

DESIGN AND DEVELOPMENT OF COCONUT PALM (*Cocos nucifera* L.) ROOF SHINGLES

by
A.R. Floresca, F.R. Siriban and A.P. Gesmundo¹

ABSTRACT

Tapered roof shingles from coconut wood were fabricated and treated separately with four preservatives, namely: copper-chrome arsenate, pentachlorophenol, copper sulfate and copper sulfate + potassium dichromate. Untreated and treated shingles were installed side in roof framed structures and exposed outdoor in the FPRDI "graveyard" area for weather and durability tests.

Fabrication, treatment and installation costs of shingles were evaluated. Performance ratings on the different degradations such as splitting/checking and twisting of shingles, retention of original colour/appearance, and protection from weathering and fungal infection in relation to thickness, nailing patterns and treatments of coconut wood roof shingles after 11 months of weather exposure tests were evaluated and statistically analysed.

Cost comparison between coconut wood roof shingles and G.I. corrugated sheet gauge #26 are also presented in this report.

INTRODUCTION

Shelter has always been a basic necessity of man. The most common housing materials are wood and wood products derived from premium and commercially known timber species. Due to the dwindling supply of traditionally-used timber for housing, the search for cheap and available substitute materials is imperative. The escalating cost of a housing unit is directly related to the increasing cost of labour and roofing materials such as G.I. sheets, ceramic shingles, asbestos and others.

The utilization of raw materials from coconut wood for roofing shingles will stimulate industrial interests and encourage a new business venture which can help solve the unemployment problem. Moreover, information gathered from this study will aid builders and the government in the smooth implementation of its human settlement programme because coconut wood would certainly augment needed materials for house construction and eventually bring its cost down.

Shingles are small, thin pieces of wood with parallel edges and tapering thickness in which one end is thicker than the other (Brown 1950; and Panshin et al 1962). Wood shingles are conventionally used as walling and roofing materials. The wood shingle industry has been established in the United States, Canada and some European countries. In the Philippines, Zamboanga Wood Products, Incorporated (Zambo Wood) in Zamboanga City started wood shingle manufacture in the latter part of 1960. Until now, it is the only company known to produce wood shingles from local timber species, namely: 1) tangile (*Shorea polysperma* (Blanco) Merr.); 2) red lauan (*Shorea negrosensis* Foxw.); 3) almon (*Shorea almon* Foxw.); 4) mayapis (*Shorea palosapis* z.) Dyer.; 5) bagtikan (*Parashorea malaanonan* (Blanco) Merr.); and 6) tiaong (*Shorea agsaboensis* Stern) Eala et al 1979). It also manufactures wooden shingles for roofing from log ends generated from logpond trimmings.

¹ Researchers, Housing and Materials R&D Division, Forest Products Research and Development Institute, Department of Science and Technology, College, Laguna 4031, Philippines.

Wood for use in the manufacture of shingles should have the following properties: 1) durability; 2) free from splitting during nailing; 3) dimensional stability, i.e., low ratio of tangential to radial shrinkage and minimum shrinkage in all planes; 4) light weight; 5) good insulating properties; 6) adequate strength; 7) straight and even grain for ease of manufacture; 8) ability to take stain and paint; 9) ability to resist abrasion; and 10) pleasing appearance (Panshin et al 1962). Availability of sufficient supplies of raw materials at a reasonable cost is one important factor.

Under the ordinary method of using shingles in building construction, it was found (Browne 1947) that shingle materials from the heartwood of redwood and balcypress performed well without preservative treatment. It was also found that edge-grain shingles were much better than flat-grain shingles because they warped much less and withstood weathering better because shingles exposed to weather tend to curl. However, in commercial shingles from cedar, cypress and redwood the amount of curling is negligible. Superficial application of creosote, linseed oil or even used automobile crankcase oil will keep shingles from curling.

Eala et al (1979) reported that in 1978, the manufacturing cost of shingles at Zambo Wood was as follows: wood cost (at 31% recovery) = 12%; labour cost = 33%; supplies and operating cost = 32.9%; and others = 22.1%.

Shingles from coconut trunk had been fabricated at FPRDI but research on its utility and efficiency had not been extensively carried out. However, the Zamboanga Research Centre (ZRC) of the Philippine Coconut Authority (PCA) in San Ramon, Zamboanga City has successfully constructed model coconut wood houses roofed with coconut shingles (Escarillo Jr. 1984). The roof shingles were treated with copper-chrome-arsenate (CCA) and usually made of high density coconut wood. Each shingle was 102 mm wide, 406 mm long, and 4.8 mm thick at the thin end and 14.3 mm thick at the thicker end. Madrazo and Sulc (1983) cited the field exposure tests of treated coconut wood shingles for roofing materials by Palornar, R.N. and V.K. Sulc (1983). A study on the relative performance of three readily available inorganic chemicals containing either copper or chromium applied to sawn coconut timber had. also been conducted by Palomar and Sulc (1983).

In the survey conducted by Reyes (1976), roof materials used were found to be the least diversified and that the most commonly used of these materials was the G.I. sheet, in spite of the fact that it is expensive and gives the most heat discomfort. Probably the greatest drawbacks on the acceptance of nipa and cogon as roofing materials are their Short longevity or durability and inflammability. Reyes said nipa lasts 1-3 years. Cogon on the other hand, lasts only a year when installed at 13 mm thick and unbundled, but when bundled and with the proper slope of roof, cogon could last 10-15 years.

