Development of Particle Boards from Vetiver Grass

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Abstract

The research was intended to investigate the physical and mechanical properties in the making of the particle board from vetiver grass and suitable adhesives by utilizing locally available materials. Three different adhesives having different content were experimentally investigated to determine the optimum mix proportion for the making of vetiver grass boards. The adhesives used for this research were namely urea formaldehyde, polyvinyl acetate, and corn starch. The vetiver grass was cut into short length of 20 mm and 30 mm, and was used as fibers in the making of the boards. The fabrication of these vetiver grass boards was done by mixing vetiver grass with adhesives and keeping them in the appropriate formwork. Then these formworks were tightly sealed from all sides and the pressure of 80 kg/cm^2 was applied which varied from 8 to 21 hours depending upon the type of adhesive used.

Test results showed that the polyvinyl acetate based adhesive was more suitable binder for the making of vetiver grass board than urea formaldehyde and corn starch based adhesive. The polyvinyl acetate and related polymer used at 34% of the dry weight of vetiver grass chips used in the making of the boards provided the highest modulus of rupture and modulus of toughness. However, the highest modulus of resilience was obtained when polyvinyl acetate and related polymer were kept at 29% of dry weight of vetiver grass chips. When the vetiver grass boards were fabricated using 30 mm fiber length instead of 20 mm, the modulus of rupture and modulus of toughness in all bases adhesive were increased. The vetiver grass boards possessed high water absorption and thickness swelling; hence not making them waterproof. From the cost analysis, it was found that the vetiver grass boards made from urea formaldehyde based adhesive were expensive as compared to the other adhesives used for this research work. On the other hand vetiver grass boards made from corn starch based adhesive were found to be cheapest. The cost of polyvinyl acetate based adhesive was slightly higher than corn starch based adhesive. However, the cost per square meter of vetiver grass board made from polyvinyl acetate and related polymer used at 34% of dry weight of vetiver grass chips, was found out to cost 61 baht (~ US $ 1.45) which was about 40% lower than bagasse boards, available commercially in Thailand.

Keywords: PARTICLE BOARD, VETIVER GRASS CHIP, UREA FORMALDEHYDE, POLYVINYL ACETATE, CORN STARCH

1. Introduction

After His Majesty the King’s initiated on used of vetiver in Thailand, 10 ecotypes were nominated and extensive propagation programs were launched. Starting from the year 1993, the Department of Land Development could produce only 6.43 million tillers. The quantity increased to 28.56 and 99.50 millions in the year 1994 and 1999 respectively. The hand over propagation increased to 30.56, 88.40, and 98.10 million in the year 1996, 1997 and 1998 respectively. Recently, the total propagation was reaching the quantity of 282.49 million tillers which could serve the eroded area more than 90,397 hectares throughout the country. After the vetiver hedge was complete established, cutting and thinning were necessary for vegetation management. Cutting the tops of the plants and taking out the old tillers after flowering (from the clump) could increase the number of young shoots and tillers, to make a denser hedge [11]. The leaves of vetiver grass could be cut down up to 20-30 cm. Above the ground level, its leaves was used as a mulch at the base of the fruit trees to help retain stored moistures and fed the young palatable leaves to their livestock. In this research, vetiver grass will be used as raw materials to produce a low-cost particle board.

Particle board manufacturing plants account for most of the current consumption for synthetic, formaldehyde and vinyl acetate – based adhesives. These synthetic adhesives used raw materials that were derived from the petrochemical industry, excepted for urea and melamine. World prices for the raw materials were dependent on petroleum feed stock prices. The demand for crude oil was increasing and might exceed the supply. Availability and price of the raw materials were closely related and provided that realistic resin prices could be achieved. If realistic prices for resin could not be achieved, the heavy chemical industry will divert its raw materials to outlets with a better return on capital and problems may arise on the supply and price of formaldehyde and vinyl acetate – based resins. Consequently, it was necessary to find alternative supplementary raw materials for manufacturing of wood adhesives.

