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Mechanical Characterization of Composite Material as an Alternative for Partition Wall of Ethiopian Housing

Samueal Tadesse Ashagrie, Fissaha Alem Aregawi

Department of Mechanical Engineering, Aksum University, Aksum, Ethiopia

Email address:
samuealtadesse3@gmail.com (S. T. Ashagrie), fissaha100@gmail.com (F. A. Aregawi)

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Abstract: The present study, has been used both banana and Enset *(Enset eventricosum)* fiber for manufacturing the composite material used for partition wall. Enset is an indigenous natural fiber abundantly available in Ethiopia. Samples made of Enset and banana fibers for the test were collected from Jimma region and prepared by taking different fiber orientation and thickness as principal parameters. Then three mechanical tests were performed (i.e. tensile test, flexural test and compressive test). The tensile tests were performed for four samples of different thickness (i.e. 2mm, 4mm, 6mm and 8mm) with various fiber orientations using different matrixes (i.e. gypsum. *CM-43* and *Vinyl ester)*. For the flexural and compressive tests four samples of different thicknesses (i.e. 8mm, 10mm, 12mm and 14mm) for each orientation were prepared and tested by using gypsum as a matrix material. It was observed that the results obtained were fairly acceptable and closely equivalent to the existing partition wall of a house. In this study Taguchi experimental method was used for the optimization and realization of the experimental results.

Keywords: Natural Fiber Composite, Mechanical Characterization, Enset Eventricosum

1. Introduction

In today's modern world the need of efficient and effective engineering material have led to make extensive research and development of new and improved material, for instance the use of composite material, for advanced applications such as automotive body, aircraft and aerospace structures and for ordinary applications like consumer goods, furniture, low-cost housing and civil structures, are the listed one. [15]

Reinforcement provides strength and rigidity to support the structural load. Natural fibers composite are adequate for many structural purposes. Lack of study towards the mechanical properties of natural fiber limits its use. [10] In Ethiopia Enset is abundantly cultivated. Enset fiber can be easily obtained from pseudo stem after the utilization of the flush part for food.

Beside of those advantages, focusing in this area has also economic benefits to improve the agricultural sector of developing country, like Ethiopia. Ethiopia is the second most populous country in the African continent; about 94 millions of peoples are alive in 1.13 million km of land area and from this around 80% of total populations are sustained from agricultural sector. [7] Therefore focusing in natural fiber composite field indirectly creates economic benefit to millions of Ethiopian people.

Partition a house with a strong and cheap material is every ones issue. Most of the partition walls of Ethiopian houses are made up of stone, corrugated metal sheet, soil, concrete plastic material. The advanced knowledge about natural fiber's mechanical and microstructural properties will help the production of new products and applications. The focus of this thesis is to make an alternative partition wall for Ethiopian houses using natural fiber reinforced composite materials.

Figure 1. *Enset plant.*

In this work, a critical review on the characterizations of natural fiber (mainly, Enset and banana fibers) with vinyl and Gypsum as matrix has been presented .

2. Material and Methods

Material

Materials used in experimental work:-Both Enset and Banana Fiber, Matrix (vinyl ester, CM43 and Gypsum), for preparing pattern use wood, wood cutter, water, brush, and paint are used. And finally for testing use ASTM (M500-50KN).

Methods

First remove the dust and hard surfaces from the fiber then Prepare the composite lamina by hand lay method. Then prepare the specimen as conform to ASTM standards.

2.1. Fiber

Enset and banana fibers were collected and processed manually from Jimma, Ethiopia. The fibers were dried for 72 hour in sunlight to remove the moisture.

Figure 2. *Enset and banana fibers.*

2.2. Matrix

Vinyl ester (wood fix) from ABAY PAINTS, CM-43 from CARMYCO S. A. and gypsum from Yulong Technology L. C resin is obtained for this study.

Figure 3. *Wood fix and carmyfix.*

3. Preparation of the Composite

The composite are manufactured by hand lay–up technique. The mould used for manufacturing the composite is made up of Wood with debonding agent applied on the inner side. The inner cavity dimension of the mould is 200mm*300mm*14mm. the fiber is dipped in the resin and aligned in the mould where the resin is also poured. The fiber is set as constant to 20%. The upper side is pressed using a roller under room temperature until the matrix is set properly. The setup is left to cure for 24 hours at room temperature. Then the prepared composites were cut for Testing conform to the dimensions of the specimen as per ASTM standards.

