The flexural properties of medium density fibreboard overlaid with veneer from three species of wood

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Abstract. Aesthetic and strength are not easy to be combined in one wood composite product. This research aimed at combining both utilizing MDF overlaid with avocado, mahogany and pine veneer. Seven types of MDF composite plywood (comply) were designed using two adhesive types of Epoxy and Isocyanat. The adhesive spread weight was 250 g m⁻². Cold compression was conducted within 3 hours with the pressure of 15 kg cm⁻². The research results showed that flexural modulus (MOE) and flexural strength (MOR) of PMI comply (pine veneer, isocyanat adhesive) increased respectively by 129.5% and 75.9% when compared to MDF. This research recommends that MDF comply may be utilized for the structural and non-structural purposes.

1. Introduction
Plywood and Medium Density Fiberboard (MDF) are building materials found in public. Plywood and veneer material-based products are preferable as each wood type has various surface appearances, motives, and colors [1, 2]. Plywood materials supplied from the commonly used wood [3, 4], lesser known species, and fast-growing species [5–7]. Unlike plywood, MDF raw materials are more flexible derived from the wastes of the primary wood industry, household, and agro-industries [8–12]. MDF appearance tends to be similar and heavier due to its higher density.

The plywood aesthetic appearance and MDF flexibility may be found in composite plywood (Comply) products. Veneer addition not only develops its appearance but also has the potential to improve the flexural properties when applied on OSB [13]. Thus, this research aimed at investigating the flexural properties of Composite plywood made from MDF overlaid with Avocado (Persea americana), Mahogany (Swietenia mahogany) and Pine (Pinus merkusii) veneer. The research results may be utilized to determine the alternative composite products with better flexural properties.
2. Materials and methods

2.1. Materials
This research used Medium Density Fiberboard (MDF) as well as Avocado, Mahogany and Pine veneer obtained from the local markets. The adhesives used were Epoxy and Isocyanate. Both adhesives consisted of base and hardener with the composition 100:100 for epoxy and 100:14 for isocyanate. Isocyanate adhesive used the base type of PI-127T and hardener type of H3M, while epoxy adhesive used the base type of AD-102 and Hardener type of VR-502.

2.2. Methods

2.2.1. Material preparation and comply making processes. First, the medium density fiberboard was cut with the size of 35 x 35 cm. Second, the Avocado, mahogany and pine veneers were cut with the same size. Third, those three veneer types then were used to overlay the MDF face and back part with the arrangements entirely presented in table 1. The adhesive was spread with a single glue line method with the glue spread rate of 250 g m⁻² based on wet mas using a hand brush. The pressure and time of pressing was 15 kg cm⁻² and 3 hours, respectively. The comply was conditioned for two weeks and then cut based on the required size for the flexural properties test. The sample’s length and width size was 30 cm x 5 cm respectively, with the thickness following the comply’s.

| Num. | Type  | Adhesive | Face and Back Veneer |
|------|-------|----------|----------------------|
| 1    | MDF   | -        | -                    |
| 2    | AMI   | Isocyanat| Avocado             |
| 3    | AME   | Epoxy    | Avocado             |
| 4    | PMI   | Isocyanat| Pinus               |
| 5    | PME   | Epoxy    | Pinus               |
| 6    | MMI   | Isocyanat| Mahogany            |
| 7    | MME   | Epoxy    | Mahogany            |

2.2.2. Flexural properties calculation. The method used to obtain the flexural properties was through a bending test using the proximity distance of 15 x comply’s thickness. The loading type was one point loading with the loading speed 10 mm s⁻¹. The obtained data from the test were in the form of graphs between load and deflection as well as a maximum load when the comply failed. After the data were obtained, the flexural modulus (Modulus of Elasticity) and flexural strength (Modulus of Rupture) calculations were then conducted. The calculation was conducted using JAS standard: SE-11 No. 237 [14].

2.2.3. Data analysis. The data were analyzed using a completely randomized design (CRD) with 7 treatments and 5 replications. If the treatment is significant, the Duncan test will be further conducted.

3. Results and discussion

3.1 Modulus of elasticity (MOE)
Figure 1 shows a graph between load and deflection. The PMI comply leaning-curve is shown the highest when compared to the other sloping curve types. Curve height and sloping are the representation of MOE value [15, 16].

Identical with figure 1, MDF has the lowest MOE value, while the highest is owned by PMI comply type (table 2). When compared to MDF, MOE value of PMI increase up to 129.5%. As a comparison, the previous researchers have found that there is an MOE increase from the OSB comply by 117% when compared to the control [13]. The difference is resulted from two factors: MDF material homogeneity and veneer layers addition. The composite board made from more homogenous materials has better
MOE [17]. Furthermore, when conducted a bending test, the layer surface get the highest load. Consequently, the material difference used as the surface layer may result in flexural properties difference [18]. The variance test analytical results showed that the MDF overlaid using veneer influenced MOE. The Duncan analytical results also assert that PMI comply has the highest MOE (table 3).

