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Research paper

Manufacture of Sound Absorbing Material from Recycled Rice Straws for Room Acoustics Improvements

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Abstract

The Philippines, as an agricultural country, produces an excessive amount of rice straws. Burning of these huge amounts of rice straw is also discouraged due to the harmful effects in the environment such as air pollutions and the like. A good way of disposing the huge amount of rice straw is to recycle and use them as components of sound absorbing composite wood boards that may be used to improve the acoustic quality of the room. The composite wood board, with a size of 2' by 3' with a thickness of 1", is produced with the use of wood chips and rice straw with urea formaldehyde resin as the binder using the same wood-based board manufacturing methods. The sound absorption coefficient was determined by using Sabine's Equation by recording the reverberation time at various sound levels with use of a sound level meter. Through measurements, it is estimated that the absorption coefficient of the composite wood board ranges from 0.011 to 0.188 which is somewhat similar to that of the absorption coefficient of masonry walls

Keywords: *Sound absorption; Reverberation time; Rice straw.*

1. Introduction

The Philippines produces an excessive amount of rice straw. The excessive rice straws which are not utilized are being left to waste and usually burned. Burning waste materials in the open fields such as rice straws, is prohibited by the law. Not only that, it contributes to the existing problem of pollution today.

Rice is a grain classified in the grass family. 90% of rice production occurs in Asia and as of 2010 rice production amounted to 696 million tons. Rice can be considered as one of the most demanded food grains in the tropical areas surpassing maize and wheat. Rice is also considered one of the mainly produced food grain in the world as Bouman [1] cited in his journal.

Rice cultivation results in two types of by-products: straw and husk. Rice straw is the waste product of rice plants and may be furrowed down as a soil fertilizer or used as livestock feed. Approximately 0.7–1.4 kilograms of rice straws when producing one kilogram of milled rice, depending on varieties, parameters f the stubbles, and moisture content during the time of harvest. Rice straw is forage in a rice-producing area according to Kadam et al. [2].

The Philippines, being one of the producers and exporters of rice, produces about 15.2 million tons of rice which results to nearly 11.3 million tons of rice straws every year. After the rice harvesting process, various practices are performed to prepare the farm land for next cultivation. Burning is the most convenient, cheapest, and fastest way to dispose rice straws, Kanokkanjana and Garivait [3].

Open-field burning of rice straws in clearing rice fields is the most common practice all over the world; For instance, Gadde, Menke, Wassman [4] projected that less than a quarter of the excess rice straw is burnt in India while about half of the rice straws are burnt in Thailand and almost 100% of the rice straws is burnt in the Philippines.

Nidoy [5] stated that burning of rice straw causes the emission of harmful pollutants such as carbon dioxide, carbon monoxide, nitrogen oxide, and even sulfur dioxide. If rice straw burning is done continuously, it will decrease the soil's nitrogen content, as well as phosphorus, potassium, and sulfur.

Open-field burning is prohibited according to the Solid Waste Management Act (RA 9003) and Philippine Clean Air Act of 1999 which also prohibit the burning of rice straw. Because of this prohibition, it results to an excessive amount of rice straw being left to waste.

Rosmiza et al. [6] suggested in their study that to overcome the open burning of agricultural wastes such as rice straw, a more environmental-friendly waste management approaches had been examined and introduced which includes zero waste and zero burning. The proposed alternatives emphasize minimal waste; product re-use and recycle of different farm products. It also includes composting and utilization as an energy source

Rice straw, as lignocellulosic biomass, is comprised of three components: lignin, cellulose, and hemicelluloses. Cellulose and hemicelluloses are fiber organics, whereas lignin is the cell wall, according to Isikgor and Becer [7]. Natural fibers are believed to have the similar mechanism for sound absorption as other conventional artificial fibrous materials, such as glass fibers and mineral wool. These fibers are often lightweight and are safe to human health. This is the reason why these fibers are used as sound absorbers in acoustical room products and noise barriers as cited by Asdrubali, Schiavoni, & Horoshenkov [8].

There are several uses of rice straws that instead of burning them and add to air pollution, it can be used in several aspects and usages. A study from South Korea by Yang et al. [9] found that rice straw can be used as a wood particle in constructing sound absorbing wooden materials. The rice straw–wood particle composite boards are described to absorb noises, conserve the temperature of indoor living spaces, and to be able to replace for wood particleboard and insulation board in wooden constructions. Another research shows that rice straws can also be used as a component in preparation of insulating materials for roofs [10].

This study focuses on the use of rice straw as a component material for acoustic wood board product that can be used as a sound absorbent material.

2. Problem Statement

This research focuses the on the use excess rice straws as part of the raw materials in assembling a composite board that can be used as a sound absorbent material. The step by step procedures in .the construction of the composite board is shownFor acustics measurementsa mini acoustics room is designed and constructed ، as a testbeed to measure the performance of the rice straw composite board in improving the acoustics quality of the room. Two test signals are used، speech signals and music signals. From the acoustics and time measurements، sound level meters are used to monitor the degradation of the speech and music signals in the room. From these experiments، the reverberation times of the signals are determined and eventually، the sound absorption coefficient of the composite board can be computed.