2. Fabrication of Vetiver Grass Boards

The details of mix proportions for fabrication vetiver grass boards were tabulated in Tables 1 and 2.

2.1 Preparation of Raw Material

The vetiver grass, which was taken from Amphur Pahk Chong, Sara Buri Province, by cutting about 1.5-2.0 m. length. This vetiver grass belonged to species of Veteveria zizanioides (Linn.) Nash in Songkhla 3 ecotype. The natural color of leaves was green. The vetiver grass was in a damp and fresh condition. Firstly, the vetiver grass was then spread on the concrete floor and directly exposed to sunshine for 1 to 2 weeks. Subsequently, dried vetiver grass was cut into the required length of 20 and 30 mm. manually by using scissors and kept in sacks before mixing with adhesive. The moisture content of the vetiver grass chip was found to vary from 1-5%.

2.2 Preparation of Matrix

Three bases of adhesive were selected to be used as matrix namely urea formaldehyde, polyvinyl acetate, and corn starch adhesive. They were prepared as follows:

2.1.1 Urea Formaldehyde Based Adhesive

This matrix was made from synthetic resin, which consisted of components by ratio as follows:

Urea Formaldehyde Powder	100	by weight
Water	100	by weight

Urea formaldehyde adhesive was mixed in glue mixer. Firstly, 75% of water was poured into urea formaldehyde powder and the mixture was thoroughly mixed for five minutes. Subsequently, the remaining water was added.

2.1.2 Polyvinyl Acetate Based Adhesive

1). LN 248 Adhesive

LN 248 adhesive manufactured by National Adhesives Company, Limited was used.

2). Polyvinyl Acetate and Related Polymer Adhesive

This matrix was made from synthetic resin, which consisted of components by ratio as follows:

Polyvinyl Acetate	100	by weight
Polyvinyl Alcohol	10	by weight
Water	50	by weight

Polyvinyl acetate and related polymer adhesive was mixed in glue mixer. Firstly, 50% of water was heated at temperature of 70 ^{o}C for ten minutes to mix with polyvinyl alcohol as additive. Subsequently, the remaining water and additive were poured into polyvinyl acetate syrup and the mixture was thoroughly mixed for five minutes.

3). Polyvinyl Acetate Adhesive

This matrix was made from synthetic resin, which diluted with water by ratio as follows:

Polyvinyl Acetate	100	by weight
Water	25	by weight

Polyvinyl acetate adhesive was mixed in glue mixer. The water was poured into polyvinyl acetate syrup and the mixture was thoroughly mixed for five minutes.

2.1.3 Corn Starch Based Adhesive

This matrix was made from natural resin, which consisted of components by ratio as follows:

Corn Starch	100	by weight
Citric Acid	20	by weight
Polyvinyl Alcohol	15	by weight
Water	150	by weight

Corn starch adhesive was mixed in glue mixer and heated at temperature of 70 ^oC throughout completed mixing. Firstly, polyvinyl alcohol was mixed with 40% of water and mixture was heated for ten minutes. Subsequently, corn starch was mixed with 40% of water until complete solution and poured into polyvinyl alcohol syrup which the mixture was thoroughly mixed for fifteen minutes. Finally, the remaining water and citric acid were added.

After corn starch adhesive completed mixing that some additive were used for increasing strength and workability. This matrix could be divided into two types as following:

1). LN 248-Corn Starch Adhesive

This matrix was made from three components by ratio as follows:

Corn Starch Adhesive	100	by weight
LN 248	20	by weight
Water	10	by weight

LN 248-corn starch adhesive was mixed in glue mixer. Firstly, corn starch adhesive and LN 248 syrup were mixed for five minutes. Subsequently, the water was added.

2). Polyvinyl Acetate-Corn Starch Adhesive

This matrix was made from three components by ratio as follows:

Corn Starch Adhesive	100	by weight
Polyvinyl Acetate	20	by weight
Water	15	by weight

Polyvinyl acetate-corn starch adhesive was mixed in glue mixer. Firstly, corn starch adhesive and polyvinyl acetate syrup were mixed for five minutes. Subsequently, the water was added.