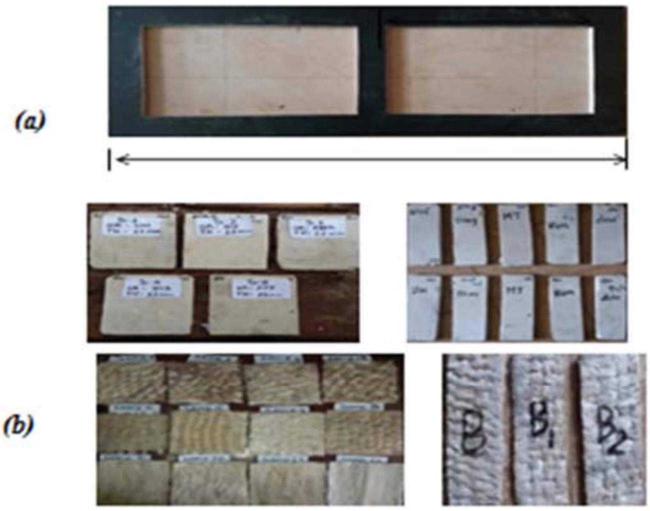

Figure 4. *(a) mold (b) prepared composites and the specimen.*

3.1. Tensile Test

Figure 5 shows the specimens prepared for tensile test. The specimens are prepared with unidirectional (longitudinal and transverse loading), mat or weave and diagonal fiber orientation. [8] The testing is done using ASTM to measure the force required to break a polymer composite spacemen and the extent to which the specimen stretches or elongates to that braking point. The testing was done in standard laboratory atmosphere of 25°C.

Figure 5. *Tensile test specimens with different orientation.*

Universal Testing Machine (M500-50KN) was used at cross-head speed of 50 mm/minute.

Figure 6. *Test specimens and ASTM (M500-50KN) for tensile testing.*

3.2. Flexural Test

Flexural strength is defined as a material ability to resist deformation under load. It is a 3-point bend test, which generally promotes failure by inter-laminar shear. [8] The test is conducted as per ASTM standard using ASTM (M500-50KN).

Figure 7. *Flexural test specimen.*

3.3 compressive test

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate. [8]

Compressive strength can be measured by plotting applied force against deformation in a testing machine, such as a universal testing machine.

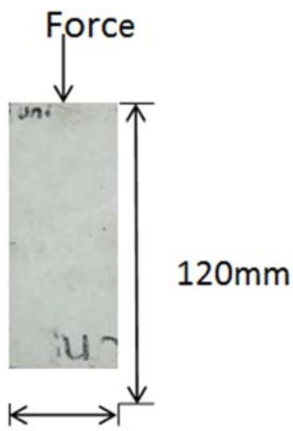

Figure 8. *Specimens for compressive test.*

3.4. Design of Experiments Via Taguchi Method

Taguchi's philosophy is an efficient tool for the design of high quality manufacturing system. Dr. Genichi Taguchi, a Japanese quality management consultant, has developed a method based on orthogonal array experiments, which provides much-reduced variance for the experiment with optimum setting of process control parameters. Thus the integration of design of experiments (DOE) with parametric optimization of process to obtain desired results is achieved in the Taguchi method. The S/N ratio takes both the mean and the variability into account.

The S/N ratio is the ratio of the mean (signal) to the standard deviation (noise). [16] The ratio depends on the quality characteristics of the product/process to be optimized; The Taguchi experimental method was used to optimize the tests carried out based on the experimental parameters. The following tables show the factors used for the tensile, flexural and compressive tests.

Table 1. *Factors used for the tensile, flexural and compressive tests.*

FACTORS	VALUE OR TYPE			
1. Orientation	vertical	Horizontal	Weaving or mat	twill weaving or diagonal
2. Thickness	2	4	6	8
3. Fiber type	banana	Enset		
4. Matrix	vinyl	Carmyfix		

4. Results and Discussions

The experimental result by using Taguchi method and significant parameters affecting the result has been identified and discussions are presented here.

4.1. Tensile Tests

The tensile test result using tensile test machines (M500-50KN) shows that Enset fiber has better mechanical properties compared to banana fiber composites, Compared to banana fiber composites. The stress strain diagram for the composite material initial rises in linear regression.

The following graph and table shows overall mechanical properties of the composite depending on the experimental parameters.

4.1.1. Unidirectional Orientation with Longitudinal Loading

Table 2. *Unidirectional orientation with longitudinal loading.*

No	Factors					Tensile test parameters			
	orientation			Matrix type	Fiber type	Young's moduls in (Mpa)	Ultimate tensile strength (M	Strain at peak (%)	Load at peak (N)
1	Unidirectional	Longitudinal force	2	Wood fix	banana	290.7	20.06	6.9	910.2
					Enset	470.9	19.78	4.12	923.7
				CR	banana	344.15	19.96	5.8	918.2
					Enset	285.77	20.29	7.13	933.7
			4	Wood fix	banana	387.3	14.36	3.7	1318.6
					Enset	343.9	14.78	4.3	1360.6
				CR	banana	254.1	14.48	5.7	1332.6
					Enset	255.3	15.81	6.2	1454.6
			6	Wood fix	banana	218.4	9.17	4.2	1266.3
					Enset	228.2	11.2	4.9	1343.2
				CR	banana	219.5	9.27	5.1	1270.6
					Enset	240.3	12.5	5.2	1423.4
			8	Wood fix	banana	89.5	10.54	7.2	1234.4
					Enset	175.5	11.05	6.3	1652.2
				CR	banana	136.9	10.54	7.2	1402.3
					Enset	145.6	11.5	8.4	1520.3