In addition to the veneer type difference used to coat the MDF, adhesive choice has also contributed to MOE increase. Both adhesives have more reactive functioning groups that the adhesive strength is very high [19, 20]. The previous research has presented the bonding quality of both adhesives on various materials [21–26]. Good adhesive quality has the potential to improve the density and MOE composite board.

![Figure 1. Graph between Load and Deflection for all comply samples.](image)

### Table 2. MOE and MOR comply.

| Comply type | MOE$^a$ (kg cm$^{-2}$) | MOR$^b$ (kg cm$^{-2}$) |
|-------------|------------------------|------------------------|
| MDF         | 65.496±5.005           | 316±18                 |
| MMI         | 79.761±13.059          | 414±100                |
| MME         | 91.885±7.325           | 471±25                 |
| AMI         | 73.956±1.983           | 474±147                |
| AME         | 79.105±5.297           | 406±9                  |
| PMI         | 150.348±10.251         | 556±50                 |
| PME         | 137.928±13.171         | 516±12                 |

$^a p$-value=0.000  
$^b p$-value=0.001

### 3.2. Modulus of Rupture (MOR)

The calculation result of MOR value is shown in table 2. It shows that MDF has the lowest MOR average than the other six comply types. PMI type has higher MOR value followed by PME in the second place. The variance test analytical results showed that MOR value was influenced by the comply design. Veneer addition proven increasing MOR value up to 75.9%. Furthermore, table 4 shows that the Duncan analytical results assert that PMI has the highest MOR value.

Different adhesive type provides contributions to the MOR value (table 4). AME Comply type (Avocado veneer, epoxy adhesive) has lower value than that of AMI (Avocado veneer, isocyanat adhesive). Isocyanat adhesive improved the MOR value higher than that of epoxy after implemented to Avocado and pine veneer, yet in contradiction to mahogany veneer. The specialty of mahogany characteristics with epoxy consistently occurred in MOR and MOE.
Table 3. Duncan analysis on MOE.

| Type | N  | Subset 1 | Subset 2 | Subset 3 | Subset 4 |
|------|----|---------|---------|---------|---------|
| MDF  | 5  | 6.5497E4| 7.3956E4| 7.9105E4| 7.9761E4|
| AMI  | 5  | 7.9105E4| 7.9105E4| 7.9105E4| 9.1885E4|
| AME  | 5  | 7.9105E4| 7.9105E4| 7.9105E4| 7.9105E4|
| MMI  | 5  | 7.9761E4| 7.9761E4| 9.1885E4| 9.1885E4|
| MME  | 5  | 8.0317E4| 8.0317E4| 8.0317E4| 8.0317E4|
| PME  | 5  | 9.1885E4| 9.1885E4| 9.1885E4| 9.1885E4|
| PMI  | 5  | 1.3793E5| 1.3793E5| 1.3793E5| 1.3793E5|

Significance: .050 .395 .065 .059

Means for groups in homogeneous subsets are displayed
Based on the observed means
The error term is Mean Square (Error) = 99961382.500

Table 4. Duncan analysis on MOR.

| Type | N  | Subset 1 | Subset 2 | Subset 3 | Subset 4 |
|------|----|---------|---------|---------|---------|
| MDF  | 5  | 3.1620E2| 4.0540E2| 4.0540E2| 4.0540E2|
| AME  | 5  | 4.0540E2| 4.0540E2| 4.0540E2| 4.0540E2|
| MMI  | 5  | 4.1420E2| 4.1420E2| 4.1420E2| 4.1420E2|
| MME  | 5  | 4.7060E2| 4.7060E2| 4.7060E2| 4.7060E2|
| AMI  | 5  | 4.7360E2| 4.7360E2| 4.7360E2| 4.7360E2|
| PME  | 5  | 5.1600E2| 5.1600E2| 5.1600E2| 5.1600E2|
| PMI  | 5  | 5.5620E2| 5.5620E2| 5.5620E2| 5.5620E2|

Significance: .074 .057 .130

Means for groups in homogeneous subsets are displayed
Based on the observed means
The error term is Mean Square (Error) = 6306.214

4. Conclusion

The composite plywood (Comply) designed in this research has the potential to be developed for broader use as there are MOE and MOR value increases respectively by 129.5% and 75.9%. The increase occurred on the pine veneer and isocyanat adhesive (PMI Comply). The Comply from mahogany and avocado veneer also experienced flexural properties increase with a smaller percentage.

5. References

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