Influence of varying density on the mechanical and physical properties of Medium Density Fibreboard (MDF) containing kenaf

Noorli Ismail¹,², Muhammad Azzim Mohamed Jomali², Hasniza Abu Bakar¹,²*, Tong Yean Ghing¹,², Nik Mohd Zaini Nik Soh¹,² and Raden Maizatul Aimi Mohd Azam³

¹Jamilus Research Center and Sustainable Construction, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia (UTHM), 86400, Batu Pahat, MALAYSIA.
²Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia (UTHM), 86400, Batu Pahat, MALAYSIA.
³Civil & Structural Engineering Branch, Public Works Department (JKR), 50480 Kuala Lumpur, MALAYSIA

Corresponding author: hasniza@uthm.edu.my

Abstract. Generally, Medium Density Fibreboard (MDF) is made from rubberwood, wood fiber and pine wood with combination of non-woody plant and agricultural residues in producing furniture and laminated floor. The usage of kenaf as main production of MDF had attracted attentions from researchers due to its anatomy of physicals and high content of organic compound namely are cellulose, hemicellulose and lignin. Due to these advantages, kenaf showed the huge potential in producing MDF with the bigger scale of production. In present study, nine (9) panel boards of MDF with sizes of 350 (length) x 350 (width) x 12 (thickness) in millimetres were fabricated based on three (3) different target densities started from 0.7 g/cm³ to 0.8 g/cm³. A total of three (3) samples for each target density were prepared for the measurements. The proportion of 65:15 which was described as ratio of kenaf particles to urea formaldehyde (UF) were selected and measured from the total volume of panel board. Testing of Modulus of Rupture (MOR), Modulus of Elasticity (MOE), Internal Bonding (IB) and Thickness Swelling (TS) were conducted in the present study. All measurements were carried out according to the BS EN 310:1993, BS EN 319:1993 and BS EN 317:1993. Results showed the increment of MOR, MOE and decrement of IB and TS were associated with increment of target density. Thus, target density of 0.8 g/cm³ for MDF is the best selection due to high MOR and MOE and low IB and TS corresponding to other two (2) target densities. The decrement of panel thickness also capable to achieve high density associated with high MOR and MOE. Therefore, the significant outcome shows the kenaf plant have the potential as alternative material to produce the Medium Density Fibreboard (MDF).

1. Introduction

Kenaf also known as *hibiscus cannabinus L* which is non-woody fiber plants and can be classified as Mallow family [1-2]. Subsequently, due to the high yield production which was about three to five times greater than other types of fiber plant [3-4] and growth well in tropical climates with high rainfall [2], kenaf then was introduced in Malaysia. Furthermore, collaboration between few research development institutions in Malaysia namely are Malaysian Agriculture Research and Development (MARDI),
Universiti Putra Malaysia (UPM), Malaysia Rubber Board (MRB) and Malaysian Palm Oil Board (MPOB) had been made in order to promote the usage of kenaf in Malaysian production industries. These collaboration among different institutions in Malaysia helps to reduce the usage of timber, thus it can decrease the deforestation rate in Malaysia [6].

Generally, the kenaf crop can be used to produce furniture, fibreboard, pulp, paper products, bio-composites, automotive panel and their components as an alternative materials [5]. Moreover, kenaf morphology also has high cellulose, holocellulose and lignin contents [7-10] that leading to have good bonding between the layers if it was formed as a panel [11]. Due to these characteristics, kenaf shows a good potential as main contents in producing MDF which consists of dry formed product of several panels combined together with a synthetic resin binder. The conventional MDF averagely was able to provide tensile strength between 283 MPa and 800 MPa and elastic modulus (MOE) from 200 MPa to 600 MPa [34]. However, the manufacturer of MDF [12] stated that the mechanical properties of MDF was varies depending on the panel thickness. Table 1 shows the increment of density in MDF’s panel capable to achieve high mechanical properties of MOR and MOE. While, the decrement of panel thickness increased the thickness percentages of swelling which was indicated that MDF should be avoided contact with the water sources.