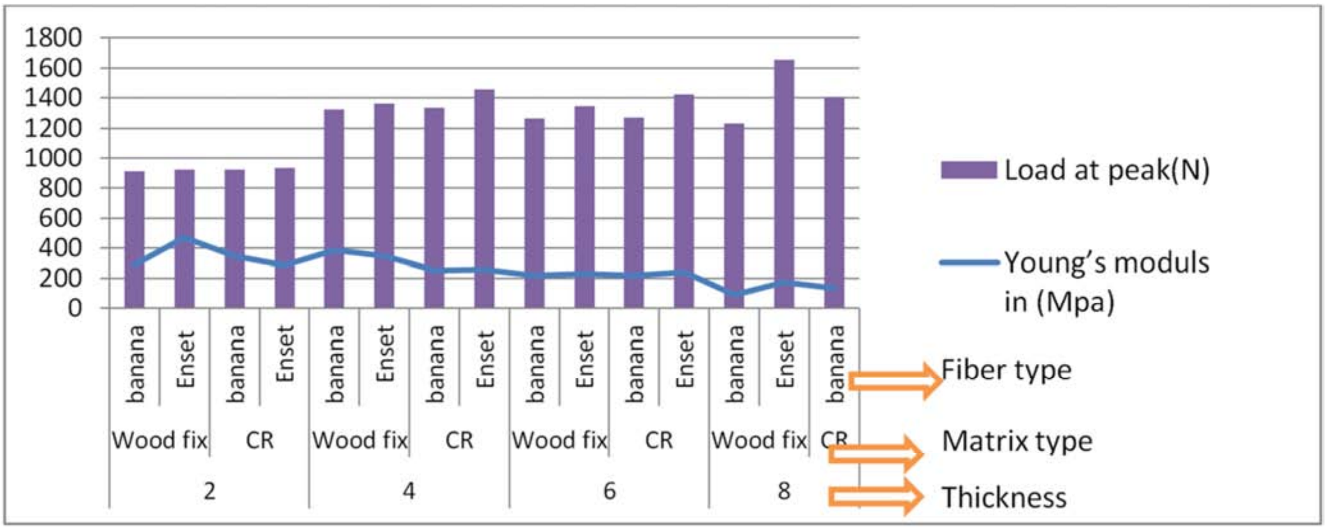

Figure 9. *Unidirectional orientations with longitudinal loading.*

4.1.2. Unidirectional Orientation with Transverse Lading

Table 3. *Unidirectional orientation with transverse lading.*

	Factors					Tensile test parameters			
	Orientation			Matrix type	Fiber type	Young's moduls in (Mpa)	Ultimate tensile strength (Mpa)	Strain at peak (%)	Load at peak (N)
1	unidirectional	Transverse loading	2	Wood fix	banana	3.96	0.66	21.4	39.6
					Enset	3.32	0.638	19.2	38.3
				CR	banana	2.69	0.52	19.3	63.4
					Enset	3.18	0.6	21.2	40.2
			4	Wood fix	banana	2.52	0.57	22.6	68.4
					Enset	2.58	0.551	21.3	66.2
				CR	banana	2.67	0.51	19.1	92.6
					Enset	2.69	0.602	20.3	72.3
			6	Wood fix	banana	2.67	0.51	19.1	92.6
					Enset	2.62	0.535	20.4	96.4
				CR	banana	2.63	0.54	20.8	97.9
					Enset	2.68	0.601	22.4	108.6
			8	Wood fix	banana	3.17	0.58	18.3	139.6
					Enset	4.12	0.966	23.4	132.3
				CR	banana	3.33	0.62	19.2	150.4
					Enset	3.75	1.062	26.3	156.3

