IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

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To cite this article: I Yasin and A Priyanto 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **535** 012001

IOP Conf. Series: Materials Science and Engineering **535** (2019) 012001 doi:10.1088/1757-899X/535/1/012001

Analysis of bamboo mechanical properties as construction eco-friendly materials to minimizing global warming effect

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Abstract. Burning fossil fuels increases the amount of carbon dioxide in the atmosphere. Carbon dioxide is the main cause of the greenhouse effect and global warming. Climate change causes an increase in the number of human deaths due to diseases and natural disasters. In general, in the past decade there has been deforestation of 13 million ha / year. The highest deforestation rates (> 3.4 million ha / year) occur in South America and Africa while in Asia also experience deforestation in many places. Bamboo forests are very important especially in East and Southeast Asia as well as in Africa. The potential of bamboo is very large in controlling soil erosion, water conservation, land rehabilitation and carbon sequestration. In carbon sequestration bamboo contributes very significantly. The use of bamboo as an environmentally friendly construction material is very important to do. Testing of bamboo mechanical properties based on ISO 3129-1975 standards, which includes testing of fiber parallel compressive strength, parallel fiber shear strength, fiber parallel tensile strength and straight fiber tagak flexural strength. Setting-up testing is carried out after each specimen in the condition of the kiln dry water content is in the range 12-13% according to the requirements of the ISO 3129-1975 standard. Analysis of variants (Anova) of pressure treatment on bamboo material has an effect on some of the mechanical properties of bamboo. Pressure treatments up to 2.5 MPa have a significant effect on the elastic modulus, tensile strength and shear strength of bamboo while the compressive strength is not significantly affected by the pressure treatment of bamboo material. Bamboo forests have a big influence in reducing the impact of global warming and climate change.

1. Introduction

As a result of the use of fossil fuels and nuclear power, the temperature of the heat generated flows into the atmosphere. Since 1880 global warming has accumulated in air, water and land. In general, thermal pollution contributes significantly to 55% of global warming [1]. In the last 100 years, the surface of the earth has risen to an average temperature of 1 degree Celsius or 1.3 degrees Fahrenheit. Burning fossil fuels increases the amount of carbon dioxide in the atmosphere. Carbon dioxide is the main cause of the greenhouse effect and global warming. Climate change causes an increase in the number of human deaths due to diseases and natural disasters [2]. From the June 1972 environmental conference in Stockholm to the June 1992 Earth Summit in Rio de Janeiro and other international conferences on the environment, polemic for environmental sustainability increased significantly and decided on international actions to reduce carbon dioxide and global warming in earth. There are three carbon stocks on earth, namely the oceans, the atmosphere and terrestrial ecosystems. Forests are able to store the largest carbon in terrestrial ecosystems, namely 1146 x 1015 g carbon or 56% of total carbon in terrestrial ecosystems [3]. So it needs fast-growing plants and is able to absorb carbon in large capacity to restore forest sustainability.

In general, in the past decade there has been deforestation of 13 million ha / year. The highest deforestation rates (> 3.4 million ha / year) occur in South America and Africa while in Asia also experience deforestation in many places. Deforestation dramatically affects the human population that lives from forests. The survival of indigenous peoples and traditional communities is threatened by deforestation. Changes in rainfall include the impact of deforestation which causes the risk of forest fires in the dry season. In addition, it also causes negative changes in water quality and biodiversity losses because more than half of the animals that live on the earth depend on forests for their survival. In general the causes of deforestation are infrastructure development, expansion of agricultural and plantation land, settlement and mining expansion [4].

