Material properties of palm bark Cross Laminated Timber (CLT) infill wall for earthquake-resistant reinforced concrete buildings: a preliminary investigation

Ahmad Hamidi1, Jafril Tanjung1*, and Teuku Budi Aulia2

1Civil Engineering Department, Universitas Andalas, Padang 25163, Indonesia
2Civil Engineering Department, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia

Abstract: This study conducts a preliminary investigation to determine the material properties of Cross-Laminated Timber (CLT) made from the bark of unproductive palm trunks. One-third of the lower part of palm trunks, aged over 20 years, was used for this purpose. CLTs were created by laminating palm boards into three and five layers, each measuring 200 mm x 20 mm x 1500 mm. A chemical epoxy was employed for lamination. The palm stems were dried in an oven at 110°C for 24 hours. Test results revealed a water content of 6.79% and a specific gravity of 0.23 gr/cm³ in oil palm stems. According to ASTM D143-94-2005 and JIS Z210-21118 standards, wood's acceptable moisture content ranges from 12% to 20%. Given its low specific weight and minimal water content, palm oil trunks, including infill walls, show promise for use in earthquake-resistant construction.

1 Introduction

1.1 Earthquake resistant buildings

Indonesia is one of the countries with a high intensity of earthquakes because Indonesia is in several ring of fire routes, especially on the west side of the islands of Sumatra and Java. Under these conditions, existing buildings must be planned and built by earthquake-resistant building standards. This was done to minimize and avoid material or soul losses.

The earthquake that occurs will cause vibrations/shaking of the ground in all directions and vibrate the buildings standing around the location. The force due to the earthquake event is assumed to be the shear force that exists at the base of the building and this force will be continued on the top side of the building[1]. Earthquake forces have magnitudes, directions, and intensities that always change according to time (time-varying) to give rise to a dynamic response to a structure that is a function of time[2]. One of the analyses carried out in planning earthquake-resistant buildings is dynamic analysis because the results provide information on the behavior of the structure[3].

In addition to structural planning, the selection of the type of material used is also a consideration because it will affect the mass of the building and the cross-sectional dimensions of the structure to be used.

1.2 Cross Laminated Timber (CLT)

Buildings are inseparable from human life, starting from building roads, dams, and buildings. The need for buildings related to the material requirements to be used in the building. The selection of the right material must be able to support the performance of the structure. The selection of building materials for buildings so far has mostly used reinforced concrete because it is considered strong compared to other materials, even though concrete is one of the materials with a high specific gravity (BJ) that also influences the use of cross-sections of structural elements, including the selection of reinforcement.

Wood is one of the oldest building materials after stone and has been the basic building material for many years[4]. Wood is an alternative as a material in buildings. So far, the use of wood as a building material has not been optimal because it is only used as a supporting material and as a covering for simple buildings, such as 1 or 2-story buildings. Along with technological developments in the world of wood construction, it has begun to be used as a material that is applied to structural elements. Wood with an age of more than 5 years has higher physical and mechanical properties compared to wood-aged under 5 years, such as its density value[5].

One of the methods used in the use of wood as a structural element is Cross-laminated timber (CLT). CLT is a wood structural material made by stacking baseboards orthogonally in the direction of the grain and biting them
Indonesia is a country that has a high level of vulnerability to natural disasters. Based on data from the 2018 World Risk Report, Indonesia ranks 36th with a risk index of 10.36 out of 172 countries most prone to natural disasters in the world. This condition is caused by the occupation of Indonesia tectonically as a meeting place for the Pacific Ring of Fire, as an active volcanic pathway known as the Pacific Ring of fire. This condition then becomes the cause of earthquakes, tsunamis, and volcanic eruptions. In addition, hydroclimatologically, Indonesia is also affected by the ENSO (El-Nino Southern Oscillation) and La Nina phenomena which have an impact on the occurrence of floods, landslides, droughts, and tornadoes.

A building is planned to be able to fulfill all its functional needs so that it can support the activities in it, such as an office building complete with leadership rooms, staff, meeting rooms, and so on, or an education center building complete with laboratories, study rooms, meeting rooms and so on. The need for this space is sometimes in conflict with the availability of land in its construction, so construction experts have started to develop high-rise buildings (vertical direction) to meet the space requirements with limited available land[10]. The option of development expansion in a vertical direction also has its popularity in certain planning area units. This alternative was proposed to restrain the rate of land conversion, especially those that serve a strategic function as a buffer for natural continuity as well as those that play a role as a determinant of the availability of basic human needs[11].

Earthquakes are defined as natural vibrations, which occur at certain locations and are unsustainable caused by the sudden movement of the earth's crust (earth plates) due to a source of force as the cause, both natural and man-made. Indonesia itself already has regulations governing the planning of earthquake-resistant buildings. Experts study the various types of recorded earthquakes and then process them to produce an Indonesian earthquake map, each region will have a different earthquake value depending on the movement of rocks.

Indonesia's geographical condition, which is located on the Pacific Ring of Fire, makes Indonesia a country that has the most active volcanoes and also a high potential for natural disasters. Indonesia is crossed by the Indo-Pacific Ring of Fire, which positions Indonesia as a disaster-prone country both from tectonic and volcanic activity. Indonesia is very familiar with natural disasters such as volcanic eruptions, earthquakes, tsunamis, floods, and landslides.