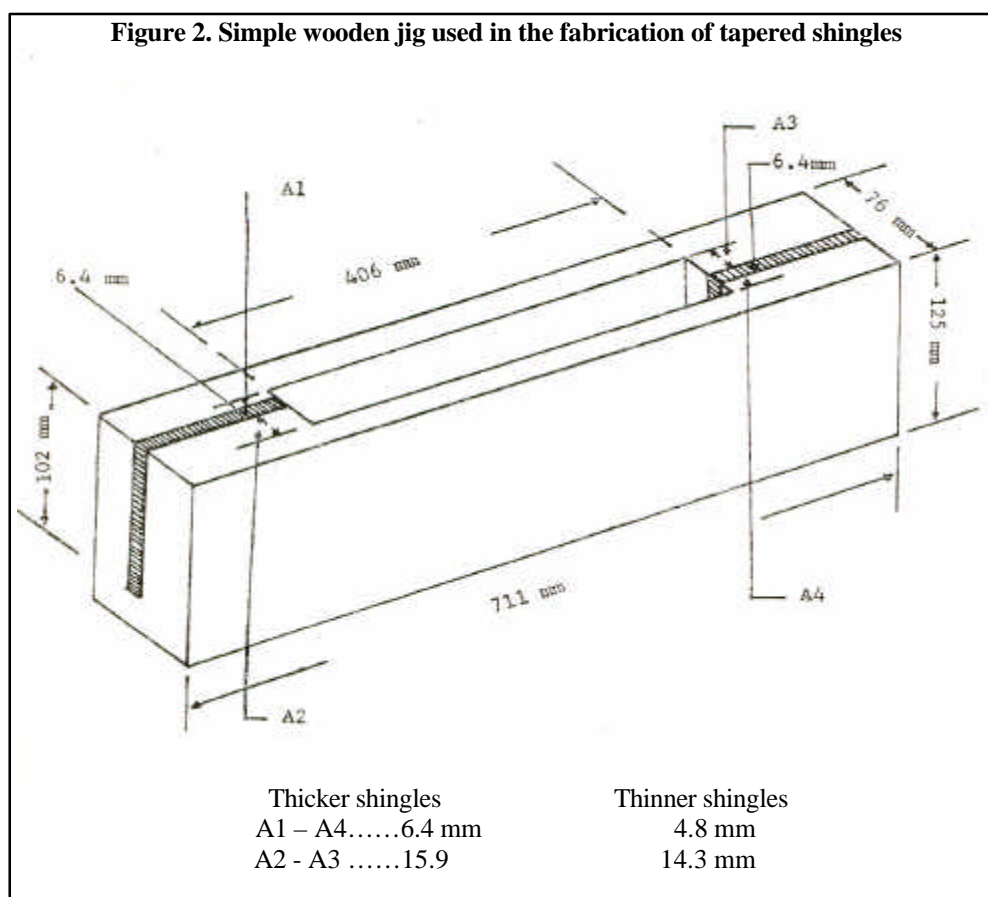
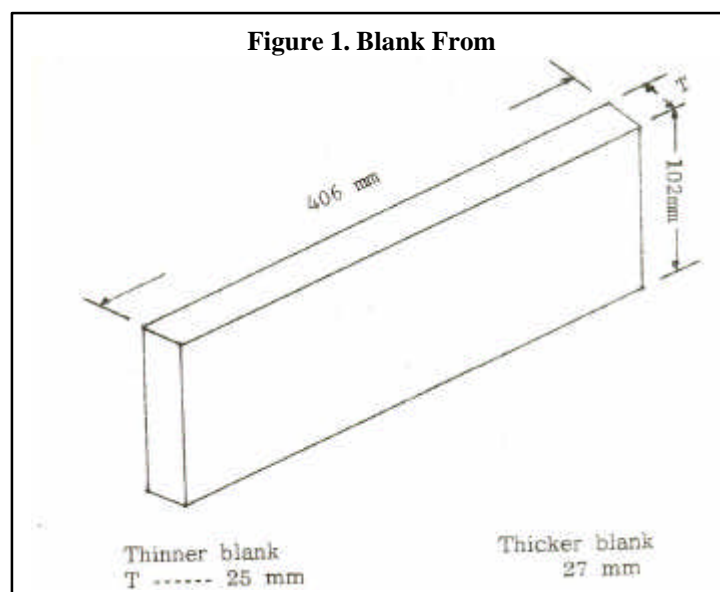
A demonstration house roofed with treated cogon (*Imperata cylindrica*) was erected at the FPRDI towcost housing area in 1981 (Siopongco et al 1982). The efficiency of its parts has not yet been extensively studied.

The objectives of this study are to: 1) evaluate processing characteristics and properties and develop appropriate technology in the manufacture of roof shingles from coconut palm; 2) design and fabricate roof shingles from coconut palm; 3) develop construction techniques in terms of installation and weather protection; and 4) assess the actual cost and service ability of the roof materials installed.

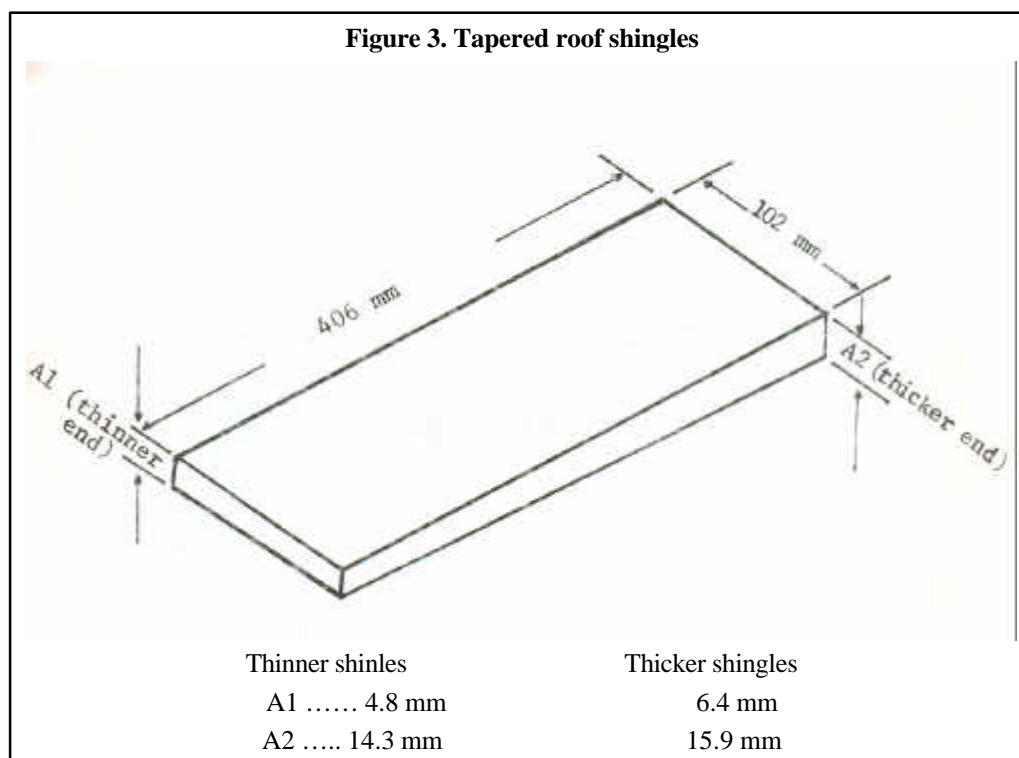
MATERIALS AND METHODS

The wood materials used were obtained from coconut logs collected from Barangay Mainit, Bay, Laguna.