Bamboo forest ecosystems are an important part of the forest ecosystem and carbon sink on the earth [3]. Bamboo is a renewable natural resource that has the highest growth speed [5]. As one of the fastest growing plants, bamboo growth is 30 mm to 100 mm per day during growth. The height of bamboo can reach 36 meters with a diameter of 1-30 cm [6]. Bamboo has more than 70 genera and more than 1000 species in botanical literature. Bamboo plants can adapt to a short life cycle. Bamboo growth can reach 70 mm per day and can reach 350 - 450 mm [7]. The development of the stem is completed in 4-6 months and bamboo reaches adults only takes 2 - 6 years, depending on the species [8]. Cylindrical bamboo stems with a diameter of 29-300 mm, 60-70% of the stem consists of fiber. The average height of bamboo is about 100 times its diameter [9]. In nature bamboo is the fastest growing plant [10].

Bamboo forests are very important especially in East and Southeast Asia as well as in Africa. The potential of bamboo is very large in controlling soil erosion, water conservation, land rehabilitation and carbon sequestration [11]. One hectare of bamboo plants can absorb more than 12 tons of carbon dioxide in free air. With the preservation of bamboo means having a carbon dioxide suction machine in large capacity [12]. In the *Bambusoideae* family, bamboo is a giant grass with a shell shape, orthotropic, has a high strength in the longitudinal direction whereas in the transverse direction it has a low strength. Bamboo fibers are denser on the outer skin for resistance to wind gusts during their growing period [13].

Fig. 1. Bamboo Fiber Structure of *Dendrocalamus asper*.

2. Literatur Review

In carbon sequestration bamboo contributes very significantly. About 80% of the area containing bamboo is in the tropical regions of South and Southeast Asia [11]. The ability of bamboo in carbon sequestration tends to be second to none compared to other plants because of the speed of biomass accumulation and the effective fixation of solar energy and carbon dioxide. A quarter of biomass in the tropics and one fifth in the subtropical region comes from bamboo. The development of bamboo can reach 15 km from the center of growth with a stem diameter reaching 30 cm [14]. Bamboo clumps can hold up to 25% of rain water falling to the ground, this percentage is far greater than conifers and pine plants. Bamboo is able to withstand large amounts of rainfall due to the thick layer of leaves and strong clumps. Interception of bamboo clumps depends on stem quantity and leaf area index [15]. The annual interception of rainfall in the *Dendrocalamopsis latiflorus* bamboo forest is 128.1 mm with a medium distance of 3 x 4 meters and an overall density of 5000 bamboo stems per hectare. The interception ratio is 14.5% with runoff coefficient of 7.47%. So that bamboo clumps have a positive correlation between clump density and rainfall [11]. Bamboo leaf drop effectively keeps the soil moist and reduces water evaporation from the ground. Bamboo leaf waste can hold 2.75 times more weight than its own dry weight. Bamboo leaves have high water retention capacity and can increase soil organic content [16]. The capacity to hold leaf waste water in bamboo forests with a mixture of species of *Phyllostachys pubescens* and *Cunninghamia lanceolata* reached 21.29 $t.hm^{-2}$, much higher if bamboo forests which only consisted of *Cunninghamia lanceolata* reached 7.37 $t.hm^{-2}$. *Dendrocalamus latiflorus* bamboo leaf waste with a density of 825 stems per hm^2 has a capacity of absorbing moisture from 2.7 to 2.9 times the dry weight [17]. The same conclusion regarding the capacity of bamboo leaves in moisture absorption has been produced by other researchers ([17], [18], [19], and [20]).

