American Journal of Applied Sciences

Original Research Paper

Development of Roofing Tiles Support Made from Bituminous Plywood

[1]Ouro–Djobo Samah, [2]Sinko Banakinao, [3]Komlan Lolo and [3]Kodjo Attipou

[1]Department of Civil Engineering, Centre Regional de Formation Pour Entretien Routier, Togo
[2]Department of Civil Engineering, National Superior School of Engineers, University of Lomé, Togo
[3]Department of Mechanical Engineering, National Superior School of Engineers, University of Lomé, Togo

Article history
Received: 30-12-2021
Revised: 23-07-2022
Accepted: 19-08-2022

Corresponding Author:
Kodjo Attipou
Department of Mechanical Engineering, National Superior School of Engineers, University of Lome, Togo
Email: kodjo.attipou@yahoo.fr

Abstract: In this study, a new design of roof support was investigated to improve the system of roof coverings with roofing tiles. Usually, wood frames or slabs are often used as support for roofing tiles, which presents many disadvantages such as the expensive cost of the slabs and sometimes inefficient Corresponding wood frames. The new design proposed in this study uses the technique of Kodjo Attipou wood frames, but by interposing between the frames and the roofing tiles, a barrier is made of bituminous plywood. The barrier is composed of plywood 1.22 m in width, 2.44 m in length and 4 mm in thickness. The plywood is covered with a cloth of cotton fibers, impregnated in petroleum bitumen fluidized by kerosene. A test of permeability was conducted and has shown good results after 3 weeks of imbibition in water. The new composite material obtained can then serve as intermediate support in the system of roof coverings with roofing tiles and wood frames.

Keywords: Tile, Support, Bitumen, Plywood, Waterproofing

Introduction

In the West African sub-region and particularly in Togo, various materials such as straw (Fig. 1 and 2), metal sheets, tiles made of fibers, cement, baked clay, or mortar cement are used for roof coverings (Wallonie, 2016; Youcef and Bahia, 2011). The support used with these materials was generally wood frames (Fig. 3). The use of wood frames is widespread but its deformation and vulnerability to attack of insects cause often operating inconvenience of the roof (Picard, 1992). It is also noticed, especially with the roofing tiles resting directly on wood frames (Fig. 4), that under brutal effect, shocks of heavy loads break the roofing tiles and cause leaks of the roof. To overcome these drawbacks, support made of reinforced concrete is often realized before laying the tiles (AFNOR NF P84 204-1-1 Reference DTU 43-1). This technique results in an additional cost.

Therefore, it is of interest to investigate alternative roof coverings that are efficient and economic. The present study is within the framework of promoting the use of local and environment-friendly materials (Banakinao *et al*., 2017; Lolo *et al*., 2017; Banakinao *et al*., 2016; Drovou *et al*., 2015; Keita *et al*., 2014; Sorgho *et al*.,2014; Pasch and Pizzi, 2002; Lefeu and Francy, 1999). The new design of roof coverings proposed in this study uses layers of bituminous plywood, at different proportions and different compositions, with fibers of cotton, as intermediate support between the wood frames and the roofing tiles, to guarantee the waterproofing of the roof.

Materials and Methods

Tools and Equipment

The tools and types of equipment used for the manufacture of bituminous plywood and permeability tests were: Brushes, scissors, hot plate, tares, water tank, ball unit and ring, penetrometer bitumen, and viscometer.

Materials

To manufacture the bituminous plywood, four raw materials were used:

- Plywood of format 1.22 × 2.44 m with 4 mm thickness
- A fabric fiber of cotton
- Bitumen fluidized
- Sand with three different moduli of fineness

The plywood used was a set of thin sheets of wood pressed against each other. The manufacture of the plywood meets the French standards: NF EN 636, NF EN 13986, and NF EN 78.

The fabric of fibers of cotton used for this study was the type used for bagging wheat flour. The choice of wheat flour bag is due to the fact painters usually use it as oil painting canvases and it is well-known that oil paints resist for a long time on fabrics of fibers of cotton. Since bitumen is a product derived from petroleum and contains a given percentage of oil, it can be then weather resistant on this type of bag. However, a systematic prior washing of fabrics of fibers of cotton with soap, followed by a high clean water rinse was done before the application of the impregnation layer.

Fluidized bitumen is a bitumen-based liquid obtained by dissolving road bitumen in a hydrocarbon solvent of petroleum origin (NFT 65-002). For the waterproofing of the substrate, a grade 60/70 of road bitumen was used, which is fluidized at 65% with kerosene, and a petroleum diluent with a kinematic viscosity of 1.25 mm^2/s at 40◦C.

To assess the influence of the size of the granulometry of the sand on the hygroscopic behavior of the bituminous plywood, sand with three different moduli of fineness was used to manufacture three different series of bituminous plywood.