Table 1. Mechanical and physical properties of MDF subjected to different thickness [12]

| Mechanical Properties                        | Unit (mm) | >2.5-4.0 | >4.0-6.0 | >6.0-9.0 | >9.0-12.0 | >12.0-19.0 | >19.0-30.0 |
|---------------------------------------------|-----------|----------|----------|----------|-----------|------------|------------|
| Thickness tolerance                         | mm        | ± 0.2    |          |          |           |            |            |
| Average of density                          | kg/m³     |          | 800-900  | 780-840  | 760-800   | 720-760    | 700-740    | 650-690    |
| Board moisture                              | %         |          | 5-8      |          |           |            |            |
| Modulus of Rupture (MOR)                    | MPa       |          | 0.65     | 0.65     | 0.65      | 0.60       | 0.55       | 0.55       |
| Modulus of Elasticity (MOE)                 | MPa       | NA       | NA       | NA       | NA        | 1050       | 1000       |            |
| Internal bonding (IB)                       | MPa       | NA       | NA       | NA       | NA        | 850        | 700        |            |
| Swelling of thickness (TS)                  | %         | 35       | 30       | 17       | 15        | 12         | 10         |            |

2. Literature Review

Previous studies showed that the rubberwood and wood fibers were commonly used to produce MDF and sometimes with combination of others non-woody plant and agricultural residues [13-18, 21-25]. Besides, pine wood was also used as main contents of MDF [26-27]. However, full usage of non-woody plant such as kenaf is encouraged to replace the demand of wood plant due to affordable price and high yield production. Up to the present, MDF made of kenaf showed significant findings [11,19,21-23,28] in enhancing modulus of rupture, modulus of elasticity and internal bonding associated with low thickness swelling which was the main properties in producing MDF. Study of [11] confirmed that the kenaf’s MDF recorded the increment of modulus of elasticity and modulus of rupture of 51% and 64%, respectively corresponding to MDF made from rubberwood. While, [21] determined high internal bonding corresponding to rubberwood and other combination materials in MDF panel. Subsequently, [28] stated that the application of kenaf in MDF showed lower thickness swelling than MDF produced from bagasse and wheat straw [29,30]. However, the previous studies of [11,19,21-23,28-30] were conducted with target density of MDF between 0.7 g/cm³ and 0.73 g/cm³. None of studies was published with high target density for panel board of MDF containing kenaf. Therefore, three (3) target densities
were introduced namely 0.7 g/cm$^3$, 0.75 g/cm$^3$ and 0.8 g/cm$^3$ to investigate the potential of MDF made from kenaf with high density.

3. Materials and Methodology

Kenaf plant and urea formaldehyde (resin binder) were supplied by Timber Fabrication Laboratory, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia (UTHM), Malaysia. The making of MDF was started by preparing the kenaf particles followed by board manufacture prior to the testing which was described at following sub-section. Testing performed in the present study were MOR, MOE, IB and TS at Light Structures Laboratory, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia (UTHM), Malaysia.

3.1. Preparation of kenaf particles

The raw matured kenaf required to chip and crush using grinding machine to obtain kenaf particles prior to the panel board production. The process of preparing the kenaf particles was shown in Figure 1. This process was made in order to ensure the particles can be easily mixed up with urea formaldehyde.

![Figure 1](image)

**Figure 1.** Process performed to produce kenaf particles by preparing (a) raw kenaf followed by (b) chipped and crushed using Grinding Machine and (c) blended with Urea Formaldehyde (UF) prior to the MDF production.

3.2. Preparation of board manufacture

Nine (9) panel boards of MDF with sizes of 350 (l) x 350 (w) x 12 (t) in millimetres were fabricated based on three (3) different target densities which included 0.7 g/cm$^3$, 0.75 g/cm$^3$ and 0.8 g/cm$^3$. For the each target density, a total of three (3) specimens were prepared for the testing purposes. The kenaf particles of 65% and urea formaldehyde (UF) of 15% were blended using spray gun as shown in Figure 2(a). Table 2 tabulates the target densities of panel board for Specimen 1 was equivalent to total weight of 1029 g when target density of specimen was multiplied with volume of panel board. Thus, the weight of UF required was 237.46g which was measured from ratio of 15/65 multiplied with total weight of board panel, 1029g. While total weight of kenaf particles, 668.85g was required based on 65% proportion multiplied with total weight of board panel. Upon the completion of blending process, the mixture of kenaf particles and UF was manually formed into the wooden mould prior the compaction as shown in Figure 2(b).