Erosion is one of the most severe types of soil degradation that threatens land productivity and causes loss of topsoil. Bamboo is one of the most effective in controlling erosion. Bamboo which is commonly used for erosion control is *Bambusa vulgaris* [14]; [21]. The advantages of bamboo are the extensive fabrication of root fibers, interconnected rhizomes and always produce new stems that allow harvest without damaging the soil, relatively dense leaf lush which protects soil from high rainfall [11]. For erosion control purposes, in Japan bamboo is planted in places that are prone to erosion. In southwest Japan, bamboo is planted in coastal areas overlooking the Pacific Ocean. Especially in Kagoshima prefecture bamboo functions as a protector of hilly erosion called "Karami" for erosion protection for more than 100 years [22]. *Sasa* and *Indocalamus* bamboo clumps are spread in the Hakoneyama mountainous region of Japan at an altitude of 1,000 meters above sea level. *Bambusa blumeana* and *Phyllostachys pubescens* in Brazil are used for erosion control, preventing loss of soil nutrients and improving soil structure [23]. About 90% of bamboo forests in China grow naturally upstream of rivers, lakes and along the banks of riverbanks. Of the total forest area, the contribution of bamboo forests in the Yangtse river basin is 5%, the Pear river valley is 4.5% and the Huaihe river valley is 2.5% [24]. On the Dayingjiang river in Yunnan province and on the Jiulongjian river in Fujian province, bamboo plants have succeeded in protecting riverbanks after tree planting efforts have failed to protect riverbanks. Bamboo forests are very important in the protection of riverbanks [14]; [25].

Most of the bamboo rhizomes and roots are at 0 - 30 cm from the ground so that the roots and rhizomes can function best in controlling soil erosion. Roots and rhizomes are shaped like woven mats so they are effective in protecting the soil. In this case the bamboo species that has been studied is *Phyllostachys pubescens* [26]; [27]; [28]; [29], *Pseudosasa amabilis* [30], *Phyllostachys praecox* [31]; [32], *Qiongzhuea tunfdoda* [7], *Phyllostachys makinoi* [15], *Phyllostachys bisetti* [40], *Dendrocalamus latiflorus* [33], *Dendrocalamus oldhami* [34] and *Bambusa tulda* [21]. Monopodial bamboo with creeping rhizomes, total length of rhizomes per 1 hectare of bamboo *Phyllostachys heterocycla*, *Phyllostachys viridis* and *Phyllostachys nigra* each from 50 - 170 km, 90 - 250 km and 200 - 320 km [35]. Sympodial bamboo root Bambusa tulda with short rhizomes can reach horizontal areas up to a distance of 5,2 meters. Roots and rhizomes though grow superficially but are horizontally widened [21].

In the past five decades, 1.2 billion hm^2 of land (11% of total earth vegetation) has been degraded and damaged by its original biotic function [36]. A quarter of land degradation is caused by humans (agricultural practices, excessive livestock grazing, deforestation, etc.) [37]. With dense leaf clumps, large amounts of biomass accumulation and abundant literfall, bamboo plays a major role in efforts to rehabilitate degraded land. In China, India and Thailand, bamboo agro-forestry models for degraded land have been developed [38].

The use of bamboo as an environmentally friendly construction material is very important to do. Stems in a bamboo clump at the age of 5-6 years can be harvested continuously without the need to plant again because the growth of bamboo shoots is fast growing. The rapid growth of bamboo is able to reduce the problems resulting from global warming on earth. Bamboo is a renewable natural resource that is the fastest growing and the fastest absorbing carbon in the air.

3. Problem Identification

At this time the timber with good quality has been difficult to obtain, so the wood is increasingly rare for buildingconstruction. To reduce deforestation due to logging for construction materials, it is time to replace wood with bamboo. Bamboo has a good strength when used properly for construction [39]. The tensile strength of bamboo parallel fibers without the nodia of the *Bambusa arundinaceace* skin much larger than the tensile strength of the reinforcing steel, and the tensile strength of the bamboo fiber in all the thickness of *Dendrocalamus asper* [40]. Tensile strength bamboo fiber ranging between (150 - 320) MPa, greater than the tensile strength of wood fibers ranges (34 - 220) MPa [41]. Parenchyma sell structures more dense with age bamboo, the bamboo optimum density occurs in 4 years old [42]. Describes the use of bamboo which is divided into a traditional bamboo (conventional) and bamboo engineering (experience the manufacturing process) [43].