2.3 Mixing Method

The prepared mixing adhesive was poured over the vetiver grass chips as shown in Figure 1. Manual mixing of the components was done until a certain degree of uniformity was obtained. This would ensure that all vetiver grass chips be thoroughly coated with adhesive. After mixing, the moisture content of the chip cake was kept within range 10-18% by weight. The mixing procedure took approximately fifteen minutes using two laborers.

2.4 Fabrication Process

Since the mixture of vetiver grass chips and adhesive was voluminous and compressible, the casting process should therefore be done under pressure. The formwork was designed in such a way that it is easy to operate. The fabrication process was also taken into consideration so that it can be easily applied in rural area. The formwork was made from the basic construction materials which consisted of two parts, a cover plate and formwork.

After mixing the fiber and matrix, the mixture was then poured into the formwork paved with thin plastic sheet. At this point, care should be taken that no weak spots developed in the composite board. The placing sequence should be divided into two layers. After pouring in the first layer, the mixture in the formwork should be pressed by hands in order to check the uniformity as shown in Figure 2, so that the rest of the mixture for the upper layer will be properly placed. The next step in the process of making the particle board was casting. Since the vetiver grass chips cake was light and voluminous, the casting process had to be done under loading pressure. The cover plate, which was also paved with thin plastic sheet, was put into place and load was applied by means of a hydraulic jack as shown in Figure 3. In this research, the casting pressure was kept constant at 80 kg/cm^2, which was equivalent to a constant load at 100 tons. The mould was pressed until the required strength of adhesive was attained.

3. Experimental Program

3.1 Properties of Vetiver Grass

Tests have been carried out to determine the properties of vetiver grass in accordance with the ASTM standard. In this part, investigates on the physical properties of Veteveria zizanioides (Linn.) Nash in Songkhla 3 ecotype to be tested were moisture content and water absorption.

3.2 Properties of Matrix

Three bases of adhesive material namely urea formaldehyde, polyvinyl acetate, and corn starch adhesive, were used in this experimental that tested namely solid content (weight loss), density (liquid formed adhesive), and cure rate.

3.3 Physical and Mechanical Properties of Vetiver Grass Board

The physical and mechanical properties of vetiver grass boards were determined in accordance with ASTM D 1037-78 [5]. Vetiver grass boards were made from two different lengths of Veteveria zizanioides (Linn.) Nash in Songkhla 3 ecotype as raw material and six different types of adhesive materials as matrix which tested the physical and mechanical properties to be determined were moisture content and specific gravity, water absorption and thickness swelling, static bending.

4. Test Results and Discussion

A composite material was a material, which is made from two or more material, in combination, which was chemically distinct, with a distinct interface separating the components. Composites had properties, which would not be achieved by any of the components acting alone. These properties included strength and toughness. Vetiver grass board could be considered as a composite material of which the physical and mechanical properties were investigated in this research.

4.1 The Properties of Vetiver Grass

Experiments were carried out to determine the fiber moisture content and water absorption. The physical properties of vetiver grass were determined and tabulated as shown in Table 3. The average moisture content of vetiver grass chips length of 20 and 30 mm. at sun-dried condition were 1.27% and 1.39%, respectively. The vetiver grass fibers were found to be a highly absorptive material; theirs average water absorption were 210% and 223% respectively.

4.2 The Properties of Matrix

Three bases of adhesive were used for making vetiver grass boards namely urea formaldehyde, polyvinyl acetate, and corn starch. The results were summarized as follows:

4.2.1 Solid Content (Weight Loss)

The percent-solids test is important because it indicates the amount of volatile release during cure. The results of average solid content were tabulated as shown in Table 4. Urea formaldehyde based adhesive gave the highest average solid content that was 53.4%. Besides, polyvinyl acetate based adhesive, the solid content of LN 248 adhesive was 50.6% as the highest average solid content which decreased in polyvinyl acetate and related polymer, and polyvinyl acetate adhesive as 44.1% and 41.4% respectively. Moreover, the averages solid content of corn starch based adhesive comprised of LN 248-corn starch and polyvinyl acetate-corn starch adhesive were 48.7% and 44.9% respectively.

