DEVELOPMENT OF ULTRASONIC AND MICROWAVE TECHNIQUES FOR DETECTION OF DECAY IN WOODEN CROSS-ARMS

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Abstract: Most of the cross-arms of the 275 KV and 123 KV transmission lines in Malaysia and certain countries are using hard wood especially from chengal species. Due to natural weathering this wooden cross-arms is degraded and decayed. For safety reason there is a need for a simple, light, and accurate non-destructive decay detection.

In this project the microwave reflection technique and ultrasonic method which is based on the transit time have been developed for in-situ measurement.

In this study, we categorize the decay on the wood into three stages of decays namely severely decay, incipient decay and sound wood. In microwave method these stages can be related to the amount of water that can be absorbed by weathered wood and secondly on the wood density at particular moisture content especially at environmental moisture content. This method managed to detect inner decay up to 2 cm from the surface of the wood.

In ultrasonic method, an investigation has been done to find suitable method of measurement, especially detection of decay under the metal block. Appling this detection system the transit times along l-l direction for sound wood, incipient wood, and cracked wood fall under the ranges of 100µs to 200µs, 200µs to 500µs, and above 500µs respectively. To complete the study, several prototypes have been developed, which can be used for field-testing or maintenance work.

Introduction: In Malaysia, 90% wood poles and wooden cross-arms are used as transmission line supports for power pylon towers of power rating 275KV and 132KV. The hardwoods from chengal species[1] are used for this purpose. The hot and humid climate in tropical countries like Malaysia facilitates the growth of fungi and other destructive microorganisms in wooden structures. Thereby, deterioration of wooden structures occurs in the form of splits, cracks, and other defects that permit the entry of fungi into the cores of the poles, rendering them unsuitable for use as line supports.

(a) (b)

Figure 1 : (a) 132 kV transmission tower (b) Close-up picture of a wooden cross-arms

Concerning about the safety to life and property, service interruption and efficient method for maintenance and replacement of the wooden cross-arms therefore, there is a need for a portable, easy, light, small, NDT and accurate sensor for decay detection.
The wooden cross-arms structure of the pylon is shown in Figure 1. Normally the wooden cross-arms can be used up to 30 years depending on the species, the age of the supplied wood and weather. The weathered wood can be classified into three categories, namely sound wood, incipient wood and severely decayed wood. Sound wood appears no sign of visible decay, still hard and without any visible attack from fungi. For incipient wood, the samples appear to be attack by brown rot fungi and quite soft and can be broken using little extra force. Severely decayed wood shows some signs of crevices and small valleys on the surface, very soft and can be easily broken.
It is a great challenge to develop a device which can detect the decay or deterioration of the wood from the ground or remote detection. In the conventional method the maintaining staff has to climb up (20-30 meters height) and used knocking procedure and the decision is based on the detected sound.
In this project, microwave and ultrasonic NDT method have been proposed to detect the level of decay in the wooden-cross arms. This paper will highlight the development of both methods and looking at their strengths and weaknesses.

Results:

(a) Microwave technique

In this technique the stage of decay is determined by looking at the variation of microwave reflection power with the extent of moisture absorbed by the sample [2,3] or base on the density or compactness of the samples [4].
During the rainy season, the maximum MC that can be absorbed by the sound wood is about 15%, while for decayed wood it is about 35% and corresponding to detected current of the microwave detector of about 0.3 mA and 0.6 mA respectively. This indicates, there is a possibility of using MC and its corresponding detected current as the indicator of decay. If the detected current for a particular sensor is more than 0.5 mA, the wood is considered already decay. However the measurement has to be performed immediately after the rain and it is not appropriate as far as the operator safety is concerned.
The above problem can be solved by considering the variation of the density of the sample with the stage of decay. It is found that at environmental moisture content (EMC), the density of the sound wood is about 800 kg/m^3 and about 625 kg/m^3 for severely decayed wood which are corresponding to reflection power of about 0.14 mW and 0.02 mW respectively. The measurement base on the density of the wood is preferable as the measurement can be performed at most of the time especially during the dry season.
Microwave reflection technique is still facing a lot of challenges such as surface roughness, lower penetration depth (up to 2cm) and unable to detect the level of decay for the wood behind the metal plate at the end-joints.