Bamboo as a wood substitute material that is environmentally friendly, strength and stiffness needs further research. Abundant supply of bamboo is abundant, it is very effective and efficient because it doesn't require many personnel and conventional method used [38]. Bamboo as an environmentally friendly and renewable material, can influence the effects of global warming, maintain the sustainability of the green environment and make the earth a comfortable and friendly place for human life.

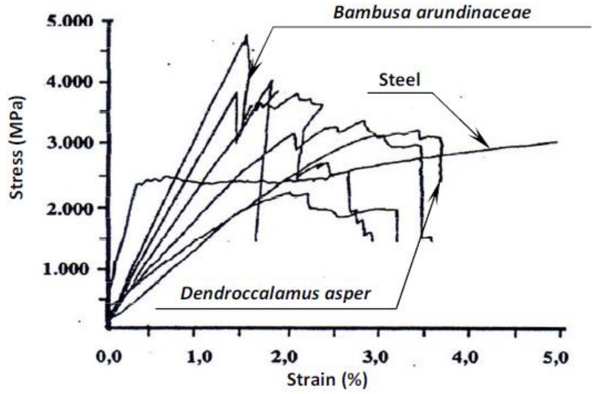


Fig 2. Bamboo Stress-Strain Graphic [40].

4. Objectives

The objective of this research to analyze the mechanical properties of bamboo so that it can know the strength and stiffness of bamboo material as a wood substitute construction material. In the construction process, bamboo material gets a pressure treatment especially on the connection, in the process of getting the desired geometric shape, in making laminated beams etc.

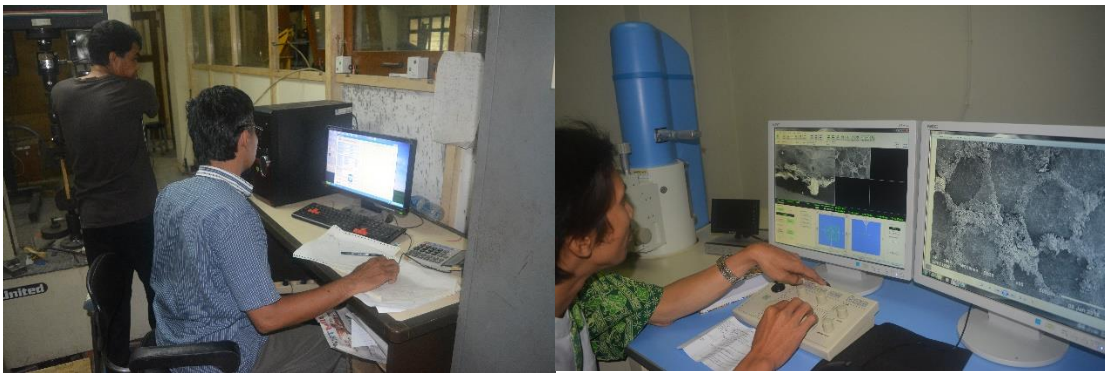
IOP Conf. Series: Materials Science and Engineering **535** (2019) 012001 doi:10.1088/1757-899X/535/1/012001

5. Method

Testing of bamboo mechanical properties based on ISO 3129-1975 standards, which includes testing of fiber parallel compressive strength, parallel fiber shear strength, fiber parallel tensile strength and straight fiber tagak flexural strength. Setting-up testing is carried out after each specimen in the condition of the kiln dry water content is in the range 12-13% according to the requirements of the ISO 3129-1975 standard. Adapaun specimens of specimens are as in Table 1. Testing of bamboo mechanical properties using UTM (Universal Testing Machine) and observation of changes in bamboo fiber was observed using a SEM (Scanning Electron Microscopy).

Table. 1. Mechanical Properties Testing of *Dendrocalamus asper* Specimen.