The 3,000 mm long log samples (butt portion) of coconut were converted into 32 x 110 mm flitches, then air-dried for about 3 to 4 weeks. Coconut wood flitches with medium and high density were used for roof shingles. The flitches were planed to a uniform thickness of 25/27 mm and width of 102 mm prior to cutting into 406 mm long "blank" forms (Fig. 1). The blanks were sawn into tapered shingles using a simple wooden jig (Fig. 2) to hold the blank when fed manually to the table saw. The final product are two pieces of tapered shingles which were 102 mm wide, 406 mm long, and 4.8/6.4 mm thick at the thin end and 14.3/15.9 mm at the thicker end (Fig. 3).



The shingles were treated separately by soaking in 8% solution of copper-chrome-arsenate (CCA), 5% solution of copper sulfate (CS), and 5% solution of copper sulfate + potassium dichromate (CS + PD) for three days and overnight in 5% solution of pentachlorophenol (PCP) dissolved in diesel fuel. Eighteen shingles per treatment per thickness were used. Prior to treatment, the average moisture contents of medium and high density coconut shingles were about 17.0% and 17.8%, respectively.



The treated and untreated roof shingles were installed side by side in roof framed structures and exposed outdoors in the FPRDI "graveyard" area with 7/12 slope (Fig. 4). The shingles were exposed on January 6, 1986.

The shingles were installed by nailing them with a 38 mm CWN to the 32 mm x 45 mm purlins spaced 165mm o.c (Fig. 5). Installation of shingles began at the lowest portion of the roof framings. Shingles were installed by overlapping row by row from the eaves to the ridge. A straight wooden board was used to guide rows of shingles during installation (Fig. 5). Two nailing patterns were applied, i.e., 50% of the shingles with 2 nails and the other 50% with only 1 nail.

The first row of shingles were installed so that the thicker ends were oriented at the eaves and the thinner ends towards the ridge of the roof (Fig. 5). The thinner ends also coincided above the second purlin. Provision for swelling or expansion to prevent possible buckling or warping of shingles have been made by providing 3 mm spacing between the shingles when placed side by side. The shingles were nailed by driving 2 nails spaced 50 mm apart and edge distance of 25 mm thru the first purlin only. To prevent splitting, coconut shingles were prebored about 80% of the nail diameter prior to nailing. The protruding portion of shingles installed at the first row were trimmed at a distance of about 54 mm from the centre of the first purlin.

The second row of shingles was installed so that it covered the side joints of the first row of shingles (Fig. 5). The thicker ends were also oriented at the eaves and the thinner ends exactly above the third purlin. Side spacing of shingles used was 3 mm apart. The shingles were nailed in the same manner as in the first row. The nails were driven through the second purlin. At this position, the thicker ends of the shingles were exactly 53.5 mm below the centre of the first purlin.

Figure 4. Coconut wood roof shingles exposed outdoors at the FPRDI “graveyard” area.



All succeeding , odd rows of shingles were installed in line and in the same manner as in the first row of shingles, except that only one nail per shingle was used. Singles in the even rows were also installed in line and in the same manner as in the second row of shingles. Only one nail per shingle was used in the 4th row of shingle thru the purlins on which the thinner ends of proceeding row of shingles was resting.

The exposed shingles were periodically inspected to assess their performance with regards to splitting/checking on the nail portion, twisting of shingles., retention of original colour/appearance, weathering and fungal infection. The effect of nailing pattern was also

investigated. The exposed shingles were evaluated after 11 months of outdoor exposure and the assessment was made based on the percentage ratings presented below:

Degree of splitting/checking		%
1.	No splitting/checking	100
2.	Splits/checks, 102 mm long	75
3.	Splits/checks, 203 mm long	50
4.	Splits/checks, 304 mm long	25

Degree of twisting

1.	No twisting	100
2.	Twist, 6.4 mm high	75
3.	Twist, 12.7 mm high	50
4.	Twist, 19.0 mm high	25

Retention of original colour/appearance

1.	No significant change in colour/appearance	100
2.	Slight deviation from the original cleanliness and-color but color remains uniform and pleasing	75
3.	Moderate change in appearance; needs refinishing	50
4.	Marked deviation from the original appearance-with displeasing colour	25

Protection of wood surface from weathering/fungal infection

1.	No significant weathering of surface	100
2.	Slight softening of the surface fibers-and brittle when proved resulting to-a fiberless cork-like surface	75
3.	Moderate softening of surface up to-about 4.5 mm deep	50
4.	Deep softening with slight erosion of-the the surface fibres	25

Analysis of variance on the performance ratings based on the different degradations of the coconut wood roof shingles was conducted using the Randomized Complete Block Design. Mean performance ratings were further compared using Duncan's Multiple Range Tests.

The cost of using coconut wood roof shingles was compared to G.I. corrugated 2 sheets using roof framing with an area of about 58 m², using the exchange rate of US\$ 1 = PHP20.00.