(b) Ultrasonic technique

In this technique, the status of decay or detection of the crack is determined by measuring a transit time for the ultrasonic pulse to travel along the specific positions of the wooden cross-arms. For this purpose the ultrasonic tester (model Steinkamp BP-V (45kHz)), with measuring range from 0.1 to 9999.9 μs and an accuracy in the order of ± 0.05μs is used.
The measurement of transit time is done by locating the transmitter at the centre of the cross-section of the end-joint and the receiver is placed at several points along the upper plane named

as upper method or making a U-shaped at specific distance from the end-joint named as U-method.

(i) Upper method

The structure of the Chengal wood end-joint and transit time measurement set-up are illustrated in Figure 2. The transmitter is fixed at the centre of cross-section (the *w-p-s-z* plane) of the end-joint and the receiver is moved along the lines A, B, C, D and E, starting from the end point of the cross-arm.

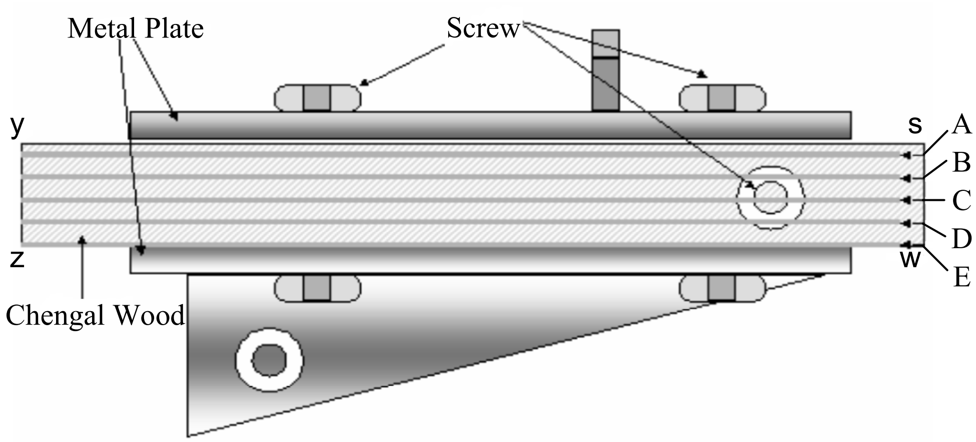


Figure 2 :Experimental Set-Up for Upper method (Top View).