No.	Mechanical Properties of Specimen	Without Lateral Compression	With Lateral Compression		
			1,5 MPa	2 MPa	2,5 MPa
1	Compression Strength	10	10	10	10
2	Shear Strength	10	10	10	10
3	Tensile Strength	10	10	10	10
4	MoE	10	10	10	10



(a) (b)

Fig 3. Testing Mechanical Properties Bamboo Specimen use UTM (a) and SEM (b).

6. Result and Discussion

Tests for water content of specimens without minimal pressure were 5.47% and a maximum of 13.97% with an average of 12.95%. At a pressure of 1.5 MPa the water content is at least 6.80% and a maximum of 19.42% with an average of 12.81%. The amount of water at a pressure of 2 MPa is a minimum of 6.47% and a maximum of 16.48% with an average of 12.52%. Water content pressure of 2.5 MPa is a minimum of 8.39% and a maximum of 13.87% with an average water content of 12.43%.

The gravity of the specimen without pressure is a minimum of 0.56 gr / cm^3 and a maximum of 0.70 gr / cm^3 with an average of 0.64 gr / cm^3. At a pressure of 1.5 MPa the gravity value is a minimum of 0.66 gr / cm^3 and a maximum of 0.91 gr / cm^3 with an average of 0.73 gr / cm^3. The gravity value at a pressure of 2 MPa is a minimum of 0.62 gr / cm^3 and a maximum of 0.92 gr / cm^3 with an average value of 0.75 gr / cm^3. At a pressure of 2.5 MPa the gravity of bamboo is a minimum of 0.70 gr / cm^3 and a maximum of 0.93 gr / cm^3 with an average value of 0.78 gr / cm^3. The partial correlation of gravity with the pressure pressure variation is not significantly related. This is because pressure presses with 2.5 MPa have not damaged the structure of bamboo fibers.

The average MoE of bamboo without pressure is 152.10 MPa, the average MoE at a pressure of 1.5 MPa is 155.75 MPa, the average MoE at a pressure of 2 MPa is 157.62 MPa and the average MoE at a pressure of 2.5 MPa is 153.00 MPa. In the results of this test, the MoE of the bamboo with 2 MPa was higher than the other variations of pressing. The average MoE without pressure is 17955.77, the average MoE with a pressure of 1.5 MPa is 19586.85, the average MoE with a pressure of 2 MPa is 20055.53 and the MoE is mean with pressure 2.5 MPa is 19391.91. The highest MoE is seen at a pressure of 2 Mpa.

The average tensile strength parallel to the untapped bamboo fiber is 330.93 MPa, the average tensile strength parallel to the fiber at a pressure of 1.5 MPa is 343.84 MPa, the average tensile strength parallel to the fiber at a pressure of 2 MPa is 344.75 MPa and the average tensile strength parallel to the fiber at a pressure of 2.5 MPa are 328.21 MPa. From the results of tensile testing the highest average tensile strength was obtained at a pressure of 2 MPa. From the results of the correlation test, it was found that the tensile strength of the bamboo base on the pressure of the 1.5 felt was significantly correlated with the tensile strength of the bamboo material which was pressed at a pressure of 2.5 MPa. This is because at the pressure of the 2.5 MPa press the bamboo has begun to break down. At press pressure up to 2 MPa does not show a significant relationship because bamboo fiber has not been damaged.

The average shear strength without pressing is 7.55 MPa, the average shear strength at a pressure of 1.5 MPa is 7.66 MPa, the average shear strength at a pressure of 2 MPa is 7.76 MPa and the average shear strength at press pressure of 2.5 MPa is 6.71 MPa. From the test results, it was seen that the highest average shear strength at press pressure of 2 MPa. From the results of testing the partial correlation of shear strength with various variations of press pressure not significantly related. So that the pressure of the press does not affect the magnitude of the sliding bamboo blade. This is because the pressure of the press up to 2.5 MPa does not affect the shear strength parallel to the fiber.