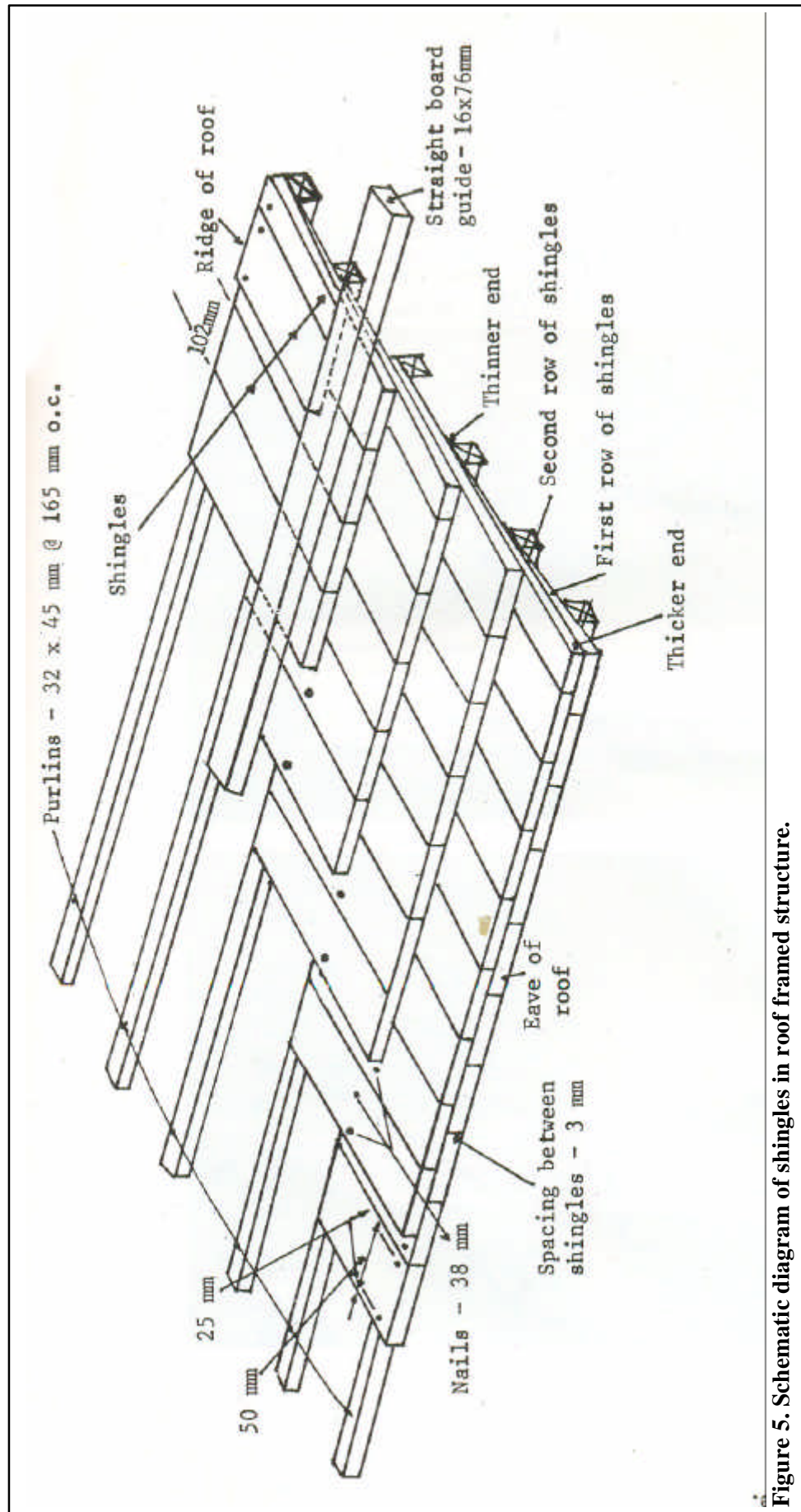


Figure 5. Schematic diagram of shingles in roof framed structure.

RESULTS AND DISCUSSION

The fabricated shingles from coconut wood had a width of 102 mm and length of 406 mm with thickness of 14.3/15.9 mm on one end and 4.8/6.4 mm on the other (Fig. 3). The estimated fabrication cost per shingle was about US\$0.025. The average time required for the fabrication of a shingle was 3 min. and 25 sec. The total number of coconut wood shingles that could be fabricated per hour from "blank" form to tapered shingles was 250 pieces. The average retention (kg/m^3) and absorption (g/m^2), and treatment cost per shingle for the different preservatives used are presented in Tables 1 and 2, respectively. Generally, thicker shingles and medium density coconut wood shingles had higher retention and absorption than thinner shingle and high density coconut wood shingles. This means that treatment cost per shingle was also higher in thicker and medium density coconut wood shingles than the thinner and high density coconut wood shingles. In the installation or laying of coconut wood shingles, it was estimated that the cost per m was US\$1.825 (Table 3).

The results of analysis of the variation in the performance ratings on the twisting and splitting of coconut wood roof shingles with respect to thicknesses, nailing patterns and treatments are presented in Table 4. The variation in performance ratings on the degree of twisting of both high and medium density shingles with respect to thicknesses, nailing patterns and treatments did not vary significantly. The degree of occurrence of the splitting of shingles with respect to thickness in both high and medium density wood, and nailing, patterns in medium density did not also vary significantly. Splitting of shingles with respect to the treatments in both high and medium density, and nailing patterns in high density, however, differed significantly as shown in Table 4. Results of further analysis of the extent of variation using Duncan's Multiple Range Tests are presented in Tables 5 and 6. The most suitable combinations of thickness, nailing pattern and treatment for high density coconut wood shingles will be any of the thicknesses with 2 nails and with treatment of either copper-chrome-arsenate or pentachlorophenol. In medium density coconut wood shingles, any of the thicknesses and nailing patterns and treatments of either pentachlorophenol or copper-chrome-arsenate can also be used. In both the high and medium density coconut wood shingles, the thinner with 2 nails and treatment of copper-chrome-arsenate is preferred for economy and ease of installation.

The results of the analysis on the variation of performance ratings on the retention of original color/appearance and protection of surface from weathering of coconut wood roof shingles with respect to thicknesses, treatments and densities after 11 months of exposure are presented in Table 7. The performance of the shingles with respect to thickness and densities did not vary significantly, but differed significantly with respect to treatments as shown in Table 7. The results of further analysis on the extent of variation using Duncan's Multiple Range Tests (Table 8) also showed that the three treatments were significantly different at 1% level of significance. There was no significant change in colour/appearance and weathering of surface observed in shingles treated with copper-chrome-arsenate, pentachlorophenol, and copper sulfate.