The panel board of MDF was pressed using Cold Press Machine at temperature 150˚C and pressure of 3 MPa for 6 minutes as displayed in Figure 2(c). Then, Fig. 2(d) shows the MDF were kept at temperature of 25 ±3˚C in the oven with 65% of relative humidity for 24 hours followed by curing process for 7 days. The process conducted in preparing the board panel of MDF was referred to Figure 2 for better understanding.
Table 2. Total weight of kenaf particles and urea formaldehyde (UF) based on different target density in making MDF

| Specimen No | Target density (ρ) (g/cm³) | Volume of panel board (V) (cm³) | Weight of UF (15%) (g) | Weight of kenaf particles (65%) (g) | Weight of panel board (ρ x V) (g) |
|-------------|-----------------------------|---------------------------------|------------------------|------------------------------------|----------------------------------|
| 1           | 0.70                        | 1470                            | 237.46                 | 668.85                             | 1029                             |
| 2           | 0.75                        | 1470                            | 254.42                 | 716.63                             | 1102.50                          |
| 3           | 0.80                        | 1470                            | 271.38                 | 764.40                             | 1176                             |

3.3. Experimental Testings

After the curing process was completed, the main board panels of 350 (l) x 350 (w) x 12 (t) in millimetres were cut into four (4) sizes was used for the testing purposes as shown in Table 3. The size specimen of 290 (width) x 50 (length) x 12 (thickness) was prepared for testing of MOR and MOE as accordance to BS EN 310:1993. While BS EN 319:1993 was used as the guidance for testing of IB and TS on the specimen with sizes of 50 (width) x 50 (length) x 12 (thickness). The board panel was bonded to loading block using epoxy glue as displayed in Figure 3(a) prior the testing. All the testing of MOR and MOE was determined using Universal Testing Machine. Accordance to BS EN 319:1993, determination of swelling in thickness was conducted after immersion in water. Figure 3(b) shows the vernier clipper was used to measure thickness of specimen before and after water immersion with time interval of 24 hours. Then, the different thickness of panel board was divided with thickness before immersion and expressed as percentages.
Table 3. Measurement of size specimen accordance to specification of standard [31-33]

| Testing performed         | Size specimen (width x length x thickness) | Specification of the standard |
|---------------------------|-------------------------------------------|-------------------------------|
| Modulus of rupture (MOR)  | 290 x 50 x 12                             | BS EN 310: 1993               |
| Modulus of elasticity (MOE)|                                          |                               |
| Internal bonding (IB)     | 50 x 50 x 12                              | BS EN 319: 1993               |
| Thickness swelling (TS)   |                                          |                               |

Figure 3. (a) The specimen of MDF was glued and bonded to loading block prior internal bonding test; (b) Vernier clipper was used to measure thickness of swelling on kenaf’s MDF

4. Results and discussions
The result of MOR, MOE, IB and TS were plotted by classifying each parameters into different target densities as shown in Figure 4 and Figure 5. Figure 4 records MOR and MOE of panel with density of 0.8 g/cm³ increased doubled corresponding to panel density of 0.7 g/cm³ associated with decrement of IB and TS as seen in Figure 5. Furthermore, the average of MOR, MOE and TS recorded for target density of 0.7 g/cm³ was in similar range as prescribed by [12] with thickness between 12 mm and 19 mm as stated in Table 1. While, the range of MOR, MOE and IB recorded in this study was also similar to MDF’s panel which was consists of hundred percent kenaf in study of [21] with target density 0.7 g/cm³. Similar pattern was also found in study of [28] which was recorded similar TS at about 11.45% with application of kenaf stick in MDF production in target density between 0.72 g/cm³ and 0.73 g/cm³. Small percentage of TS showed higher consistency and provides good stability in interconnection between MDF’s panel [23]. Overall, the increment of target density of MDF indicated the increment of MOR, MOE and decrement of IB and TS. Thus, target density of 0.8 g/cm³ for MDF is recommended due to high MOR and MOE and low IB and TS corresponding to other two (2) target density.
Finding showed that the increment of target density of MDF indicated the increment of MOR, MOE associated with decrement of IB and TS as described in [12]. Therefore, target density of 0.8 g/cm$^3$ for MDF is recommended due to high MOR and MOE and low IB and TS compared to other two (2) target densities. In conclusion, Kenaf (Hibiscus Cannabinus L) can be potentially be used as an alternative material in producing Medium Density Fibreboard (MDF) which able to produce high mechanical properties and low physical properties.

6. References

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