4.2.2 Density (Liquid Formed Adhesive)

The results of average density by liquid formed were determined and tabulated as shown in Table 4. The result of average density was highest at 1.21 g/cm^3, urea formaldehyde adhesive. The lowest density was found in polyvinyl acetate based adhesive at 1.08 g/cm^3, polyvinyl acetate and related polymer adhesive and polyvinyl acetate adhesive. Additionally, the average density of the LN 248 adhesive was 1.09 g/cm^3. Moreover, the average density of LN 248-corn starch and polyvinyl acetate-corn starch adhesive were 1.13 and 1.12 g/cm^3 respectively.

4.2.3 Cure Rate

The lab shear test was used to determine rate of the shear strength after curing for 24 hours. The results of the shear strength after curing for 24 hours of different types of adhesive were plotted as shown in Figure 4. From the results can be observed that urea formaldehyde adhesive showed the highest shear strength as 77.80 kg/cm^2. And LN 248-corn starch adhesive showed the lowest shear strength as 36.40 kg/cm^2.

4.3 The Properties of Vetiver Grass Boards

The properties of vetiver grass boards were experimentally investigated. The main variables were the adhesive type, adhesive content, and fiber length. The three bases of adhesive used for making vetiver grass board namely urea formaldehyde, polyvinyl acetate, and corn starch. The urea formaldehyde based adhesive comprised only urea formaldehyde adhesive. The polyvinyl acetate based adhesive comprised of LN 248, polyvinyl acetate and related polymer, and polyvinyl acetate adhesive. The corn starch based adhesive comprised of LN 248-corn starch and polyvinyl acetate-corn starch adhesive. Each type of adhesive had three different quantities to test for comparison. And two fiber lengths used for making vetiver grass boards were 20 and 30 mm.

4.3.1 Moisture Content and Specific Gravity

The moisture content and specific gravity of the vetiver grass boards were greatly affected on the inherent properties of the board. The test results of moisture content and specific gravity expressed as percentage by weight of each specimen type and ratio of oven dried weight to air dried volume. It was evident from the results graphically presented in Figures 5 and 6, that the moisture content of vetiver grass board was increased with higher percentage of adhesive. Considering the length of fiber in all based materials of adhesive, higher moisture content of vetiver grass board was found when used 30 mm that compared with 20 mm at the same content of adhesive. It was found out that the moisture content of vetiver grass board affected by water absorption properties of fiber.

4.3.2 Water Absorption and Thickness Swelling

Since vetiver grass was a natural fiber and decomposed when subjected to moisture or water, the water absorption and thickness swelling of vetiver grass board should therefore be investigated. The test results of water absorption and thickness swelling after 2 and 24 hours submersion were graphically presented in Figures 7 and 8, that the results were able to record only vetiver grass board making from urea formaldehyde adhesive. The others, the vetiver grass boards decomposed after one minute and five minutes submersion when used corn starch and polyvinyl acetate based adhesive respectively. The water absorption and thickness swelling after 2 and 24 hours were decreased with higher percent of adhesive. In case of urea formaldehyde adhesive at 36% of dry weight of vetiver grass chips, considering the length of fiber, higher the water absorption and thickness swelling after 2 and 24 hours were found when used 30 mm that compared with 20 mm. It was found out that the water absorption and thickness swelling after 2 and 24 hours affected by water absorption properties of fiber.

4.3.3 Static Bending

ASTM defined flexural strength as the property of a material that indicated its ability to resist failure in bending. Tests were performed to determine the flexural strengths expressed in terms of the modulus of rupture. Other relevant properties obtained from this test were the modulus of resilience and modulus of toughness. The failure crack patterns of the test boards were observed from the tests that if the failure occurred immediately after the ultimate load under flexure, hence a brittle failure. On the other hand, no sudden failure occurred on the test boards that fabricate from polyvinyl acetate based adhesive.