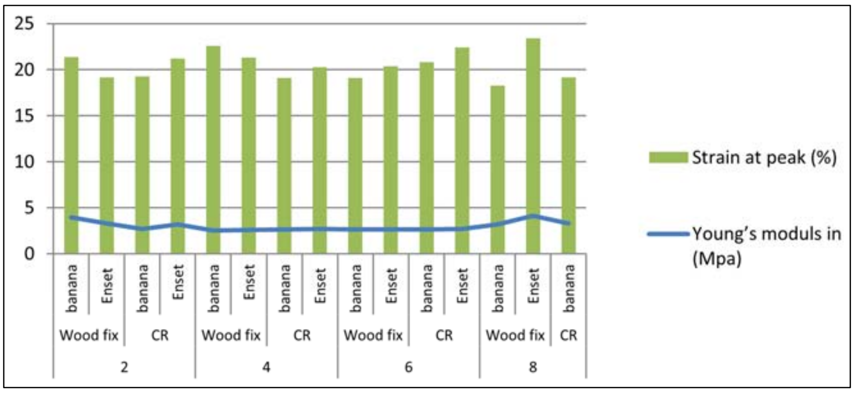

Figure 10. *Unidirectional orientation with transverse lading.*

4.1.3. Mat or Weave Shape of Fiber Orientation with Tensile Loading

Table 4. *Mat or weave shape of fiber orientation.*

	Factors				Tensile test parameters			
	Orientation		Matrix type	Fiber type	Young's moduls in (Mpa)	Ultimate tensile strength (M)	Strain at peak (%)	Load at peak (N)
2	Mat or weave	2	Wood fix	banana	173.8	7.32	3.8	609.1
				Enset	166.25	7.98	4.2	628.4
			CR	banana	183.8	7.72	4.8	629.1
				Enset	194.13	8.15	4.2	638.4
		4	Wood fix	banana	146.3	5.7	3.9	913.2
				Enset	170.3	5.8	3.4	926.4
			CR	banana	109.8	5.6	5.1	896.2
				Enset	101.7	4.68	4.67	1123.6
		6	Wood fix	banana	109.9	4.62	4.2	1108.4
				Enset	115.3	4.59	5.8	1102.4
			CR	banana	134	8.31	6.2	1994.2
				Enset	76.5	4.28	5.06	1370.8
		8	Wood fix	banana	72.56	4.22	5.8	1352.3
				Enset	91.8	4.16	4.6	1351.9
			CR	banana	58.73	4.17	7.1	1334.5
				Enset	91.8	4.16	4.6	1351.4

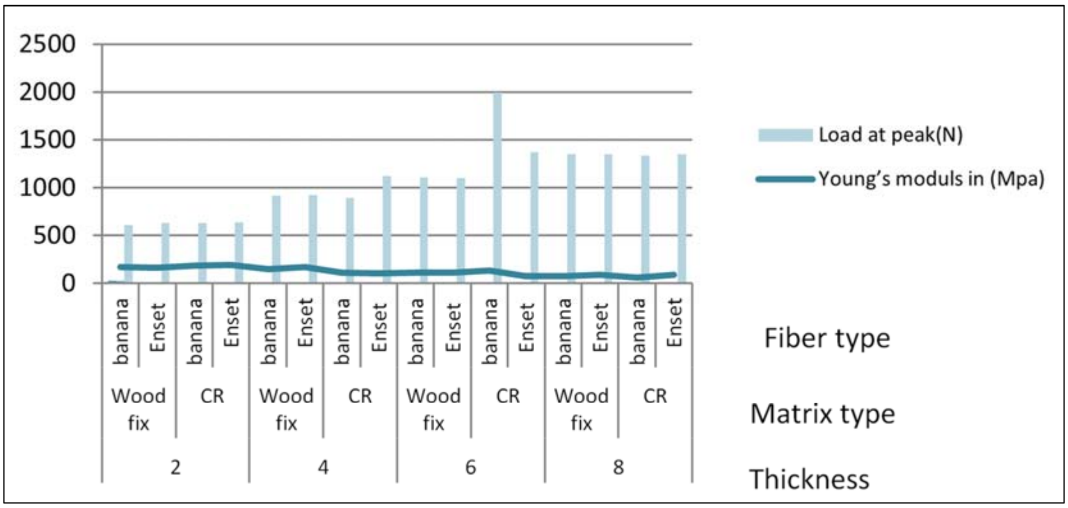

Figure 11. *Mat or weave shape of fiber orientation.*

4.1.4. Diagonal Shape of Fiber Orientation with Tensile Loading

Table 5. *Diagonal shape of fiber orientation.*

No	Factors				Tensile test parameters			
	Orientation		Matrix type	Fiber type	Young's moduls in (Mpa)	Ultimate tensile strength	Strain at peak (%)	Load at peak (N)
3	diagonal	2	Wood fix	banana	125.17	4.5	3.6	288.4
				Enset	112.46	4.72	4.2	302.3
			CR	banana	112.4	4.2	4.2	302.2
				Enset	105.2	5.05	4.8	323.3
		4	Wood fix	banana	75.15	3.18	4.2	406.8
				Enset	62.6	3.38	5.4	433.4
			CR	banana	66.6	3.2	4.8	421.4
				Enset	67.09	3.48	5.2	446
		6	Wood fix	banana	113.57	3.29	2.9	632.4
				Enset	56.05	3.53	6.3	678.4
			CR	banana	65.32	3.39	5.2	652.2
				Enset	53	3.6	6.8	692.2
		8	Wood fix	banana	88.9	3.11	3.5	796.06
				Enset	50.6	3.047	6.08	780.2
			CR	banana	75.3	3.18	4.3	814.3
				Enset	42.5	3.14	7.4	806.4

