

Corrugated Roofing Sheet from Non - woven Coir Felt

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Abstract: Coconut coir is an invaluable gift of nature. This unique material has been used to make materials of our daily need, household articles, handicrafts and many others. Lignocellulosic natural fibers exhibit properties like biodegradability, recyclability either by composting or by incineration, desirable to be considered as characteristics of sustainable materials. Natural coir fiber composites roofing product manufactures from Coir and Bamboo combined with synthetic resin or other suitable binder is an alternate for corrugated roofing products a venture to develop technology to manufacture corrugated roofing sheet from non-woven coir –felt is quite innovative. Since coir felt is highly porous material and simultaneously flexible, woven bamboo mat was used along with coir felt in the manufacture of corrugated sheet. The prepared corrugated sheets were tested for water permeability, bond integrity and physical mechanical properties. The corrugated sheets passed all the tests except impact resistant test. Exposure study indicates that roofing sheets are suitable for use in place of conventional roofing sheets.

Introduction: Roof is an important component in any construction, particularly, in housing. In order to optimize the cost of construction; engineers have always been on the lookout for efficient and light roofing materials which requires minimum maintenance, lesser support and labour to install. At present, corrugated roofing sheet made of asbestos cement and galvanized iron are of most use and popular. The principle of corrugation allows use of minimum material by virtue of enhanced moment of inertia attained due to geometry of corrugation. Recent studies indicate that asbestos cement corrugated sheet (ACCS) is hazardous material from health point of view and has been banned from use in many developed countries. On the other hand, corrugated galvanized iron sheet (CGIS) and aluminium corrugated sheet require lot of energy for production. Other less known corrugated sheet materials like plastic PVC, FRP are not widely used, because these are relatively costly and have short life. None of these sheets are bio degradable.

The idea of manufacture of durable roofing sheet using bio degradable material is quite innovative. Roofing sheet, as is well understood, will be subjected to natural weathering and degradation by biological agents. Hence, enhanced service life of this material under exposed condition is not expected unless proper measure for protection is taken. However development of durable corrugated sheet from woven bamboo mat has proved that made with appropriate technology, bio degradable organic fibre can be used to make durable and weather resistant product for use under exterior condition. Non-woven coir felt has potential as raw material for production of roofing sheet.

All India Final Estimates of area and production of Coconut

States /Union Territories	2006-2007 (Revised)			2007-2008 (Final)		
	AREA ('000 ectares)	Production (Million nuts)	Productivity (Nuts/ha)	AREA ('000 Hectares)	Production (Million nuts)	Productivity (Nuts/ha)
Andhra Pradesh	101.90	1326.40	13017	101.32	1119.26	11047
Assam	19.00	153.00	8053	19.00	136.00	7158
Goa	25.50	126.70	4969	25.50	127.60	5004
Gujarat	16.40	138.30	8433	16.40	138.30	8433
Karnataka	401.00	1625.00	4052	405.00	1635.00	4037
Kerala	870.90	6054.00	6951	818.80	5641.00	6889
Maharashtra	21.00	175.10	8338	21.00	175.10	8338
Nagaland	0.90	0.20	222	0.90	0.20	222
Orissa	51.00	275.80	5408	51.00	275.80	5408
Tamil Nadu	374.60	5429.90	14495	383.37	4968.20	12959
Tripura	3.30	7.00	2121	5.80	11.40	1966
West Bengal	25.10	359.10	14307	28.60	355.50	12430
A & N Islands	21.40	89.00	4159	21.60	80.60	3731
Lakshadweep	2.70	53.00	19630	2.70	53.00	19630
Pondicherry	2.10	27.90	13286	2.20	26.60	12091
All India	1936.80	15840.40	8179	1903.19	14743.56	7747

Source: Directorate of Economics & Statistics, Ministry of Agriculture, Govt. of India.

Although coconut palms grow throughout the world's tropical regions, the vast majority of the commercially produced coir comes from India and Sri Lanka. India produces about one fourth of the world's 55 billion coconuts each year, out of which only 15% of the husk fibre are actually recovered for use.