3. Methodology

The construction and acoustics measurements for the composite board using rice straws as part of the wood material has two phases of study. The first phase shows the step by step manufacturing process of the composite material and the construction of the mini acoustics room that is used to test teh performance of the composite wood in terms of its sound absorption abilities in different frequencies. The second phase is the acoustic measurements using the mini acoustics room. the voice and music signals are considered during the testing and measurement stage inside the room. Figure١ shows the two phases covered in this study.

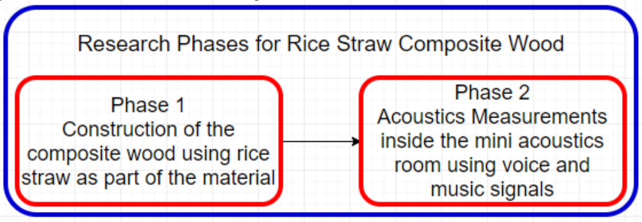

Fig. Two Phases of Rice Straw Composite Wood Project :١

3.1 Construction of the Rice Straw Composite Wood

The followings procedures are used to construct the composite wood material made up of rice straws.

3.1.1. Gathering of rice straws

The first step used to is gather enough rice straws and wood chips that will be used in the construction of the composite wood material.

3.1.2. Mold Preparation

Two sheets of galvanized iron are used as the base and cover of the mold. the smooth surface of the iron sheets ensures a smooth and plane surface of the composite wood. Wood braces braces are used at the sides of the galvanized irons to support and form the shape of the wood. Figure٢ shows the mold preparation for the manufacture of the composite rice straw lumber.

Fig. Mold Preparation for the Rice Straw Composite Wood :٢

3.1.3 Preparation of Resin

After the mold has been formed, the preparation of the urea formaldehyde and mixture of wood chips are done. 2.7 kilograms of wood chips. These wood chips are recycled material gathered from the sawn lumber in the city. 26.9 kilograms of formaldehyde resin was also prepared. Figure 3 shows the preparation of the resin and the wood chips.

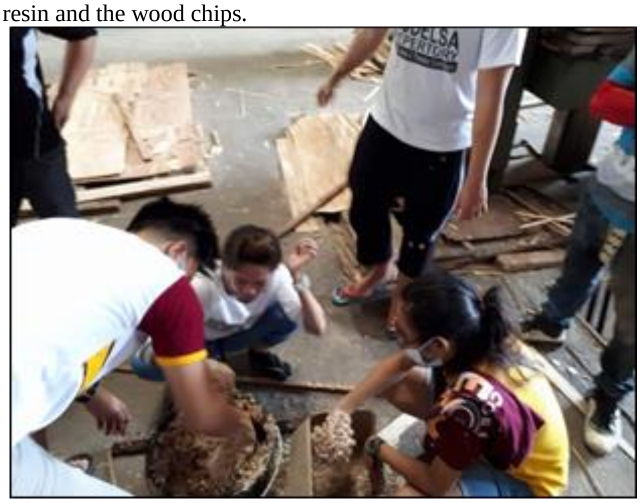

Fig. Preparation of Wood Chips and Formaldehyde Resin :٣

3.1.4. Placement of Rice Straws in the Molds

As soon as the mold، resins and the wood chips are prepared، the rice straws are carefully places in the mold together with the formaldehyde resin and wood chips. Several layers of the mixture are places in the mold to assure compactness and strength for the wood composite. Figure٤ shows how the rice straws are placed in the mold.

Fig. Placement of Rice Straws in the Mold :٤

3.1.5. Wood forming using Cold Pressure Machine

The mold، together with the rice straws، resins and the wood chips are then pressed together with other wood boards using a cold press machine. ١٥٠psi was used in the press to make sure that the materials are intact .The composite wood is left overnight to dry and improve its strength. Figure٥ shows the cold press machine pressing the assembled composite wood.

Fig. .Cold Press Machine Pressing the Assembled Composite Wood :٥

Plate 6 shows the cutting of the two 3 feet by 8 feet boards into eight pieces of 2 feet by 3 feet with a sawing machine similar to the one used in commercial wood products.

3.1.6. Cutting of the composite wood

The assembled composite wood is cut into eight pieces with diemnsions of٢ feet by٣ feet. These composite wood materials are now ready for the construction of the mini acoustics room. Figure٦ shows the finsihed product of the composite wood

Fig. Finished Product showing :٦٢ ft x٣ft Composite Woods

3.1.7. Construction of the Mini Acoustics Room

A mini acoustics room was constructed and used for tests and measurements to see if there if be any improvements with the revebrberations time in the room. To determine the difference in the sound quality inside the room، ordinary wood materials are first used and then replaced by the composite wood material. In both instances، the sound levels are measured using sound level meters. The reverberation times are also estiamted during these measurements wherein the signal drop by٦٠dB and more. The floor plan layout of the mini acoustics room used is shown in figure٧.