1). Modulus of Rupture
ASTM defined modulus of rupture as a measure of the ultimate load-carrying capacity of a material. The comparison of moduli of rupture of the entire test results and graphically was shown in Figure 9. From this graph, polyvinyl acetate based adhesive gave the highest average moduli of rupture which decreased in urea formaldehyde and corn starch based adhesive, respectively.

2). Modulus of Resilience
The amount of energy recovered per unit volume of a material when it was stress to its elastic limit and then stress was the elastic resilience of the material. The highest value of the modulus of resilience was obtained in material having high elastic strength and a comparatively low modulus of elasticity. The comparison of moduli of resilience of the entire test results and graphically was shown in Figure 11. From this graph, polyvinyl acetate based material of adhesive gave the highest average moduli of resilience which decreased in urea formaldehyde and corn starch based materials of adhesive respectively.

3). Modulus of Toughness
ASTM defined toughness as the capacity of a material to absorb energy during the application of load to fracture. It was said to be dependent on both strength and ductility. A tough material will withstand great deformation under high stress. The modulus of toughness was expressed in terms of the work performed in deforming a material to fracture. The comparison of moduli of toughness of the entire test results and graphically was shown in Figure 13. From this graph, polyvinyl acetate based adhesive was the highest average moduli of toughness which decreased in urea formaldehyde and corn starch based adhesive respectively.

5. Conclusion

Based on the results obtained in this research, the following conclusions can be made.
1. The polyvinyl acetate based adhesive was a more suitable binder for making vetiver grass board than urea formaldehyde and corn starch based adhesive respectively.
2. The polyvinyl acetate and related polymer, at 34% of dry weight of vetiver grass chips, provided the highest modulus of rupture and modulus of toughness. However, the highest modulus of resilience was obtained when used the polyvinyl acetate and related polymer at 29% of dry weight of vetiver grass chips.
3. When the vetiver grass boards were fabricated using 30 mm fiber length instead of 20 mm, they increased the modulus of rupture and modulus of toughness in all based adhesive.
4. The vetiver grass boards had high water absorption and thickness swelling; therefore they were not waterproof. Thus, its use is limited.
5. The cost per square meter of particle board, making from polyvinyl acetate and related polymer adhesive, at 34% of dry weight of vetiver grass chips, was 61 bath. This was about 40% lower than bagasse board, which was available commercially. Moreover, the cost per square meter of particle boards, making from urea formaldehyde adhesive, at 24% of dry weight of vetiver grass chips, was 171 bath which was very high compared with the other two bases of adhesive used in this investigation.

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Table 1 Detail of Mix Proportions of Vetiver Grass Boards Using 20 mm Fiber Length

Adhesive Used for Making Vetiver Grass Boards		
Type	**Quantity* (%)**	**Abbreviation**
Urea Formaldehyde	24, 30, 36	UF24, UF30, UF36
LN 248	18, 21, 24	LN18, LN21, LN24
Polyvinyl Acetate and Related Polymer	24, 29, 34	PA24, PA29, PA34
Polyvinyl Acetate	18, 22, 26	P18, P22, P26
LN 248-Corn Starch	20, 23, 26	CL20, CL23, CL26
Polyvinyl Acetate-Corn Starch	21, 24, 27	CP21, CP24, CP27

* Percent of adhesive by weight based on dried weight of vetiver grass chips

□

Table 2 Detail of Mix Proportions of Vetiver Grass Boards Using 30 mm Fiber Length

Adhesive Used for Making Vetiver Grass Boards		
Type	**Quantity* (%)**	**Abbreviation**
Urea Formaldehyde	36	3UF36
Polyvinyl Acetate	26	3P26
Polyvinyl Acetate-Corn Starch	27	3CP27

* Percent of adhesive by weight based on dried weight of vetiver grass chips

Table 3 Physical Properties of Vetiver Grass

Veteveria zizanioides (Linn.) Nash in Songkhla 3 ecotype	Average of Moisture Content (%)	Average of Water Absorption (%)
Fiber Length 20 mm	1.27	210
Fiber Length 30mm	1.39	223