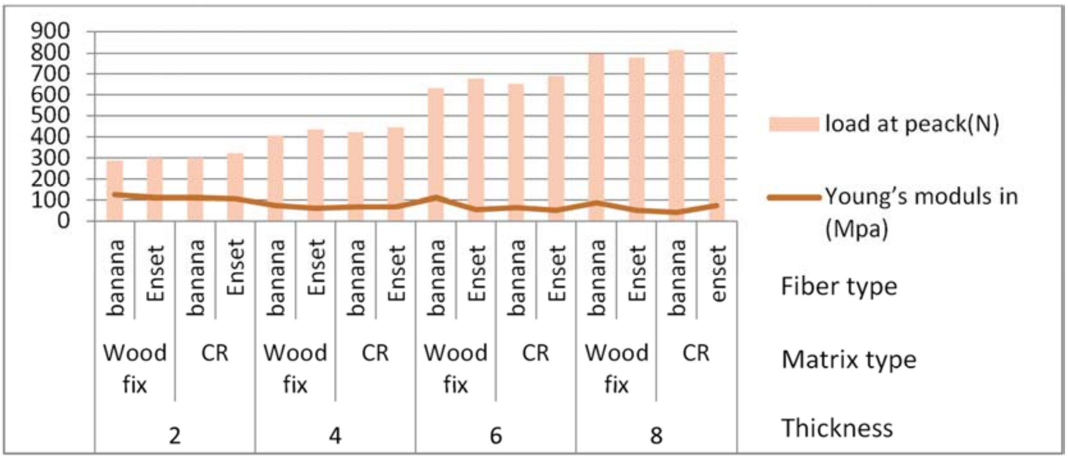

Figure 12. *Diagonal shape of fiber orientation.*

4.2. Flexural or Bending Tests

The flexural strength of the composite varies due to the experimental parameters. The flexural strength and the overall mechanical properties of the composite were shown below.

Table 6. *Flexural or bending tests.*

Factors	Bending test					
	Thickness	Cross-section area mm	Fiber type	Peak load, N	3pt bend stress at peak Mpa	3pt bend deflection at yield in mm
Unidirectional	8	320	Banana	4.9	0.0025	6.2
			Enset	6.2	0.0028	6.4
	10	400	Banana	10.4	0.0029	6.8
			Enset	11.2	0.0031	6.9
	12	480	Banana	19.3	0.0036	6.8
			Enset	21.2	0.0037	6.7
	14	560	Banana	37.32	0.0041	6.5
			Enset	39.9	0.0042	6.4
Mat shape	8	320	Banana	22.6	0.0168	2.01
			Enset	26.2	0.0171	4.3
	10	400	Banana	41.4	0.0174	3.21
			Enset	48.4	0.0179	6.32
	12	480	Banana	83.2	0.0181	5.42
			Enset	96.2	0.0186	8.28
	14	560	Banana	164.4	0.0189	7.62
			Enset	173.3	0.0193	9.78
Diagonal	8	320	Banana	16.3	0.0081	2.9
			Enset	18.4	0.0077	3.7
	10	400	Banana	28.27	0.0087	2.5
			Enset	30.26	0.0089	2.7
	12	480	Banana	58.4	0.0093	2.2
			Enset	64.3	0.0093	2.4
	14	560	Banana	118.3	0.012	1.9
			Enset	123.3	0.011	2.21
Random	8	320	Banana	76.4	0.00245	4.6
			Enset	69.2	0.00132	3.2
	10	400	Banana	72.25	0.0031	4.9
			Enset	86.5	0.0049	5.1
	12	480	Banana	84.6	0.0071	5.6
			Enset	99.8	0.00966	5.3
	14	560	Banana	94.6	0.00988	6.8
			Enset	105.4	0.00193	6.2

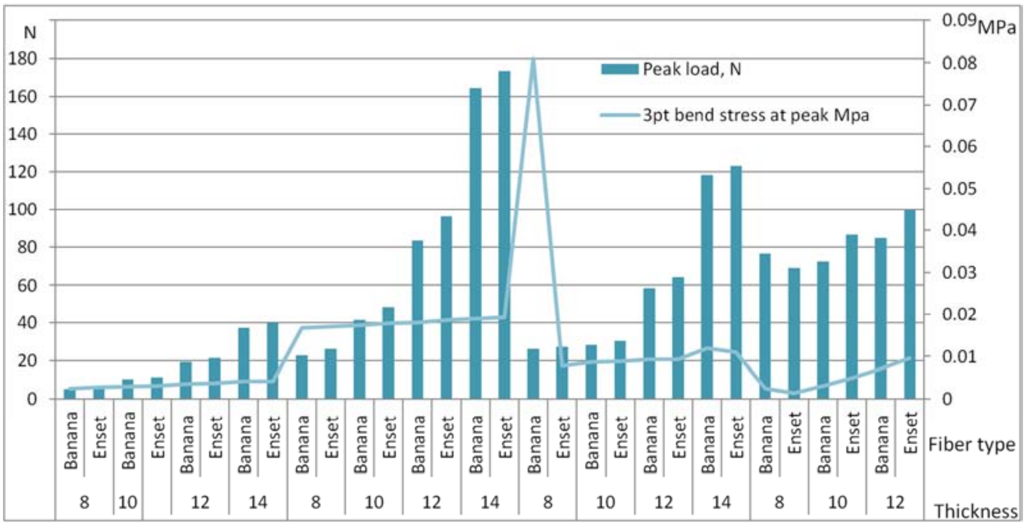

Figure 13. *Flexural or bending tests.*

4.3. Compressive Test

The mechanical properties obtained by compressive test using ASTM universal testing machine (M500-50KN) were tabulated bellow.