In the analysis of the variation of performance ratings on the protection of surface from fungal infection of both high and medium density coconut wood shingles after 11 months exposure, no significant effects were observed as shown by the "F" ratios (Table 9). This may be due to the short period of exposure, i.e., 11 months in test only.

Table 1: Average retention and absorption for the different treatments of Roof Shingles from coconut (*Cocos nucifera* L.)

Density Thickness Of shingles	Retention (kg/m ³)				Absorption (g/m ²)			
	Copper- Chrome Arsenate	Pontachlo- Rophenol	Copppe Sulphate	Copper sulphate + pottasium dichromate	Copper- Copper- Arsenate	Pontachlo- Rophenol Arsenate	Copppe Sulphate	Copper sulphate + pottasium dichromate
High Density								
Thicker Shingles (6.4 x 15.9 x 102 x 406 mm)	7.852	4.804	5.357	5.051	82.556	50.509	56.325	53.108
Thinner Shingles (4.8 x 14.3 .x 102 x 406 mm)	6.982	4.853	4.900	4.604	64.662	44.948	45.379	42.641
AVERAGE	7.417	4.828	5.128	4.828	73.609	47.728	50.852	47.874
Medium density								
Thicker shingles	10.238	5.452	5.792	6.282	107.636	57.320	60.897	66.048
Thinner shingles	9.907	6.164	5.780	7.081	91.754	57.087	53.533	65.582
AVERAGE	10.072	5.808	5.786	6.682	99.695	57.204	57.275	65.815

**Table 2: Estimated average treatment cost per shingle of shingles from coconut
(*Cocos nucifera L*) wood**

Treatment	C o c o n u t			
	Highe density		Medium density	
	Thicker	Thinner	Thicker	Thinner
Copper-chrome Arsenate	US\$ 0.0085	US\$ 0.0065	US\$ 0.0110	US\$ 0.0090
Pentachlorophenol	0.0014	0.0120	0.0160	0.0160
Copper sulphate	0.0025	0.0020	0.0030	0.0025
Copper sulphate + Potassium dichromate	0.0055	0.0040	0.0065	0.0065

Table 3: Estimated average installation cost per Square Meter (m³) of roof shingles from coconut (*Cocos nucifera L.*) wood

Particular	Coconut
Installation of roof framed structure	US\$ 0.725
Installation of shingles	US\$ 1.825
T O T A L	US\$ 2.55

Table 4: Analysis of Variance of Performance Ratings on the twisting and splitting of Coconut (*Cocos nucifera* L.) Wood Roof Shingles with Repeat to Thicknesses, Nailing Patterns and Treatments

Degradation	Sources of Variations	Degrees Of Freedom	High Density			Medium Density		
			Sum of Square;	Mean Squares;	F-ratio ¹ ;	Sum of Squares	Mean Squares;	F-ratio ¹
Twisting of Shingles	Between thickness	1	162.25	162.25	.738276 NS	126.26	126.25	.671749 NS
	Between treatments	4	845.5	211.625	.962944 NS	891.75	222.937	1.1862 NS
	Between nailing patterns	1	168	168	.76444 NS	72.5	72.5	.385757 NS
	Interaction between Thickness and treatments	4	373	93.25	.42431 NS	477	119.25	.63450 NS
	Interaction between thicknesses and nailing patterns	1	944.75	944.75	4.29884 *	80	80	.425663 NS
	Interaction between treatments and nailing patterns	4	535.5	133.875	.609163 NS	750.5	187.625	.998312 NS
	Interaction between thicknesses, treatments and nailing patters	4	764.5	191.125	.86966 NS	274.75	68.6875	.365471 NS
	Error	160	35163	219.769		219.769	30070.7	187.942
	Total	179	38957.5			32743.5		
Splitting of Shingles	Between thickness	1	35.375	35.385	.40726 NS	80	80	.899698 NS
	Between treatments	4	2757	689.25	7.9351 **	4478.12	1119.53	12.5905 **
	Between nailing patterns	1	1421.87	1421.87	16.3696 **	18.625	18.625	.20946 NS
	Interaction between Thickness and treatments	4	244.75	61.1875	.704431 NS	308.875	77.2187	.868419 NS
	Interaction between thicknesses and nailing patterns	1	21	21	.241766 NS	5.5	5.5	.0618542 NS
	Interaction between treatments and nailing patterns	4	144.875	36.2187	.416974 NS	112.5	28.125	.3163 NS
	Interaction between thicknesses, treatments and nailing patters	4	905.5	226.375	2.60618 *	386.75	96.6875	1.08737 NS
	Error	160	13897.7	68.8609		14227	88.9187	
	Total	179	19428.1			19617.4		

¹ ns – Not significant

** - significant at the 1% level

* - significant at the 5% level

Table 5: Variation of performance Ratings (%) on the Splitting at the Nailed Portion of Medium Density Coconut (*Cocos nucifera* L.) Wood Roof Shingles with Respect to Treatments After 11 Months of Outdoor Exposure^{1/}

Treatment	Thicker		Thinner	
	1 nail	2 nails	1 nail	2 nails
Control (untreated)	80.4 (abc)	89.2 (a)	83.7 (abc)	83.9 (abc)
Copper-chrome-arsenate	84.4 (abc)	91.9 (a)	86.4 (abc)	92.6 (a)
Pentachlorophenol	77.1 (bcd)	90.7 (a)	84.3 (abc)	91.4 (a)
Copper Sulfate 75.9(cd), 74.8(cd), 83.9(abc)	74.9 (cd)			
Copper Sulfate + Potassium dichromate	83.8 (abc)	82.4 (abc)	67.9 (d)	87.4 (abc)

^{1/} Mean of 9 replicates. Means having the same letter are not significantly different at 5% level of significance (Duncan's Multiple Range Tests).