Table 4 Physical Properties of Matrix

Types of Adhesive	Average Solid Content (%)	Average Density (g/cm^3)
Urea Formaldehyde Based Adhesive		
- Urea Formaldehyde Adhesive	53.4	1.21
Polyvinyl Acetate Based Adhesive		
- LN 248 Adhesive	50.6	1.09
- Polyvinyl Acetate and Related Polymer Adhesive	44.1	1.08
- Polyvinyl Acetate Adhesive	41.4	1.08
Corn Starch Based Adhesive		
- LN 248-Corn Starch Adhesive	48.7	1.13
- Polyvinyl Acetate-Corn Starch Adhesive	44.9	1.12

Figure 1 The Completed Mixing Adhesive was poured over Vetiver Grass Chips

Figure 2 Pressing by Hands in Order to Check the Uniformity

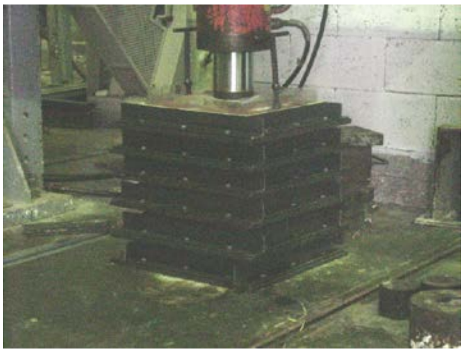

Figure 3 Applied Load by Hydraulic Jack

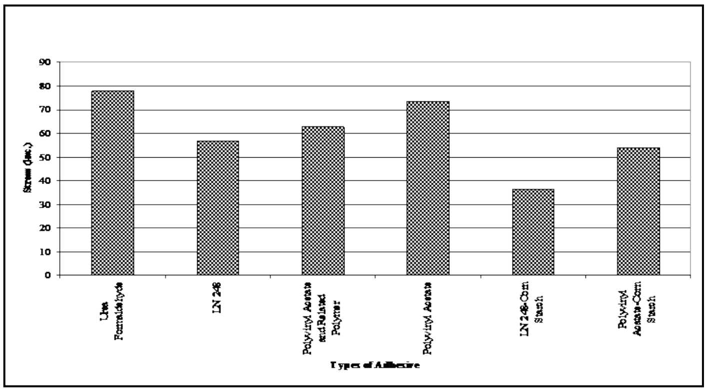

Figure 4 Comparison of Shear Strength of Adhesive after Curing for 24 Hours

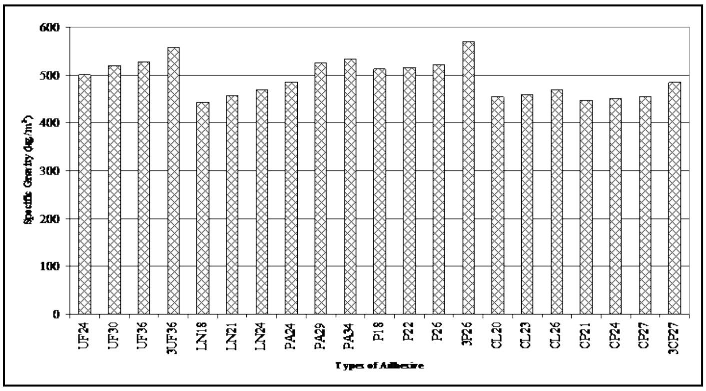