Table 7. *Compressive test.*

				Bending test		
		Cross-section area mm	**Fiber type**	**Peak load, N**	**Stress at peak Mpa**	**Deflection at yield in mm**
Unidirectional	8	320	Banana	706	2.2	3.8
			Enset	732.6	2.3	4.2
	10	400	Banana	1375.6	3.44	4.6
			Enset	1412.5	3.5	4.8
	12	480	Banana	2678.5	4.2	3.6
			Enset	2773.3	5.77	5.2
	14	560	Banana	4345.16	7.76	3.9
			Enset	4446.2	0.0044	3.107
Mat shape	8	320	Banana	620	1.93	3.34
			Enset	640.4	2.4	4.6
	10	400	Banana	1116.3	2.78	2.92
			Enset	1273.75	3.18	3.8
	12	480	Banana	2432.2	5.06	3.06
			Enset	2547.5	5.45.	3.3
	14	560	Banana	5095.5	9.12	2.9
			Enset	6120	9.14	3.1
Diagonal	8	320	Banana	230.2	0.95	2.01
			Enset	318.2	0.93	4.8
	10	400	Banana	518.2	1.5	2.4
			Enset	605.2	2.48	3.2
	12	480	Banana	1082.4	3.52	2.6
			Enset	1384	3.52	3.3
	14	560	Banana	2143	3.82	3.4
			Enset	2388.3	3.96	2.5
Random	8	320	Banana	288	0.9	4.6
			Enset	329.1	1.02	4.2
	10	400	Banana	520.6	1.3	4.3
			Enset	655.4	1.63	3.9
	12	480	Banana	1260.3	2.62	3.8
			Enset	1306.3	2.72	3.7
	14	560	Banana	1625.8	4.53	3.8
			Enset	2608.1	4.72	3.5

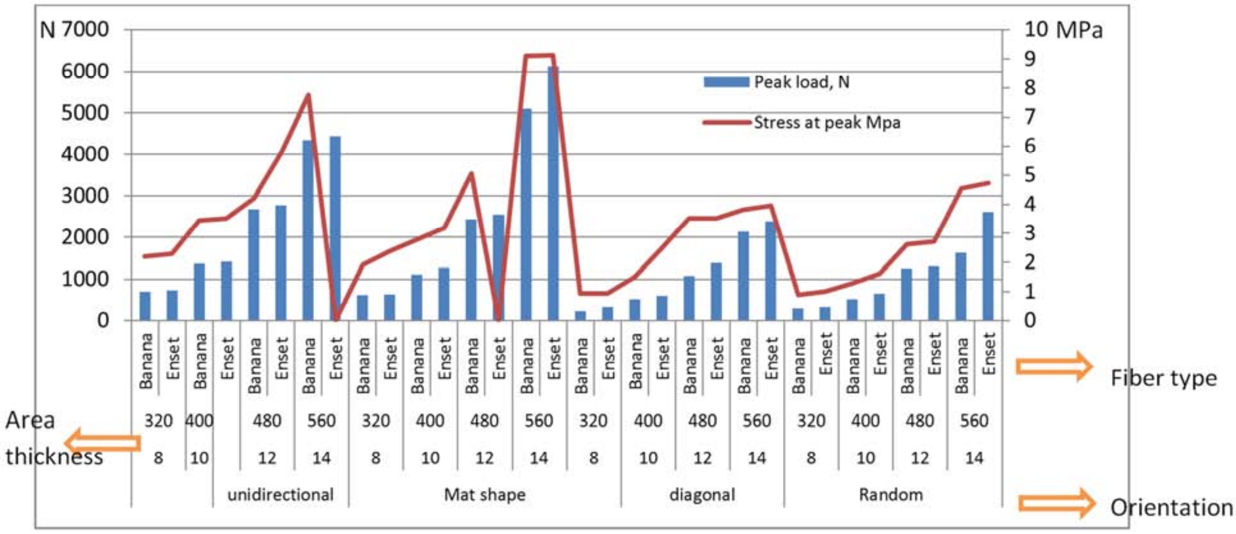

Figure 14. *Compressive test.*

4.4. Taguchi Experimental Results

Figure 15 shows graphically the effect of the four control factors on the composite result. The analysis is made using the popular software specifically used for design of experiment application known as MINITAB 18. Before any attempt is made to use this simple model as a predictor for the measures of performance, the possible interaction between the control factors must be considered. Thus factorial design incorporates a simple means of testing for the presence of the interaction effects.