Table 6:- Variation of performance Ratings (%) on the Splitting at the Nailed Portion of Medium Density Coconut (*Cocos nucifera* L.) Wood Roof Shingles with Respect to Treatments After 11 Months of Outdoor Exposure¹

Treatment	Mean Value
Control (untreated)	94.1 (b)
Copper-chrome-arsenate	93.5 (a)
Pentachlorophenol	95.6 (a)
Copper sulfate	87.8 (b)
Copper sulfate + Potassium dichromate	89.4 (b)

^{1/}Mean of 36 replicates. Means having the same letter are not significantly different at 5% level of significance (Duncan's Multiple Range Tests).

Table 7: Analysis of Variance of Performance Ratings on the Retention of Original Colour/ Appearance and Protection of Surface From Weathering of Coconut (*Cocos nucifera* L.) Wood Roof Shingles with Respect to Thicknesses, Treatments and Densities After 11 Months of Outdoor Exposure

Source of Variations	Degrees Of Freedom	Sum of Squares	Mean Squares	F.-ratio ¹
Between thicknesses	1	6.75	6.75	.277703 NS
Between treatments ²	2	14242.5	7121.25	292.977 **
Between densities	1	6.75	6.75	.277703 NS
Interaction between thicknesses and treatments	2	-5	-2.5	-.102853 NS
Interaction between thicknesses and densities	1	-6	-6	-.246847 NS
Interaction between treatments and densities	2	-5.25	2.625	-.107996 NS
Interaction between thicknesses, treatments and densities	2	7	3.5	.143994 NS
Error	168	4083.5	24.3065	
Total	179	18330.2		

^{1/} NS – Not significant

** - Significant at the 1% level

^{2/} Control (untreated), Copper-chrome-arsenate/or Pentachlorophenol/or Copper sulphate, and Copper sulphate + Potassium dichromate.

Table 8: Variation of Performance Ratings (%) on the Retention of original Colour/ Appearance and Protection of Surface from Weathering of Coconut (*Cocos nucifera* L.) Wood Roof Shingles with Respect to Treatments After 11 Months of Outdoor Exposure

Treatment	Retention of Original Color/Appearance	Protection of Surface from Weathering
Control (untreated)	87.3(c)	87.3(c)
Copper-chrome-arsenate/ Or Pentachlorophenol Or copper sulfate 100 (a)	100 (a)	100 (a)
Copper sulfate + Potassium dichromate	97.5(b)	97.5 (b)

¹ Mean of 60 replicates. The means are significantly different at 1% level of significance (Duncan's Multiple Range Tests).

Table 9: - Analysis of Variance of Performance Ratings on the Protection of Surface From Fungal Infection of High and Medium Density Coconut (*Cocos nucifera* L.) Wood Roof Shingles With Respect to treatments After 11 Months of Outdoor Exposure

Sources of Variation:	Degrees of Freedom	Sum of Squares	Mean Squares	F-ratio ^{1/}
Between treatments ²	1	3126.72	3126.72	-560308 NS
Error	28	-.15625	-.00558036	
Total	29	3126.56		

^{1/} NS – Not significant

^{2/} Control (untreated), and Copper-chrome-arsenate/or Pentachlorophenol/or Copper sulfate/or Copper sulfate + Potassium dichrome

The estimated bill of materials for the cost study comparing coconut wood roof shingles and G.I. corrugated sheet #26 roofing using roof framing with an area of about 58 m² are presented in Table 10. To have a comprehensive comparison, all factors were taken into consideration, including not only the material costs but the differences in labour and framing costs inherent in the two types of roof construction (Figs. 6 and 7). The cost comparison between these two types of roof construction are presented in Table 11. Comparison shows that in coconut wood roof shingles (Fig 6), the labour cost was higher by about 16.43% but the materials were cheaper by about 5.93%. On the total cost (Table 11), however, coconut wood roof shingles were still cheaper by about 1.23% than the G.I. corrugated sheet roofing (Fig. 7). In the comparison, the cost of coconut lumber for shingles was, the market sales price of US\$ 74.20/m³. However, if the cost of coconut lumber is based on the production cost of US\$ 27.56/m³ (Alcachupas et al 1984)³ coconut wood roof shingles was, 20.02% cheaper than the G.I. corrugated sheet roofing. An annual cost in place analysis would be appropriate but we don't know the service life of the shingles.

Table 10: - Estimation and Bill of Materials for Cost Study of Coconut (*Cocos nucifera* L.) Wood Shingles Compared to Corrugated G.I. Sheets Roofing

Description	Cost
I. Gauge #26 Corrugated G.I. Sheets	
A. Roofing	
1. Lumber (coconut wood). Rafters, ridge beam, fascia boards, purlins and cleats 1.014 m ³ at US\$74.20/m ³	US\$ 75.239
2. G.I. Sheets:	
a. Corr. G.I. shts. - 24 shts., Ga. #26 x 3658mm(12') at US\$8.10/sht. (US\$2.21/linear m)	194.40
b. G.I. ridge roll - 4 pcs., Ga.#26 x 460 mm x 2440 mm at US\$2.90/pc.	11.60
c. G.I. flushing - 8 pcs., Ga.#26 x 460 mm x 2440 mm at US\$2.90/pc.	23.20
3. Nails:	
a. Roof nails with lead washers - 10 kg, 51 mm (2") long at US\$1.25/kg	12.50
b. CWN (Assorted sizes, 25 mm to 102 mm (1" to 4"long) - 10 kg at US\$0.75/kg	7.50
Cost of Materials	US\$324.439
4. Labour (2 men):	
a. Installation of rafters, purlins and fascia boards - 6 days at US\$3.50/man/day	42.00
b. Installation of corr. G.I. shts.flushing and ridge roll - 4 days at US\$3.50/man/day	28.000
Cost of Labour	US\$ 70.000
* 1 US\$ = P 20.00 (1985)	
B. Ceiling (Drop ceiling):	
1. Lumber (coconut wood). Ceiling joists and hangers - 0.991m at US\$74.20/m ³	US\$ 73.50
2. Ceiling board - 21 boards, 6 mm x 1220 mm x 2,440 mm std. lawanit at US\$4.40/board	92.40
3. Nails:	
a. CWN (51 mm and 76 mm long)- 9 kg at US\$ 0.75/kg	6.75
b. Finishing nails (25 mm long) - 4 kg at US\$0.75/kg	3.00
Cost of Materials	US\$ 175.65
4. Labour (2 men):	
a. Installation of ceiling joists and hangers - 5 days at US\$3.50/man/day	35.00
b. Installation of ceiling boards - 4 days at US\$3.5/man/day	28.00
Cost of Labour	US\$ 63.00
II. Coconut Wood Shingles	
A. Roofing	
1. Lumber (coconut wood):	
a. Rafters, ridge beam, fascia boards and purlins - 1.230 m at US\$74.20 m ³	US\$ 91.266
b. Coconut wood shingles (Thinner - 102 mm wide, 406 mm long, and 4.8 mm thick at the thin end and 14.3 mm at the thicker end) – 3,886 pcs:	
1. Coconut wood for shingles - 2.924 m ³ at US\$74.2/m ³	216.961
2. Fabrication cost at US\$0.25/shingle	97.15
3. Treatment (CCA) cost at US\$0.008/shingle	31.088