The average compressive strength parallel to the bamboo fiber without pressing is 23.52 MPa, the average compressive strength parallel to the fiber at a pressure of 1.5 MPa is 25.04 MPa, the average compressive strength parallel to the fiber at a pressure of 2 MPa is 27.38 MPa and the average compressive strength parallel to the fiber with a pressure of 2.5 MPa are 27.82 MPa. From the results of these tests it was found that the more affected the pressure of the press higher the greater the compressive strength. From the results of the correlation test it was found that the compressive strength parallel to the fiber at a pressure of 2 MPa was significantly associated with compressive strength parallel to the fiber in the 2.5 MPa pressurization pressure. This is due to the fact that at the pressure of the 2.5 MPa bamboo fiber begins to experience compaction. In testing the perpendicular fiber strength, the highest compressive strength of the bamboo base material was subjected to a pressure of 2.5 Mpa.

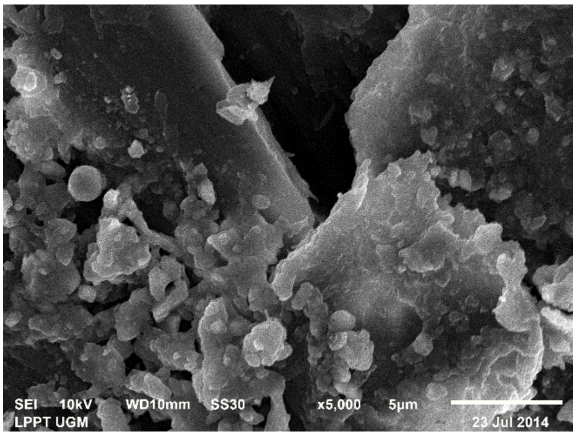


Fig. 4. SEM condition of bamboo fiber at a pressure of 2.5 MPa.

7. Conclusion

Analysis of variants (Anova) of pressure treatment on bamboo material has an effect on some of the mechanical properties of bamboo. Pressure treatments up to 2.5 MPa have a significant effect on the elastic modulus, tensile strength and shear strength of bamboo while the compressive strength is not significantly affected by the pressure treatment of bamboo material. This shows that the strength of the bamboo structure can be used as a substitute for wood construction material.

Bamboo forests have a big influence in reducing the impact of global warming and climate change. Bamboo can be used as an environmentally friendly material and reduce the use of wood as a construction material. Bamboo plants have the ability to cope with natural disasters and their significant ability to absorb carbon in the air gives the future a comfortable and healthy life.

8. References

[1] Gervet, B., 2007, *Deforestation Contributes to Global Warming*, Renewable Energy Research Group, Division of Architecture and Infrastructure, Lulea University of Technology, SE-97187 Lulea, Sweden.

[2] Venkataraman, M., Smitha, 2011, *Causes and Effects of Global Warming*, Indian Journal of Science and Technology, Vol. 4 issue 3, ISSN: 0974- 6846.

[3] Li, Z., Fu M., Xu, D., 2003,*Bamboo Ecosystem and Carbon Dioxide Sequestration*, Journal of Bamboo Research, 22(4): 1-6. (InChinese)

[4] Paulo, M., 2012, *Deforestation Around the World*, Intech, First published March, Croatia, ISBN 978-953-51-0417-9.

[5] Lessard, G., Chouinard, A., 1980, *Bamboo research in Asia*,In: Proceedingsof a workshop held in Singarpore, IDRC, Ottawa, Canada.

[6] United Nations, 1972,*The Use of Bamboo and Reeds in Building Construction*, New York: United Nations, pp 95.

[7] Anon, 1988,*The New Encyclopedia Britannica (Micropaedia)*, vol. 1. Encyclopedia Britannia Inc., Chicago, pp. 980.

[8] Wong, K.M., 1995,*The Bamboos of Peninsular MalaysiaForest*, Research Institute Malaysia (FRIM) in collaboration with Forest Research Center, Forestry Department, Sabah, Malaysia. Malayan Forest Records, No. 41.