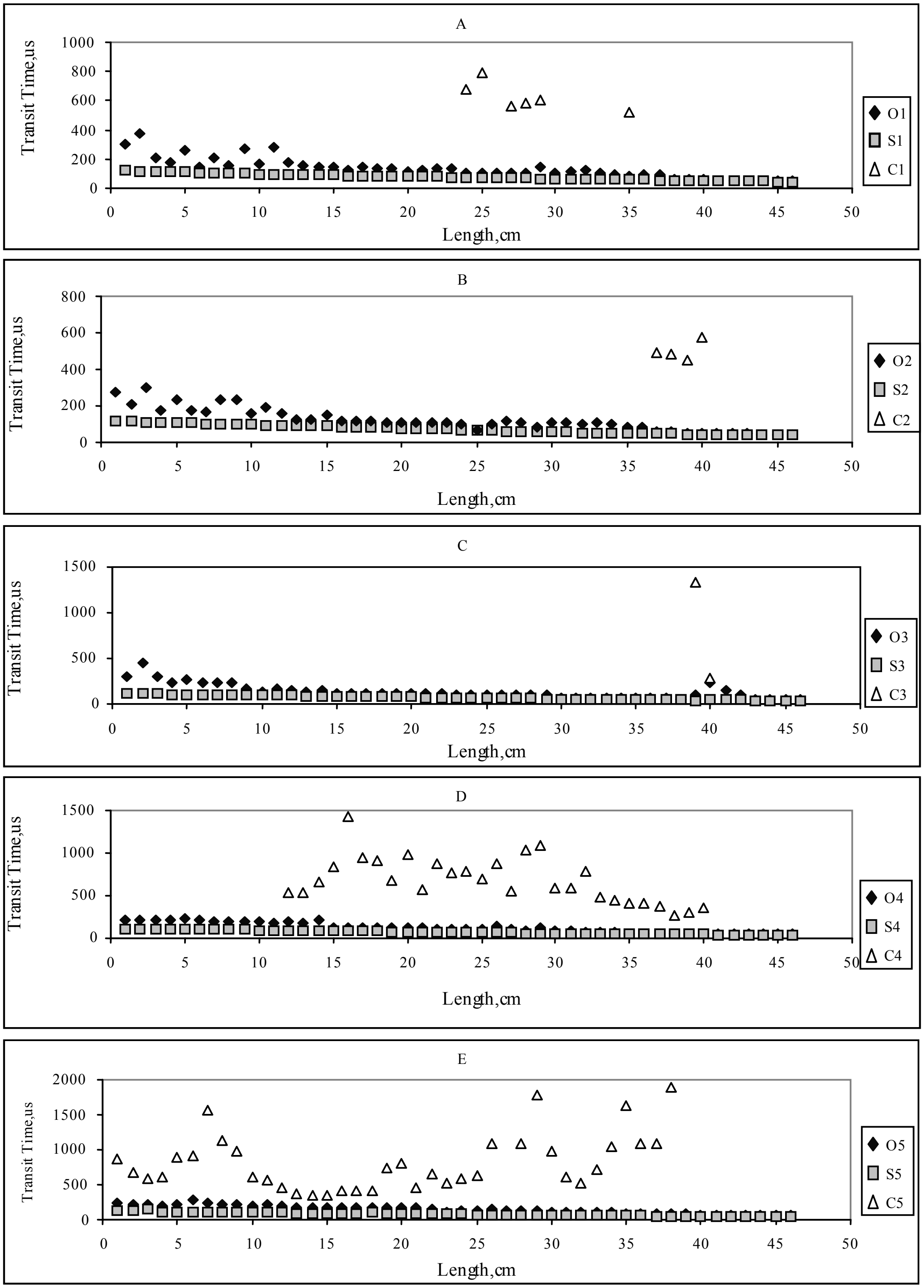


Figure 3 : Transit Time Detected for Sound Wood (S), Old Wood (O), and Cracked Wood (C) by using Upper method. Graphs A, B, C, D, and E correspond to the measurement lines as in Figure 2.

Figure 3 shows the transit times as the receiver moves along the surface of the end-joint. Based on graphs A, B, C, D, and E the transit time for the sound wood varies from about 40μs to 120μs. While for old wood , the transit time is in the range of about 50μs to 300μs. However, for the crack wood , the transit time is above 300μs and mostly beyond the limit of detection, which may be due to the absorption of the signal by the crack line. A better transmission is observed along line D and E of the cracked wood as the pulses can be detected by the instrument and the reading is high and above 300μs.