2. G.I. ridge roll - 4 pcs., Ga. #26 x 460 mm x 2,440 mm at US\$2.9/pc.	11.60
3. Nails:	
a. CWN (Assorted sizes, 25 mm to 100 mm long) - 29 kg at US\$0.75/kg	21.75
b. Roof nails with lead washers (38 mm long) - ½ kg at US\$1.25/kg	0.625
Cost of Materials	US\$ 470.44
4. Labour (2 men):	
a. Installation of rafters, purlin, facia boards and ridge roll - 7 days at US\$3.5/man/day	US\$ 49.00
b. Installation I shingles (Area of roof = 58 m ²) - US\$1.825/m ²	105.85
Cost of Labour	US\$ 154.85

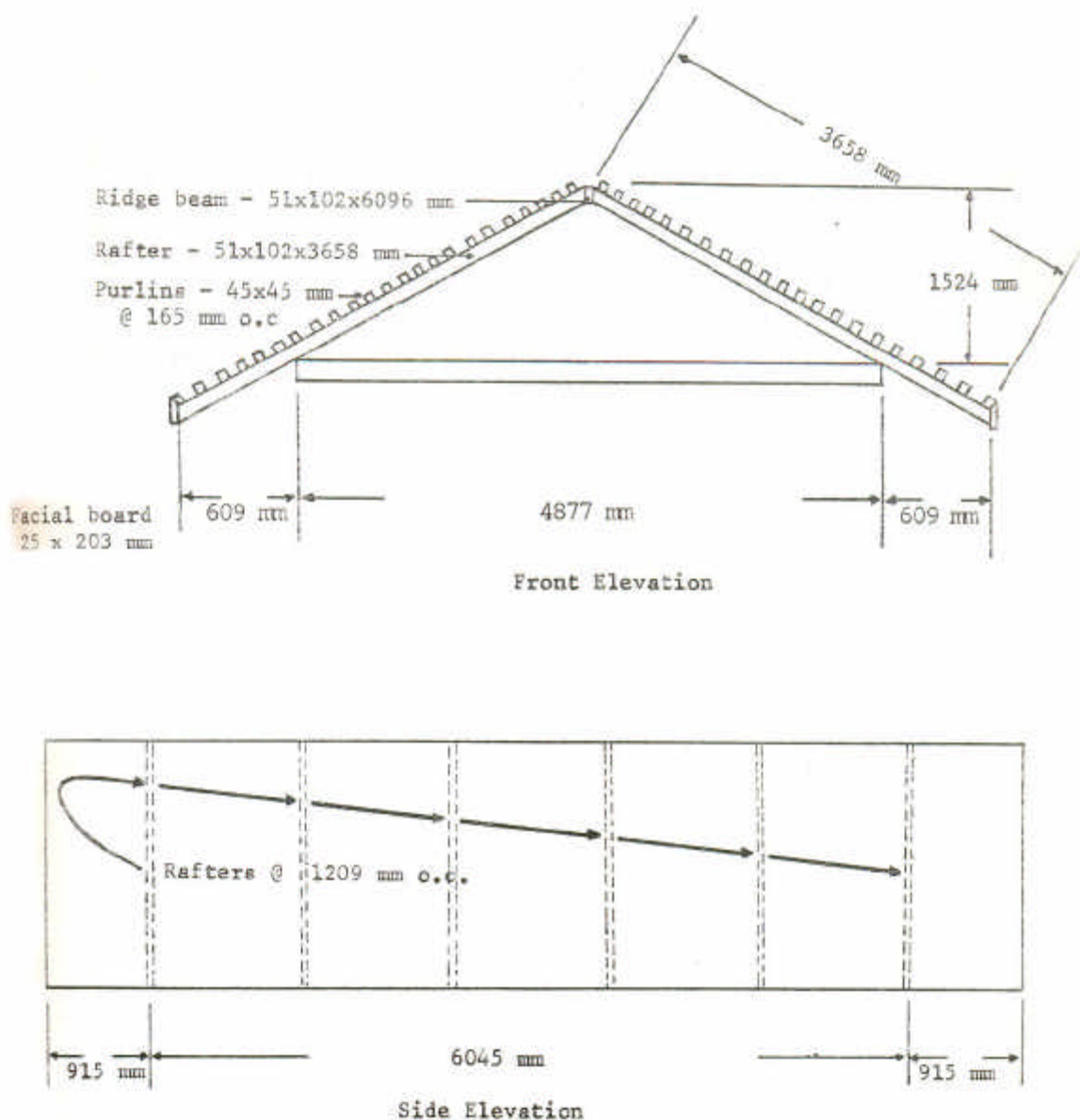


Figure 6. Typical Roof Framing for Coconut Wood Shingles.