According to the World Bank and UNISDR in BNPB (2015; 23) it is explained that Indonesia is ranked 12th as a country that has high vulnerability, causing many victims due to various types of disasters. Floods, extreme weather, volcanic eruptions, landslides, and drought in Indonesia caused a high death toll from 1815 to 2015. In 2016, there were 2,384 disasters recorded, this number increased from the previous year's 1,732 in 2015.

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![Fig. 1. Illustration of an Earthquake.](https://doi.org/10.1051/e3sconf/202346415011)
The impact caused by the earthquake in the form of damage to buildings and casualties should have been minimized by proper planning of earthquake-resistant buildings. Building planning in earthquake-prone areas that is often applied today is performance-based seismic design in the form of using non-linear analysis techniques with computer applications so that the intensity of ground movement can be easily obtained, then it can predict the critical condition of buildings when an earthquake occurs and reinforce these critical conditions.

Performance-based seismic design is a process that can be used for planning new buildings or upgrading existing buildings with a realistic understanding of safety risks (life), and readiness (occupancy). and property losses (economic loss) that may occur as a result of the coming earthquake[13].

1.4 Material and method

The material used is wood from palm stems. The palm stem in question is the lower 1/3 side of the palm trunk which has stronger physical properties when compared to the other 2/3 sides.

![Fig. 2. Weight of test object.](image1)

![Fig. 3. Palmwood laminating results.](image2)

Palm logs are made into laminated sheets by cross-assembling one layer over another. The adhesive material used is white fox glue. The cross-sectional dimensions of the wooden board are 11 cm x 7.5 cm.

The CLT material used is the lower side of the palm stem which has physical and mechanical properties that are stronger than the other parts. The palm stem used is palm stem that is 25 years old and has stopped producing fruit. The cutting of palm stems is done using a wood cutting machine to form sheets of wood and then a preservative process is carried out using liquid resin and allowed to settle and dry for 30 days if using sunlight as a drying medium and can use an oven for alternative drying with a shorter duration.

![Fig. 4. The process of making palm wood.](image3)

![Fig. 5. Shear force testing method.](image4)

Before making CLT, it is necessary to test the properties of the wood stems to determine the physical and mechanical properties of the oil palm stems. Tests for physical properties of oil palm stem wood include moisture content and specific gravity, while tests for mechanical properties include shear tests and flexibility tests (MOR and MOE). Testing the water content and specific gravity using a sample with dimensions of 5 cm x 5 cm x 5 cm.

While testing the magnitude of the shear force that occurs is carried out using a tool that is capable of providing horizontal loads where the CLT wall is connected to the beam and column components. The test method as shown in Figure 5.
2 Results dan discussion

2.1 Physical properties

Based on the properties test on the wood of edible oil palm, the water content was 6.79% and the specific gravity was 0.23 gr/cm³. The test results are shown in Table 1.

<table>
<thead>
<tr>
<th>Code</th>
<th>Gross weight (gr)</th>
<th>Dry weight (gr)</th>
<th>Water content (%)</th>
<th>Specific gravity (gr/cm³)</th>
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<tbody>
<tr>
<td>1</td>
<td>36.15</td>
<td>33.55</td>
<td>7.19</td>
<td>0.21</td>
</tr>
<tr>
<td>2</td>
<td>33.19</td>
<td>30.85</td>
<td>7.05</td>
<td>0.23</td>
</tr>
<tr>
<td>3</td>
<td>25.68</td>
<td>23.95</td>
<td>6.74</td>
<td>0.28</td>
</tr>
<tr>
<td>4</td>
<td>36.59</td>
<td>34.06</td>
<td>6.91</td>
<td>0.20</td>
</tr>
<tr>
<td>5</td>
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<td>30.55</td>
<td>7.11</td>
<td>0.23</td>
</tr>
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<td>6.75</td>
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</tr>
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<td>26.23</td>
<td>6.85</td>
<td>0.26</td>
</tr>
<tr>
<td>8</td>
<td>34.48</td>
<td>32.09</td>
<td>6.93</td>
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</tr>
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<td>6.74</td>
<td>0.22</td>
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<td>7.58</td>
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<tr>
<td>15</td>
<td>28.56</td>
<td>26.58</td>
<td>6.93</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Average water content: 6.79%
Average specific gravity: 0.23 gr/cm³

Based on Table 1 shows that the average value of the water content in the oil palm trunk is 6.79% and this value is still according to the standard where the maximum value is at 15%. Before processing, palm stems have a high water content value of more than 30%, but after processing in the form of drying and preserving them into wood, palm trunks can be used as construction material.

2.2 Mechanical properties

Mechanical testing was carried out to find out how much compressive and bending results occur in the palm stem wood when it is given a load. In addition, mechanical testing was carried out to determine the effect of shear forces that occur as a result of using one layer of adhesive with another.

The use of adhesive between CLT sheets is expected to provide optimal value. CLT walls are designed not to withstand the vertical force of the building because the structural loading will be supported by structural components such as beams and columns.

3 Conclusion

Based on the properties test, palm stem wood has a water content value that meets the requirements, namely 6.79% according to ASTM D143-94-2005 and JIS Z210-2118 standards which provide a maximum limit for a maximum water content value of 12% -20%. Tests for shear strength (Modulus Rupture/MOR), flexibility (Modulus Elasticity/MOE), and shear strength are expected to provide maximum results that meet ASTM D143-94-2005 and JAS 1152 standards. Based on the properties test, the use of palm wood as a building material can be used for certain components such as walls by processing according to standards first.

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