Cocos nucifera is the scientific name of the common coconut. This very tall palm tree is always an inviting symbol of the tropics. The plant is one of the most valuable plants to man. It is a primary source of food, drink, and shelter. Man can use every part of the coconut. The white nut-meat can be eaten raw or shredded and dried and used in most cooking recipes. A single coconut has as much protein as a quarter pound of beefsteak. Copra, the dried meat of the kernels, when crushed is the source of coconut oil. The husk, known as coir, is short, coarse, elastic fibers. This very diverse plant is also an excellent charcoal, which is produced from the shells, not only does it work as a cooking fuel, but also in the production of gas masks and air filters. Brown coir pad, made by needle felting, are shaped into non woven sheet. This non-woven felt is suitable for further processing into corrugated sheet.

Use of bio-degradable organic and renewable fibre like coconut coir for making roofing sheet is quite innovative. The reason being the product (roofing sheet) will be subjected to various exposure conditions and as organic material coir is liable to degrade. The corrugated roofing

sheet to be produced from coir must resist all weathering conditions during service life, but must undergo bio-degradation when dumped into soil after usable life is over.

Material and Method:

Coconut coir non-woven felt: Felts were obtained in the form of rolls of 4 feet wide. The thickness of the non-woven felt varied from 4.25 to 4.78 cm with an average thickness of 4.5 cm. Felt is light weight with an average weight of 1100gm/cm². For manufacturing good quality corrugated sheet, the uniformity in distribution of coir throughout the felt is necessary.

Woven bamboo mat: Woven bamboo mat in herringbone pattern and having sliver thickness 0.6 to 0.8 mm were used. The mat should be tightly woven having no gap between two slivers. There should be no epidermal and endodermal layers in the sliver. Sliver should not be rough and should be uniform in thickness throughout its length.

Adhesive: Cardinal Phenol Formaldehyde (CPF) resin based adhesive was used to bond the coir felt and bamboo mat together. CPF is an exterior grade resin which when used to bond lignocelluloses material the resultant material (corrugated roofing sheet in the present case) can withstand natural weathering conditions without any deterioration in bond integrity of the products. The product bonded with CPF resin can resist boil water and hence ideal for making roofing sheet.

BOPP paper: This is used as releasing agent during hot pressing of corrugated sheet. The melting point of BOPP should be above 150 °C i.e. 10 °C higher than the actual pressing temperature of the corrugated sheet.

Preservative Chemical: When used can be mixed with adhesive. Any chlorinated hydrocarbon or any other timber preservative which is compatible with adhesive can be used.

Preparation of Cardinal Phenol Formaldehyde resin: Charge required quantity of phenol and cardinal into resin kettle, followed by part of the total quantity of formaldehyde. Sodium hydroxide in aqueous solution is added to the kettle. The alkali acts as catalyst. The mixture is heated under stirring and maintained at 90°C for 90 minutes. The mixture is cooled to 60°C and remaining quantity of formaldehyde and more sodium hydroxide are added to the mixture in the kettle. Temperature is again raised to 90°C and cooked till desired viscosity of the resin is obtained. The resin is cooled, discharged from the kettle and stored in air tight container.

Preparation of Glue mix: The above resin may be used admixed with 2% filler and suitable quantity of insecticide. Necessary dilution of the resin is being done to control the ultimate resin spread onto coir felt and bamboo mats.

Application of glue:

Coir felt: Coir felt in 4.5mm thickness is loose and highly porous. Hence the felt did not hold the resin when impregnated with aqueous solution of resin. These felts were, therefore, compressed to 1.0 to 1.5 cm thick before application of resin. The compressed coir felt were soaked in glue mix. Excess glue from the body of the coir felt was squeezed out by passing through two rubber rollers. The felts were then kept for air drying so that part of the water is evaporated from resin coated felts.

Bamboo mat: Similarly, bamboo mats, having moisture content 10 – 12%, were soaked in glue and allowed to stand in slanting position for an hour to drain excess resin from the mats. The glue coated mats were then allowed air drying to remove excess water from their body.

Conditioning of glue coated coir felt and bamboo mats: Both, coir felt and bamboo mats, after glue coating, contain more than 40% moisture. After air drying the moisture content comes down to nearly 20-25%. However, this moisture content is very high before hot pressing and if hot pressing is done at this moisture content, it will create steam pocket or blister in the resultant products. Hence air dried coir felt and bamboo mats are dried in mechanical dryer to bring down the moisture content of the resin coated felt and bamboo mats to 10 – 12%.