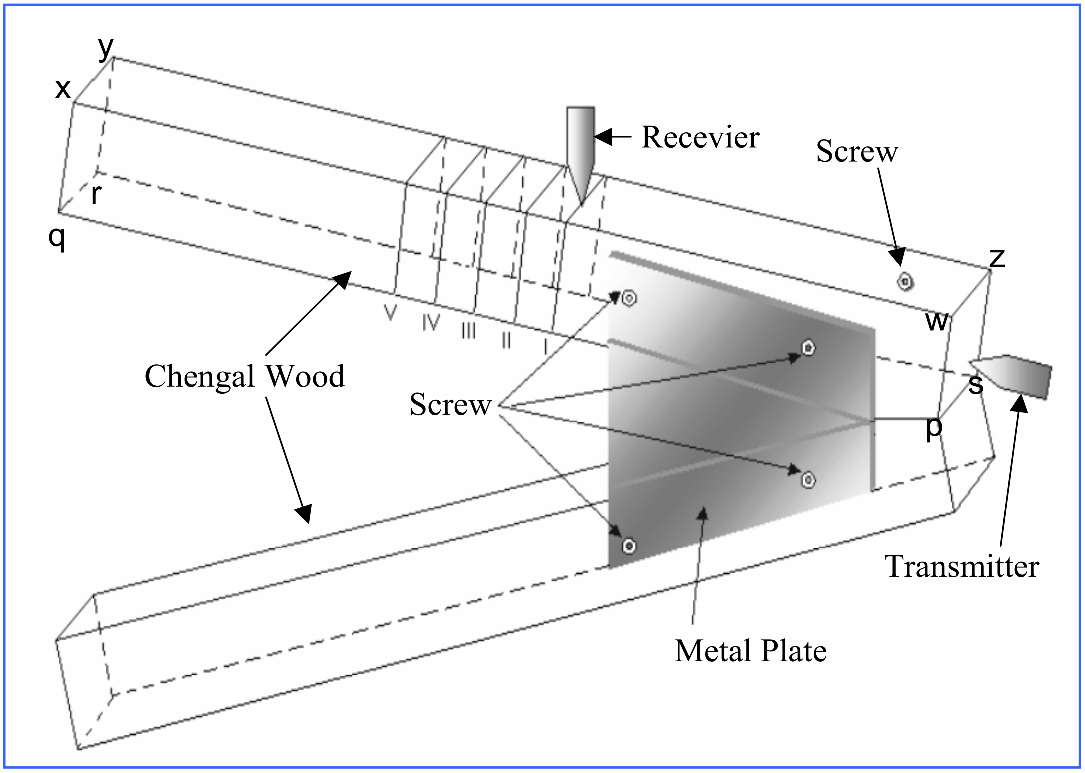


Figure 4 :Experimental set-up for U-method

(ii) U-method

The implementation of U-method to detect the transit time signal for the Chengal wood end-joint is shown in Figure 4. For all measurements, the transmitter is fixed at the center of the *w-p-s-z* plane, while the receiver is moved around the pole at positions indicated by labels I, II, III, IV . All the paths are making a U shape and in the direction of from *q* to *x*, *x* to *y* and *y* to *r*. For this sample the crack is located at the bottom part of the end-joint.
Figure 5 shows the transit times along the q→x→y→r. For the old wood , the transit time is ranging from about 200μs to 500μs when the receiver moves from *q* to *x*, 160μs to 500μs from *y* to *r*, and about 200μs to 1000μs from *x* to *y*. However, for the sound wood S, the transit time always remains in the range from about 100μs to 200μs. It is noticed that for the cracked wood, in all five graphs, the signal is hardly observed along the direction *x* to *y.* This is due to the absorption by the crack as the ultrasonic pulse travels from transmitter to receiver. In conclusion, the crack or discontinuous medium can be easily detected through this method and hence considered as the best method for the detection of cracks or level of decay for the end-joint.

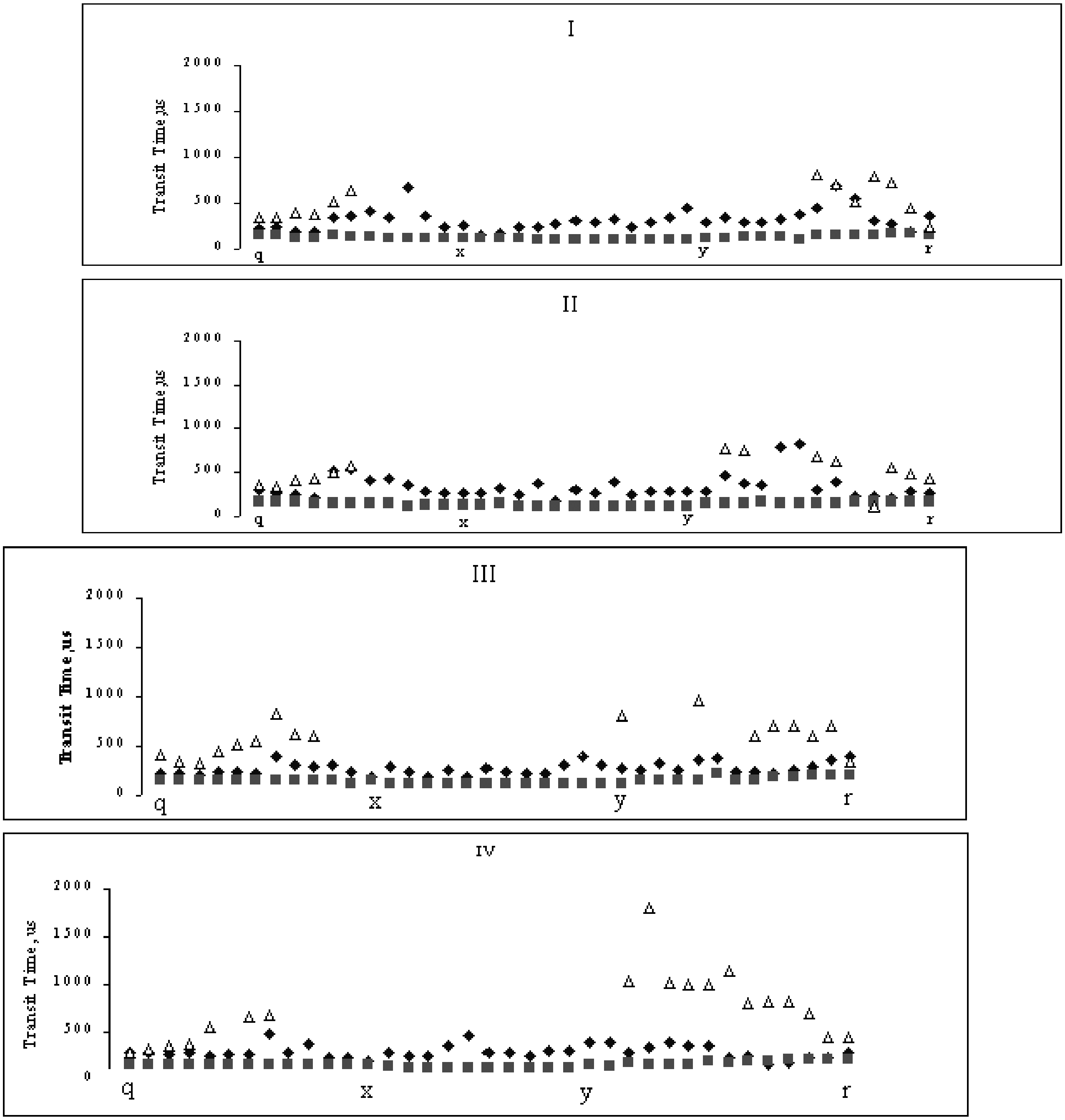
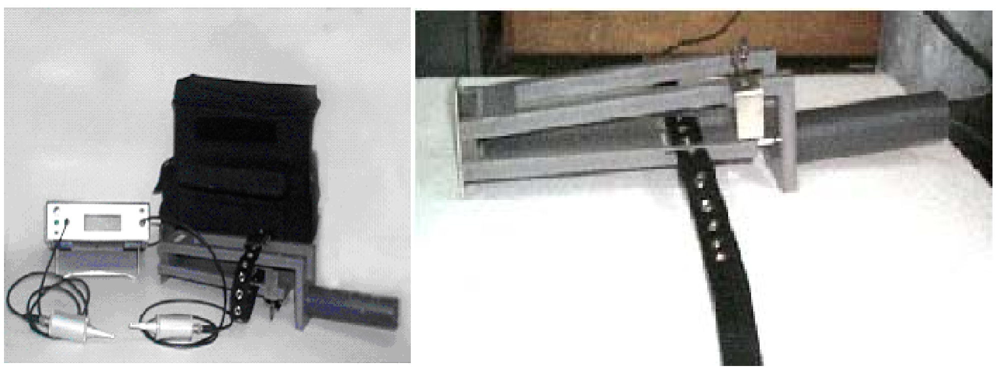