[9] Atanda, 2015, *Environmental impacts of bamboo as a substitute constructional material in Nigeria*, Case Studies in Construction Materials, Case Studies in Construction Materials 3 pp. 33–39, Elsevier, journal homepage: www.elsevier.com/locate/cscm.

IOP Conf. Series: Materials Science and Engineering **535** (2019) 012001 doi:10.1088/1757-899X/535/1/012001

[10] Alfonso, D.J., 1987,*Let's plant bamboo*,Agribus, Wkly. 1 (19), pp. 25.
[11] Zhou, B., Fu, M., Xie, J., Yang, X., Li, Z., 2005, *Ecological functions of bamboo forest: Research and Application*, Journal of Forestry Research, 16(2): 143-147.
[12] Raka, I. D. N., Wiswasta, I. G. N. A., Budi asa, I. M., 2011, *PelestarianTanamanBambuSebagaiUapayaRehabilitasiLahan Dan Konservasi Tanah Di Daerah Sekitar Mata Air PadaLahan Marginal Di Bali Timur*,Agrimeta, JurnalPertanianBerbasisKeseimbanganEkosistem, Vol. 1, No. 1.
[13] Ghavami, K., (2008), *Bamboo: Low cost and energy saving construction materials,* Proceeding Bamboo Modern Structures, CRC Press, London.
[14] Anonymous, 1997, Healing Degraded Land, INBAR Magazine, 5(3):40-45.
[15] Wu, B., Xie, H., Tan, Shu., 1992,*Preliminary study on water conservation function of Phyllostachyspubescenscommunity*, Journal ofBamboo Research, 1i(4): i8-25. (In Chinese)
[16] Huang, K., Liang, D., Zeng, Z., 1994, Rhizome Distribution of *Phyllostachysmakinio*, Journal of Fujian Forestry College, 14(3): 191-194.(In Chinese).
[17] Chen, K., 2000, Study on Water Conservation Function of Mixed Forests ofChinese Fir and *Phyllostachyspubescens*, Journal of Fujian ForestryCollege, 20(3): 258-261. (In Chinese).
[18] Zheng, Y., Yang, L., 1995,*Hydrologic Effect of Mixed Stands of Cunninghamialanceolata and PhyllostachyspubescensForests*, Journalof Fujian Forestry College, 13(3): 18-22. (In Chinese)
[19] Zeng, L.,Ren, P., Li, Z., 1998, Observation of Biological Characteristicsof *Phyllostachysniduluria*, Economic Forest Research, 16(4):9-11. (In Chinese).
[20] Lin, H., 2002, *Studies on Water Conservation Function of Phyllostachysmakinoiand FokieniahodginsiiMixed Forests*, Fujian Forestry Sci &Tech, 29(3): 18-22. (In Chinese)
[21] White, D. G, Childers, N. E., 1945,*Bamboo for Erosion Control*, J.American Society of Agronomy, 37: 839-847.
[22] Shibata, S., Iwanaga, Y., Kamimura, K., 2002,*Revegetation of Roadside Manmade Slopes with Karami Fencing and by Burying Bambusa multiplexRaeushel Culms*, In: Lou, Y., (ed) Bamboo in disaster avoidance, Beijing: INBAR, 3-11.
[23] Fu Maoyi., Xiao Jianghua., Lou Yiping., 2000,*Cultivation and Utilization on Bamboo*, Beijing: China Forestry Publishing House.
[24] Li, Y., 1998, *Current Status and Prospects of Bamboo Resources in China*, Workshop of developing bamboo and rattan, Beijing, INBAR.
[25] Dong, W., Huang, B., Xie, Z., 2002,*Study on The Pattern of Rhizome Growth of Qiongzhueatumidinodaclone*, Journal of BambooResearch, 21(4): 56-60. (In Chinese).
[26] Xiao, J., 1983, *Subterranean Structure of Timber Bamboo Forest*, Bamboo Research, 2(1): 114-119. (In Chinese).
[27] Wu, B., 1984, *Subterranean Structure and Production Analysis of Moso Bamboo Forest,* Journal of Bamboo Research, 3(1): 49-58. (In Chinese).
[28] Zhou, J., Hu, C., Yang,L., 1985,*Investigation of Rhizomes of Shoot-Oriented High-Yield Bamboo Forest*, Journal of Bamboo Research, 4(1): 57455. (In Chinese).
[29] Wang, K., He, Q., Weng, P., 2000,*Investigation and Analysis on Underground Rhizome and Root System of Phyllostacyspubescensfor Shoot and Timber*, Journal of Bamboo Research, 19(1): 38-43. (In Chinese).
[30] Chen, D., 2002,*Study on The Bamboo Rhizome Growth of PseudosasaamabilisMcCl*, Journal of Bamboo Research, 21(2): 48-53. (In Chinese).
[31] He, J., Fang, W., Lu, X., 1995,*Subterranean Structure of High-Yield and High Effective PhyllostachyspraeconForest for Shoot and Timber*, Journal of Zhejiang Forestry College, 12(3): 247-252. (In Chinese).
[32] Hu, C., Jin, A., Zheng, J., 1994,*Systematic Structure of PhillostachyspraeconRhizome*, Journal of Zhejiang Forestry College, 11(3):264-268. (In Chinese).
[33] Lin, Y., Li, H., Lin P.,2000,*Biomass Structure and Energy Distribution of DendrocalamuslatiflorusPopulation*, Journal of BambooResearch, 19(4): 36-41. (In Chinese).