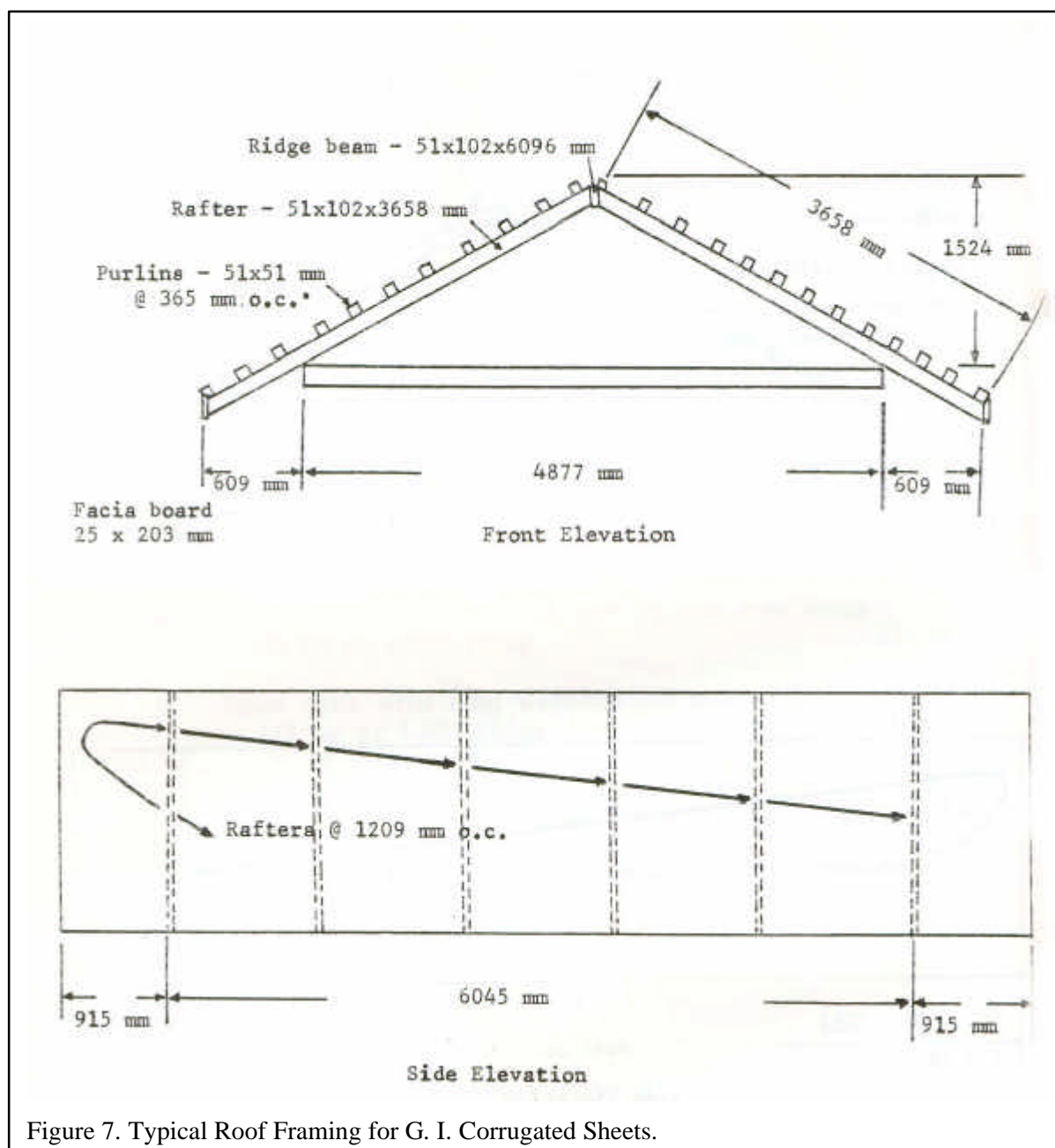


Figure 7. Typical Roof Framing for G. I. Corrugated Sheets.

Comparing the cost of coconut wood shingles and G.I. corrugated sheet roofing, the following additional data were calculated:

	G.I. Corrugated sheets	Coconut Wood Shingles
No. of pieces/m ²	1 2/3	67
Costs/m ²	US\$3.69	US\$5.963
Durability	25 years	still undetermined
Purlins	Less purlins required	More purlins required
Ceiling	Needed	Not necessary

The data show that it is cheaper to, use G.I. corrugated sheets than coconut wood shingles. The cost/m for both roofings do not reflect the installation and hardware costs. The cost of G.I. corrugated sheets and coconut wood shingles are market sales price of US\$2.214/linear meter and fabrication and treatment, including cost of coconut lumber (US\$74.20/m²) for shingles, respectively. In terms of production cost of coconut lumber (US\$27.56/m³), cost/m² of coconut wood shingles was 2.40% cheaper than the G.I. corrugated sheets. The decision to use either coconut wood shingles or G.I. corrugated sheets should take into account not only the cost but also other factors like durability, aesthetic view/appearance, heat insulation and the need for additional structures like ceiling. G.I. corrugated sheet roofing makes a house very warm especially during summer. Hence, a ceiling becomes a necessary structure to absorb some of the heat from the G.I. sheets. Such ceiling is not necessary in a house roof with coconut shingles due to the heat insulating and sound proofing properties of wood shingles. The shingles will merely absorb the heat, thereby controlling the amount of heat inside the house.

CONCLUSION AND RECOMMENDATION

In general, the service performance of the exposed treated coconut wood roof shingles can not yet be determined at this stage; the shingles are still in good condition after 11 months of outdoor exposure test. However, results showed that the most suitable combination of thickness, nailing pattern and treatment for high density coconut shingles is any of the thicknesses with two nails and with treatment of either copper-chrome-arsenate or pentachlorophenol. In medium density coconut shingles, any of the thicknesses and nailing patterns and with treatment of Either or copper-chrome-arsenate can be used. In both high and medium density coconut wood shingles, the thinner shingle with two nails, and treated with copper-chrome-arsenate is preferred for economy and of installation.

In the cost comparison study, coconut wood roof shingles was 1.23% cheaper than the G.I. corrugated sheet roofing on US\$7,4.20/m³ market sales price of coconut lumber. If the cost of coconut lumber is based on the production cost of US\$27.56/m³ coconut wood shingles is cheaper by 20.02% than the G.I. corrugated sheet roofing. Thus, the utilization of coconut wood shingles as roofing material seems encouraging for it will benefit the housing industry as well as coconut plantation owners. However, the durability of coconut wood shingles should be firmly established before its utilization as roofing materials is recommended.

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