Figure 5 : Variation of transit time using U-method for Sound Wood (S), Old Wood (O), and Cracked Wood (C) . Graphs I, II, III, IV, and V correspond to the U shapes in Figure 4.

Discussion: The detection of decay based on microwave technique has been developed by looking at the aspect of the extent of moisture content that can be absorbed by decayed wood and secondly based on the compactness or density of the decayed wood. The first principle only can be applied during the rainy day while the second one is affected by the surface roughness and lower penetration depth. Most of the decay can be found in the region under the metal plate, the

place where the water is easily trapped. It is almost impossible to detect this area as microwave radiation is almost totally reflected by the metal.
Microwave method is still useful especially to provide a quick method to determine the density of the newly supply chengal wood as some of them still at the juvenile stage and not suitable for the cross-arms.
Ultrasonic methods offer the solution for the detection of decay especially in the area under the metal plate. Both upper method and U-method can be applied however the U-method is preferable, since it needs only a few points to probe the whole volume of the materials. Based on this method, the transit time values are found to be in the range of about 100us to 150us for sound wood and 160us to 450us for old wood respectively, while no signal is detected for cracked wood. This method is recommended for maintenance purposes and a simple sensor holder (see Figure 6) can be design to perform a quick measurement and to obtain a reliable result.



(a) (b)

Figure 6 (a) transit time equipment and accessories (b) Sample holder and measurement belt

The sensor holder design is based on the size of the ultrasonic sensor (model: Steinkamp BP-V). The major part of the sensor holder is made from PVC material as to avoid any high power shock. The total length of the holder is about 60cm with one end to place the transmitter at the end is receiver. The points of measurement for the receiver are selected by simply place the probe in the hole of the measurement belt. The measurement belt has five small holes that make up of the five measurement points for each sample. The distance of the square hole from the transmitter fixed point is about 40.0cm to 45.0cm.
Conclusion: In this project we have presented microwave and ultrasonic methods for the detection of decay level of the wooden cross-arms. The U-method base on the measurement of transit time of the ultrasonic pulse passing through the wood under the metal plates is found suitable for this purpose. A portable instrument can be developed using this technique and will provide a useful tool for the maintenance staff to make a decision for the replacement of the wooden cross-arms.
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