPC with different cost-effective Based on the above effect of strength property of WPC in different length of BF and the analysis of the mechanism, the relationship between the length of 12mm and 3mm, and the mechanical properties has no significant variation. For instance, the bending strength of 3mm BF reinforced WPC is better than that of 12mm (Fig. 2), while the elongation are opposite (Fig. 1b); the tensile strength is relatively close (Fig. 1a). Therefore, there are several possible reasons: 1) Despite the length of reinforced BF, it could play a significant impact on some mechanical properties, but the effect on comprehensive enhancement caused by the two kinds may be consider to be simlar with the BF length of 3 mm and 12 mm, because of the "weak end" and "uneven" effect caused by the length of fiber roughly offset each other. 2) The range of the length of BF from 3 mm to 12 mm is a large gap, which separates by 3 times, so there maybe an optimal length of BF during that range, which will be judged by further experiments. In any case, the existing experimental results confirmed that the short-cut BF can effectively reinforce the mechanical properties of WPC, it is indisputable that it can developed new materials of BF-WPC which will have better mechanical properties than the present WPC.

How to effectively develop BF-WPC plate? In order to further explained this question, taking the tensile strength as an example: Figure 4 shows the development of curve that is related to the effect of growth of the tensile strength of each additional 1% BF.

Fig. 4 clearly shows that the effect is completely different with each additional 1% of BF. Therefore, choosing the content of 10%-20% of BF may obtain better the strengthening effect, while use as less BF as possible. In order to obtain the best effect with, different needed indicators by using different formulas, based on the experimental results shown Figs 1 and 2, such as the content of 3mm BF is 25%, would gain the best bending strength of plate(Fig. 2). Similarly, the content of 12mm BF is 18% would gain the better tensile strength of plate (Fig. 1). Acording to different purpose, it is visible that developing different cost-effective BF-WPC plate is best achieved by choosing different lengths of BF and adjusting its content.

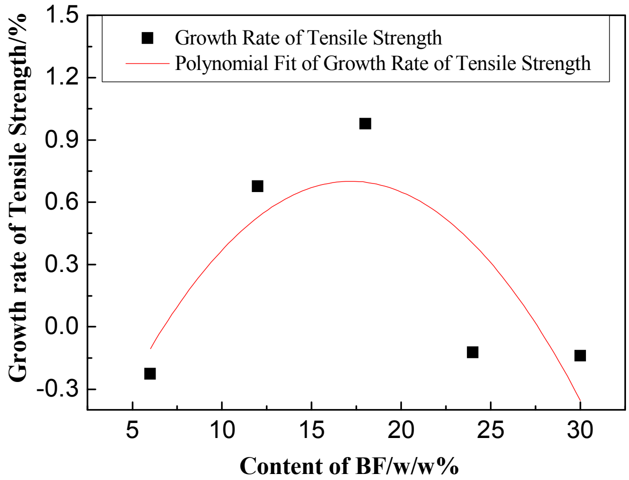

Fig.4 Reinforce effect of the tensile strength for added each 1% BF of 12 mm content Every increase in content.

Summary

(1) No matter what the length of BF is, either 3 mm or12 mm, the relationship between the tensile and bending strength of BF-WPC and the content of BF had the same reaction, which started at increasing and then gradually declining after it reaches its maximum, and the results also showed the combined value of each property. However, the growth of each property and the content of BF varies from each other, when the property reaches its peakest point: Bending strength reaches its highest strength when the content of BF is about 20%-30%, while the tensile strength is about 15%-25%. The effect of these development, the largest was more than50%, while the smallest about one third, which maybe related to the propery index and the length of short fiber.

(2)For the length of 12mm BF reinforced WPC, the length of overhanging BF is much longer than that of 3mm, especially the content of BF exceeded 30%, there may have some uneven distributions of SBF in WPC for the length of 12mm BF. Restricted to the uneven distribution and the quantity of “end weak’’, it formed the close comprehensive property of the BF-WPC with the two types length of BF. However, the reinforced effect of BF-WPC is different and is dependent on the index of these properties.

(3) Acording to different purpose, it is visible that developing different cost-effective of BF-WPC plate is achieved by choosing different length of BF and adjusting its content.

Acknowledgment

This work is supported by Natural Science Foundation of China under Grant 50908045. The authors would like to thank Zhejiang ShiJin basalt fiber Co., LTD who supplied and supported us in these experiments.

References

[1] X. Yin and H. Ren: Plastics Vol. 31(2002), p. 25-28
[2] W. Yu, Z. Sun and X. Lei: Chemical Building Materials Vol. 9(2004), p. 14-16
[3] P. Tu: New Building Materials Vol. 7(2001), p. 10-12
[4] A. Kamal, S. Pang and S. Mark: Composites Part B: Engineering Vol. 39(2008), p. 807-815
[5] J. Markarian: Plastics additives & compounding Vol. 7(2005), p. 20-26
[6] J. Guo, Y. Tang and Z. Xu: Journal of Hazardous Materials Vol. 179(2010), p. 203-207
[7] Q. Wang and W.Wang. *Wood-plastic composite materials and products* (Chemical Industry Press, Beijing 2007)
[8] A. Afrifah, A. Hickok and M. Matuana: Composites Science and Technology Vol. 70(2010), p. 167-172
[9] F. James and M. Armando: Composites Part A: Applied Science and Manufacturing Vol. 41(2010), p. 1434-1440
[10] Y. Cui, B. Noruziaan, S. Lee, M. Chang and J. Tao: Polymer Materials Science & Engineering Vol. 22(2006), p. 231-234
[11] W. Andrea and H. Salim: Building and Environment Vol. 42(2007), p. 2637-2644
[12] Y. Shu-Kai and G. Rakesh: Composites Part A: Applied Science and Manufacturing Vol. 39(2008), p. 1694-1699
[13] Y. Lei and Q. Wu: Bioresource Technology Vol. 101(2010), p. 3665-3671
[14] K. Oksman: Wood Science and Technology Vol. 30(1996), p. 197-205
[15] X. Hu and T. Shen: Hi-Tech Fiber & Application Vol. 30(2005), p. 7-13
[16] X. Hu: Hi-Tech Fiber & Application Vol. 33(2008), p. 12-18
[17] M. Wang, Z. Zhang, Y. Li, M. Li and Z. Sun: Journal of Reinforced Plastics and Composites March Vol. 27(2008), p. 393-407
[18] M. Jiri, K.Vladimir and R. Jitka: Engineering Fracture Mechanics Vol. 69(2002), p. 1025-1033
[19] B. Jin and G. Wu: Science and Technology Innovation Herald Vol. 13(2009), p. 74-75
[20] M. Černý, P. Glogar and Z. Sucharda: Journal of Composite Materials May Vol. 43(2009), p. 1109-1120
[21] Q. Liu, S. Montgonery, P. Richard and A. Mcdonnell: Polymer composites Vol. 27(2006), p. 41-48
[22] S. Guan, C. Wan, L. Wang, Y. Xu and J. Chen: *Study on mechanical properties of basalt fiber teinforced wood-plastic composites*, edtied by Acta Materiae Compositae Sinica, 2011, in press
[23] Z. Qin: *Performance and structure research of glass fiber/wood flour/polypropylene three phase composites*(Suzhou University, Suzhou 2005)
[24] H. Li and J. Tao: Engineering Plastics Application Vol. 37(2009), p. 17-19
[25] J. Xu, X. Quan, W. Gao, H. Gao and Y. Wu: Materials Review Vol. 23(2007), p. 112-115
[26] M. He, W. Chen and X. Dong: *Polymer Physics* (Fudan University Press, Shanghai 1991).