4.4.1. Taguchi Tensile Test Results

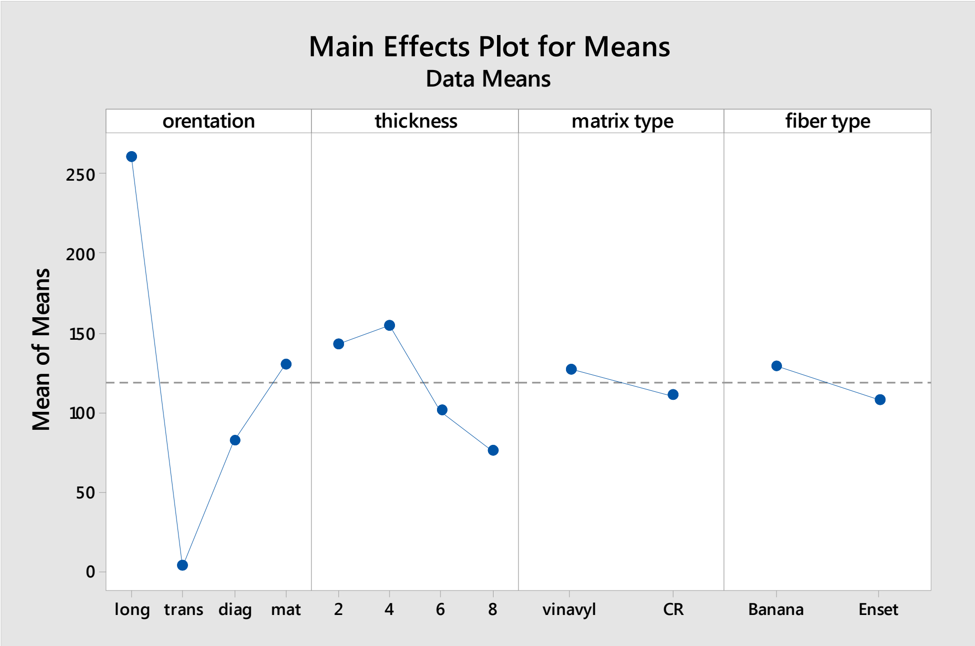

Figure 15. *Taguchi tensile test results for the main effects.*

4.4.2. Taguchi Flexural Test Result

Taguchi flexural test results for the main effects were summarized using the following graphs

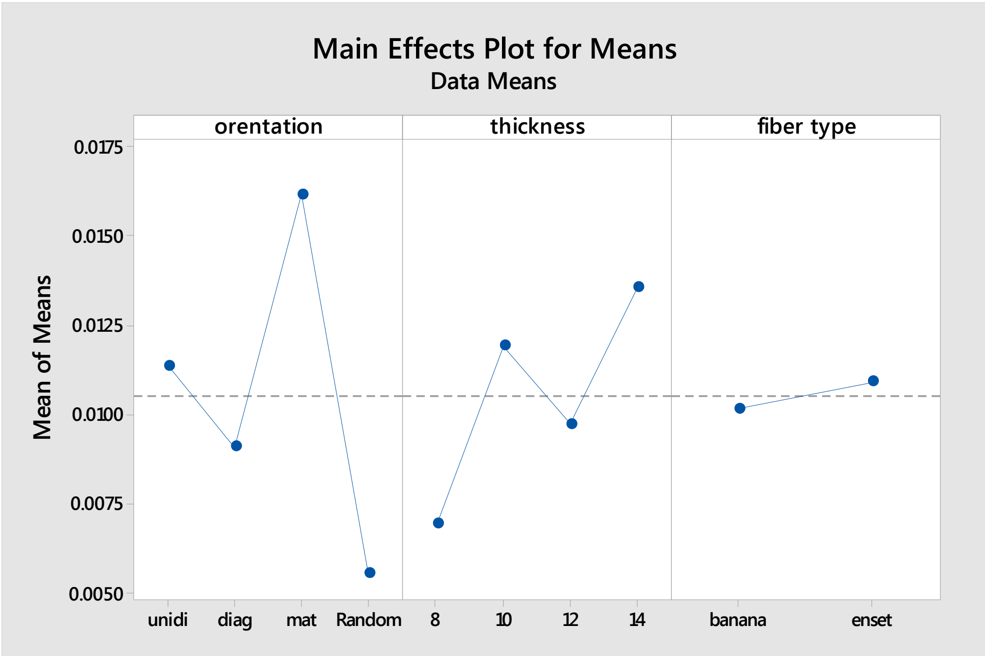

Figure 16. *Taguchi flexural test results for the main effects.*

4.4.3. Taguchi Compressive Test Result

Taguchi experimental results for compressive test were summarizes using the following graphs.