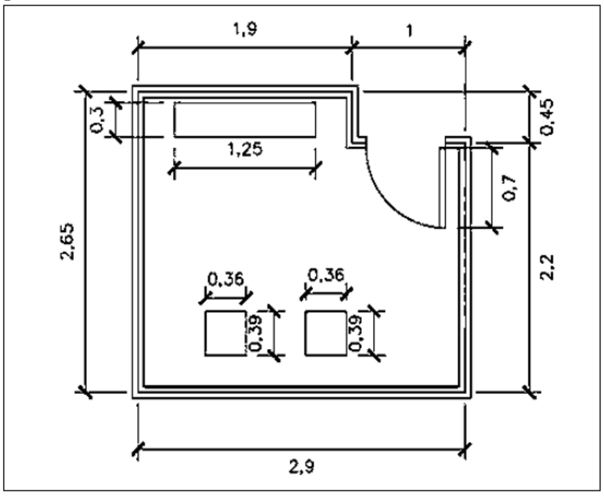

Fig. Floor Plan of the Mini Acoustics Room ٧

3.2. Acoustics Measurements

The second phase of this research is the preparation of the room for acoustic measurements and testing. Acoustics measurements are done using voice signal and music signal. A talking person induced the voice sound signal while a music player with speaker induced the music sound signal. The sound levels of the speech signals and music signals are measured using the sound level meters with five trials each. These measurements are done first using ordinary wood materials in the walls of the mini acoustics room, and second with the composite wood board materials as walls in the room.

For each trial, speech signals and music signals are first set to give a certain level of strengths such as 60dB, 70dB and so on. The sound level meters are used to verify that the test signal is within those levels. It is expected that these signal will slowly decay. The reduction in the sound levels are monitored until the signal has been reduced by one million times or by 60dB. The times from inducing the speech signals and the music signals and the time the signal decays by 60dB is considered to be the reverberation time of the signals. The results of the acoustics measurements are shown in the succeeding tables below.

Table 1: Sound level readings for voice sound signal and the reverberation time.

Sound Range	Initial Sound Level Meter Readings		Reverberation Time	
	Without Wood Board	With Wood Board	Without Wood Board	With Wood Board
(dB)	(dB)	(dB)	(seconds)	(seconds)
60	62.4	59.6	0.83	0.69
70	64.6	63.2	0.71	0.67

Table 1 shows the average data from measurements of voice or speech signal. The initial sound level meter readings are the sound levels when the speech signals are induced. The reverberation time is the time from the initial reading until the sound levels are decayed by 60dB. Five trials on each sound range are done during experiments.
After the acoustics measurements of voice or speech signals, the same procedures are done using the music signals. The measurements using the speech signals may be different from the measurements using music signals considering that voice signals have a frequency range from 300Hz to 3400Hz whereas music or audible signals have a frequency range of 20Hz to 20kHz. The results from acoustics measurements using the music signal is shown in table 2.
Table 3 shows the sound absorption coefficients of the materials used in the acoustic room at frequencies 125 Hz and 500 Hz. These values will be used for the computation of the sound absorption coefficient of the wood board

Table 2: Sound level readings for music sound signal and the reverberation time.

Sound Range	Initial Sound Level Meter Readings		Reverberation Time	
	Without Wood Board	With Wood Board	Without Wood Board	With Wood Board
(dB)	(dB)	(dB)	(seconds)	(seconds)
60	70	69.8	1.02	0.70
70	76.6	74.4	0.83	0.68
80	75.8	74.6	0.77	0.61

Table 3: Sound absorption coefficients of common building materials according to www.akustik.ua.

Material	125 Hz	500 Hz
Masonry wall (smooth concrete, painted)	0.01	0.01
Floor (carpet, thin, over thin felt on concrete)	0.10	0.25
Ceiling (plywood)	0.30	0.20
Door (solid timber)	0.14	0.06
Chair (Auditorium seat, unoccupied)	0.13	0.59
Cabinet (4mm glass)	0.30	0.10

Table 4: Summary of the computed sound absorption coefficients of the board.

Sound Signal	Reverberation Time (seconds)	Sound Absorption Coefficient
Voice	0.69	0.011
	0.67	0.047
Music	0.70	0.013
	0.68	0.048
	0.61	0.188

Table 4 shows the summary of the sound absorption coefficients computed based on various reverberation times of voice and music sound signals measured in Tables 1 and 2. It can be seen that the resulting values are close to the sound absorption coefficient of the concrete wall found in Table 3.

4. Conclusion

In this study, composite wood boards partially made of rice straws are constructed and used to improve the acoustic quality or reverberation times in the room. Through actual experiments, it is found that rice straws can be used as an alternative sound absorbing material which is very cheap and easy to construct.
Through experiment results, the produced wood board has a sound absorption coefficient ranging from 0.011 - 0.188. These values are comparable to that of the sound absorption coefficients of masonry walls thus can be used in replacement of masonry walls for sound insulation without considering its strength.

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