Figure 5 Relationship between Specific Gravity of Boards and Types of Adhesive

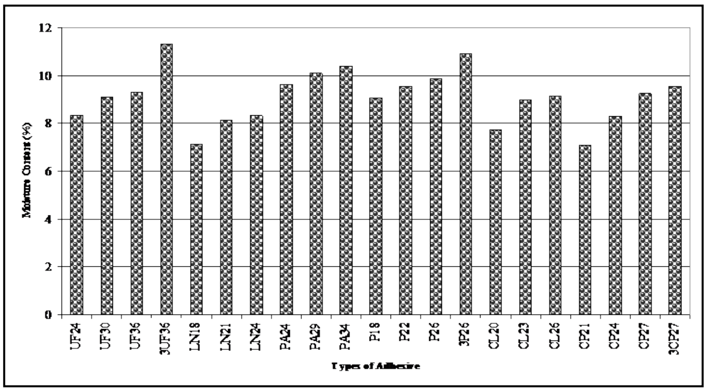

Figure 6 Relationship between Moisture Content at Air Dried Condition of Vetiver Grass Boards and Types of Adhesive

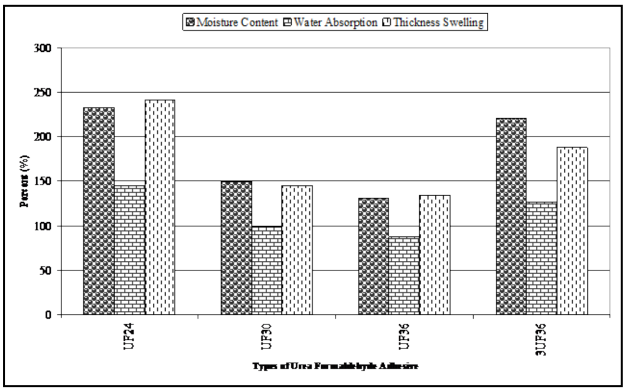

Figure 7 Relationship between Physical Properties of Vetiver Grass Boards after Submersion 2 Hours and Types of Urea Formaldehyde Adhesive

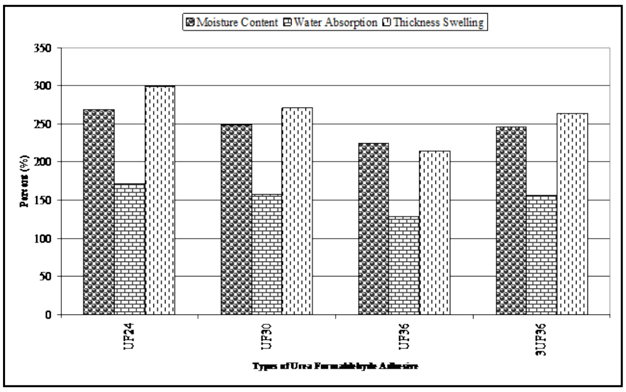

Figure 8 Relationship between Physical Properties of Vetiver Grass Boards after Submersion 24 Hours and Types of Urea Formaldehyde Adhesive

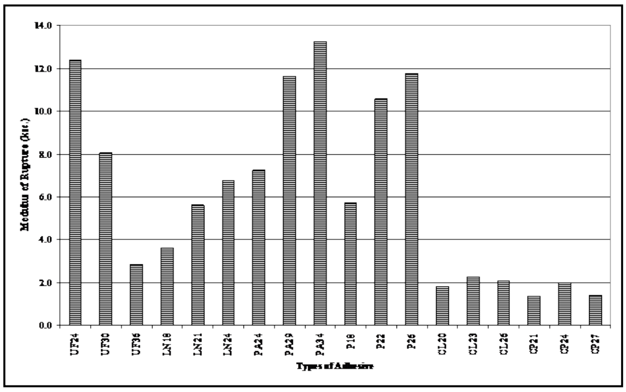

Figure 9 Comparison of Moduli of Rupture for All Types of Adhesive

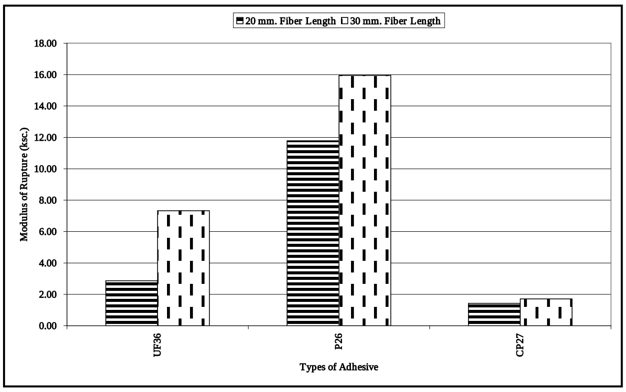

Figure 10 Influent of Fiber Length on Modulus of Rupture for Different Types of Adhesive