Assembly for Corrugated Sheet: The assembly pattern of coir felt and bamboo mat followed for making corrugated sheet is as follows:

- i) Resin coated coir felt + resin coated bamboo mat + resin coated coir felt (3 ply).
- ii) Two resin coated coir felt + one resin coated bamboo mat + two resin coated coir felt (5 ply).

These assemblies were placed between two sheets of BOPP film. The BOPP film facilitates movement of coir felt and bamboo mats to form corrugation inside dies in the hot press and also act as releasing agent by preventing the sheets from sticking to corrugated platens of the hot press.

Hot Pressing of the Assembly into Corrugated Sheet: A hydraulic hot press of 600 ton capacity fitted with 1.84m x 0.92m size sinusoidal pattern moulded dies (corrugated) and heated with thermic fluid oil to a temperature 150°C was used. The platens (dies) are fitted with digital temperature meter to monitor temperature of the platens. A hydraulic system fitted with the hot press regulates the movement of the dies and creates pressure as required. The assembled coir felt + bamboo mat is loaded into profiled platens fixed to the hot press. The platens are closed and a specific pressure of 40 kg/cm² was applied for a period of 7 minutes and 10 minutes for 3 ply and 5 ply constructions respectively at platen temperature of 145 ± 5°C. After stipulated period the hot press pressure is released and the corrugated sheets are removed from the hot press. The sheets are stacked horizontally on a flat platform and kept for conditioning for a period of 2-3 days.

Dimensioning: The hot pressed corrugated sheets have uneven edges and do not have required size. Hence these sheets, after conditioning to room temperature, are taken for dimensioning. Trimming of edges of the corrugated sheet is being done in a Double Dimensioning saw. The final size of the corrugated sheets obtained is 1.84 m x 0.92 m.

Testing of corrugated sheets: In the absence of any standards for this new product the test on this corrugated sheets were carried out as per IS: 15476 – “Bamboo Mat Corrugated Sheet - Specification”. Test results are given in Table.

Table-Test results of Coir Corrugated Sheet

Sl. No	Test	Prescribed value (IS:15476)	Value for 3 ply sheet	Value for 5 ply sheet
1.	Dimension	-	184mx0.92m	184mx0.92m
2.	Thickness	-	4.5 – 4.6 mm	7.1 – 7.3 mm
3	Density (gm/cc)	Min. 0.75	1.411	1.208
4.	Water absorption (%)	Max 15	14.1	9.24
5.	Rate of burning (minute)	Minimum 20	40	50
6.	Flame penetration (minute)	Minimum 10	8.3	50
7	Load bearing capacity(n/mm) a) Dry state b) Wet state	Min. 4.0 Min.3.0	2.0 1.6	5.65 4.04
8.	Water permeability (running water)	Do not permit water on other side of board	Leakage in one or two places	No leakage
9.	Water permeability (stagnant water)	Do not permit water on other side of board	Leakage in one or two places	No leakage
10	Thickness Swelling (after 24 hours soaking in water) %	-	Max. 2.8	Max. 2.4
11	Cyclic test (BWP grade of IS:848)	No delamination	No delamination	No delamination

From the test results, it is being observed that corrugated sheets made with 5 ply construction passes all the tests as per IS: 15476. In addition to the tests mentioned in the Table, impact on falling body (0.5 kg) from a height of 2 meters on the corrugated sheet was also been observed and 5 ply sheets only shows minor dent or crack. No fracture, through the thickness of the sheets, was observed. As for 3 ply sheet is concerned, it fails in water penetration and load bearing capacity. Penetration of water can be resisted by applying a coat of paint commonly used to paint metal corrugated roofing sheet. The painted sheets resist water penetration



Squeezing of excess resin from Coir felt



Drying of Resin Coated Coir Felt



Finished Coir Corrugated Sheet



Hot Pressing of Coir Corrugated Sheet

Conclusion: In the conclusion, it can be said that coir felt in combination with woven bamboo mat is suitable for making corrugated roofing sheet. 5 ply sheets as described above are suitable for use in exterior condition. For semi exterior or indoor condition light weight 3 ply sheet may be used. Keeping in mind of the fact that 3 ply sheets are not fully leakage proof, a coat of paint may be given to the exposed surface when used under semi exterior condition.

--- Coir Board --- Govt. of India