IOP Conf. Series: Materials Science and Engineering **535** (2019) 012001 doi:10.1088/1757-899X/535/1/012001

[34] Lin, Y., Lin, P., Ye, Y., 1998,*Biomass and Structure of Dendrocalamopsisoldhami Population*, Journal of Bamboo Research, 17(2):9-13. (In Chinese).
[35] Xiao, J., 2002,*Pay More Attention to Ecological Benefits of Bamboo Forests*, In: Lou, Y. (ed.), Bamboo in disaster avoidance, Beijing: INBAR, 49450.
[36] Oldeman, L., R., 1990,*World Map of the Status of Human-Induced Soil Degradation*, Wageningen, Netherlands: International Soil Reference and InformationCenter.
[37] UNEP, 1992,*The World Environment 1972-1992 - Two Decades of Challenge*, London: Chapman and Hall.
[38] Hermanto, N. I. S., Eratodi, I. G. L. B., Masdar, A., Morisco, 2010, *PemanfaatanBambuSebagai Material PilihanPadaStrukturBambu Modern*, ProsidingKonferensi Nasional Teknik Sipil 4 (KoNTekS 4), Sanur-Bali, 2-3 Juni 2010.
[39] Yasin, I., Priyosulistyo, H., Siswosukarto, S., Saputra, A., 2015, *The Effect of Variable Lateral Stress of Laminated Bamboo with Artificially Dent Surface on Mechanical Properties*, International Journal of Civil and Structural Engineering– IJCSE, Volume 2 : Issue 2, ISSN : 2372-3971.
[40] Morisco, 2006,*Teknologi Bambu.*Departement of Civil Engingeering and Enviromental, Gadjah Mada University, Yogyakarta.
[41] Ghavami, K., 2005, *Bamboo as Reinforcement in Structural Concrete Elements*, Cement & Concrete Composites, 27 pages 637–649.
[42] Li, S.H., Zeng, Q.Y., Xiao, Y.L., Fu, S.Y. and Zhou, B.L., 1995, *Biomimicry of Bamboo Bast Fiber with Engineering Composite Materials*, Materials Science and Engineering, C3 pages125-130
[43] Xiaohong, G. and Yulong, D., 2005, *Bamboo Science and Culture*, The Journal of the American Bamboo Society,19(1) pp. 16-22.