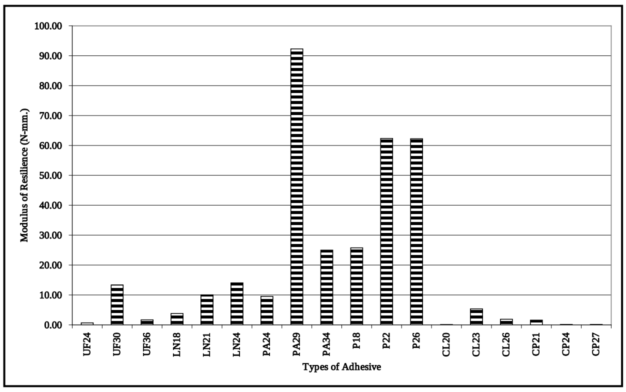

Figure 11 Comparison of Moduli of Resilience for All Types of Adhesive

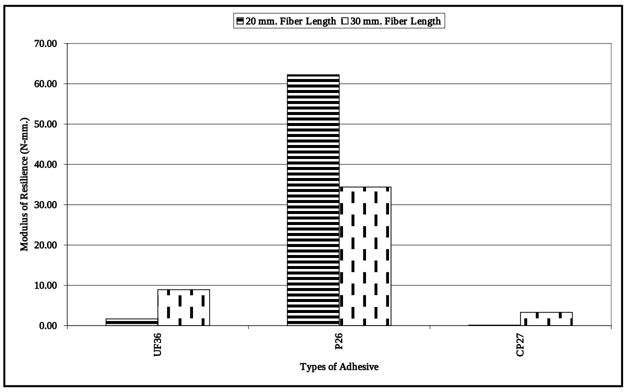

Figure 12 Influent of Fiber Length on Modulus of Resilience for Different Types of Adhesive

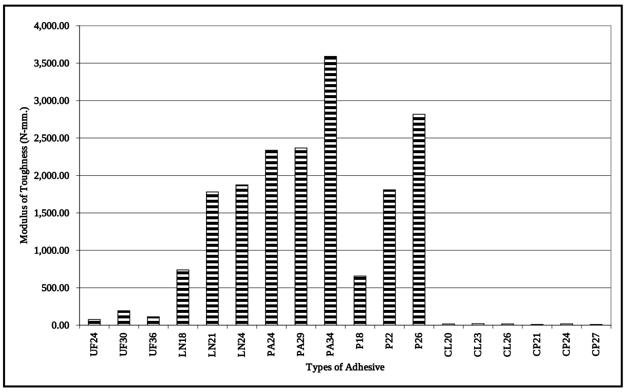

Figure 13 Comparison of Moduli of Toughness for All Types of Adhesive

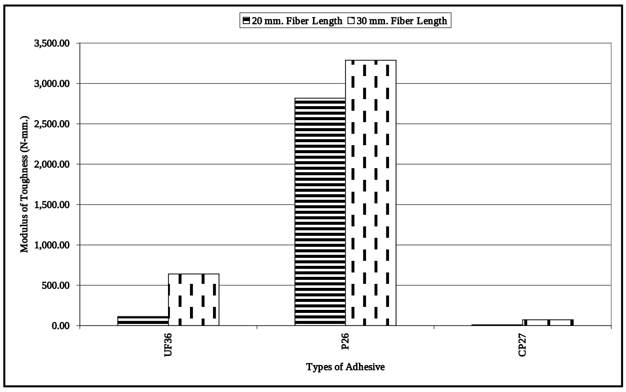

Figure 14 Influent of Fiber Length on Modulus of Toughness for Different Types of Adhesive