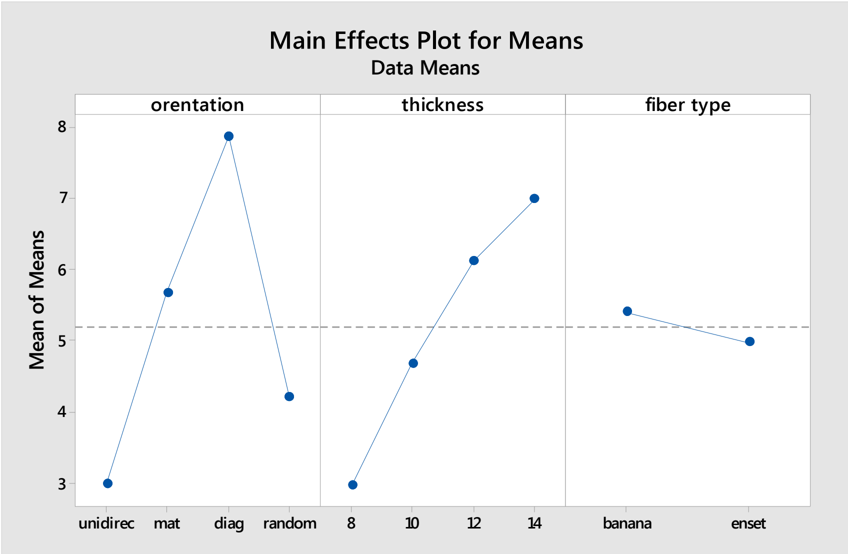

Figure 17. *Minitab DOE analysis for compressive test.*

5. Conclusions

The use of Enset fibers from naturally growing Enset plants as reinforcement in composites reduces cost and increases bio-degradability of the products hence to reduce environmental pollution

The results of this present study showed that a useful composite with good properties could be successfully developed using Enset fiber as reinforcing agent.

The results also indicate that, fiber orientation, matrix type, fiber thickness are the significant factors in determining the mechanical properties of composite using Enset as reinforcing material.

It is observed that Enset has better mechanical properties such as tensile strength, flexural strength and compressive strength compared to banana fiber.

The effect of parameters on the composites property can be successfully analyzed using Taguchi experimental design scheme. Taguchi method provides not only needs engineering judgment but also requires a rigorous mathematical model to obtain optimal process settings. From this orientation of fiber in composite is highly affecting the mechanical properties of composite.

Beside of that, the work will be extended to study other properties such as effect of fiber length, creep, fatigue, shear strength, chemical resistance and microstructure characterization.

Appropriate matrix/resin with better property such as resistance to high temperature, fire and water absorption should be used for the realization of natural fibers as partition wall. Gypsum can be the best candidates having the above mentioned property

References

[1] A. N. Shah, S. C. Lakkad Mechanical properties of jute-reinforced plastics. (1981).

[2] Agrawal, R., Saxena, N. S., Sharma, K. B., Thomas, S., Sreekala, M. S. Activation energy and crystallization kinetics of untreated and treated oil palm fiber reinforced phenol formaldehyde composites. Mater. Sci. ENG., A277 (1-2), 77-82. (2000).

[3] Agrawal R., Saxena N. S., Sharma K. B Thomas S. &. Sreekala M. S, Mater. Sci. Eng. A, (2000), Alger, M. S. M. Polymer Science Dictionary. 2nd: Chapman and Hall (1996).

[4] Bekele E, Shigeta M. Phylogenetic relationships between Ensete and Musa species as revealed by the trnTtrnF region. Genetic Resources and Crop Evolution 58:259– 269. (2011).

[5] J. santhosh, Study of properties of banana fiber renforced composites (2004).

[6] Birmeta, G. Genetic Variability and Biotechnological Studies for the Conservation and Improvement of Enset ventricosum. Doctoral thesis ISSN 1401-6249, ISBN 91-576-67810 (2004.).

[7] Birmeta, G., Nybom, H. and Bekele, E.. Distinction between wild and cultivated enset (Enseteventricosum) gene pools in Ethiopia using RAPD markers-heredities 140: 139-148. Lund, Sweden. ISSN 0018-0661. (2004).

[8] Dheeraj Kumar. Mechanical Characterization of Treated Bamboo Natural Fiber Composite. International Journals of Advanced Mechanical Engineering ISSN 2250-3234 Volume 4, Number 5 (2014).

[9] Drzal, L. T., Mohanty, A. K., Burgueño, R. and Misra, M. Bio based Structural Composite Materials for Housing and Infrastructure Applications: opportunities and Challenges. Composite Science and Technology. (2003).

[10] Ekhlas Aboud Osman Al-BahadlyA thesis submitted for the degree of Doctor of Philosophy, Faculty of Engineering Swinburne University of Technology (2013).

[11] Herakovich C. T., Mechanics of fibrous composites. New York: Wiley; (1998). http://www.jmaterenvironsci.com.

[12] Joseph P. V, Kuruvilla Joseph, Sabu Thomas, Effect of processing variables on the mechanical properties of sisal-fiber-reinforced polypropylene composites, Composites Science and Technology (1999).

[13] J. santhosh, Study of properties of banana fiber renforced composites (2004).

[14] Rong, M. J., Zhang M. Q., Liu, Y., Yang, G. C., Zeng, H. M. The effect of fibre treatment on the mechanical properties of unidirectional sisal-reinforced epoxy composites. Composites Science and Technology, 61:1337-1447. (2001).

[15] Termonia, Y. Tensile strength of discontinuous fiber-reinforced Composites. Material Science, (1990).

[16] Young R., Rowell R., Shulz T. P. & Narayan RA. ctivation and Characterization of Fiber Surfaces for Composites in Emerging Technologies for Materials and Chemicals from Biomass, Eds., American Chemical Society, pag. 115 Washington D. C. (1992).