Experimental Methodology

Methodology for Manufacturing Bituminous Panels

Waterproof plywood was made, on which bitumen was applied, alternated by sand and fabric of fibers of cotton. The methodology was realized in six (06) steps:

1. Plywood of 2.44 m of length, 1.22 m of width, and 4 mm of thickness were sampled in small square panels with a side of 30 cm (Fig. 5). The sampled panels were brushed, and washed with water, and then dried. Once dried, an impregnating layer of fluidized bitumen was applied at 0.023 g/cm^2 (Fig. 6)
2. A first hooking layer of road bitumen of grade 60/70 fluidized at 150°C was applied at 0.068 g/cm^2 (Fig. 7)
3. A washed and dried fabric of fibers of cotton was applied to the hooking layer (Fig. 8)
4. A second hooking layer of road bitumen of grade 60/70 fluidized at 150°C was applied at 0.068 g/cm^2 (Fig. 9)
5. A compacted layer of sand was then applied. The mass of the sand used depends on its modulus of fineness, i.e., 0.073 g/cm^2 for coarse sand with a modulus of fineness of 2.9, 0.04 g/cm^2 for medium sand with a modulus of fineness of 2.4 and 0.003 g/cm^2 for fine sand with a modulus of fineness of 2. Therefore, three series of panels were obtained (Fig. 10)
6. A final layer of bitumen of grade 60/70 fluidized at 150°C was applied at 0.068 g/cm^2 over the compacted layer of sand (Fig. 11)

The manufactured bituminous panels were subjected to a test of water absorption to assess their hygroscopic behavior. In addition, seven untreated plywood panels were made for comparison purposes.

Fig. 1: Straw roof

Fig. 2: Interior view of straw roof

Fig. 3: Wood frames for straw roof

Fig. 4: Tiles roof lying on wood frames

DOI: 10.3844/ajassp.2022. 99.104

Fig. 5: Panels of 30 × 30 cm^2

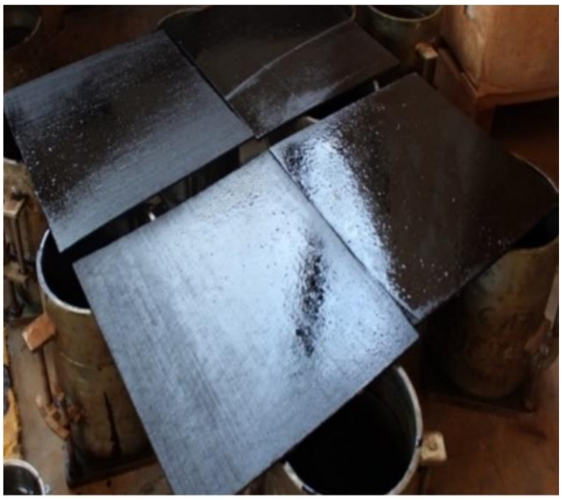

Fig. 6: Impregnating layer

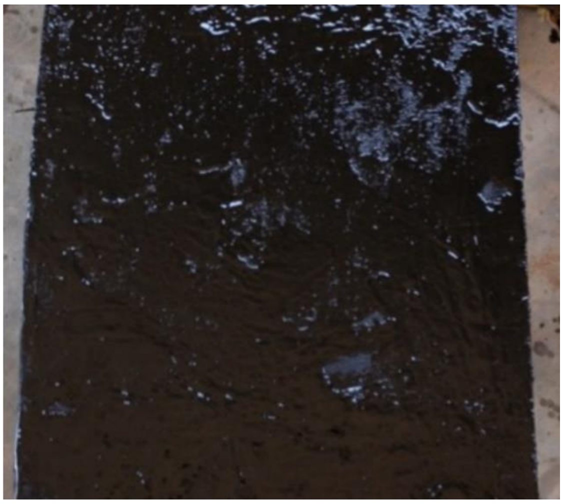

Fig. 7: First hooking layer

Fig. 8: Laying the fabric

Fig. 9: Second hooking layer

Fig. 10: Spreading the SAN

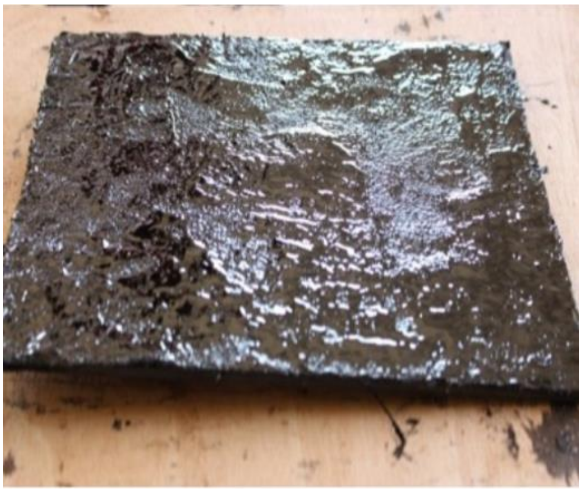

Fig. 11: Surface layer

Fig. 12: Imbibition of the panels

Test of Water Absorption

For each different modulus of fineness of sand, seven (07) samples of treated and untreated panels (seven rectangular panels 30 × 30 cm) were manufactured. There were four (04) series of seven panels for the test. After weighing each panel, the treated face was gently soaked in a rectangular tank of water of dimensions 1 × 2 m, filled to 2/3 (Fig. 12). The untreated face of the panels was preserved from any contact with water. The untreated panels were also imbibed in water at the same moment. The seven samples of each series were imbibed in water for twelve (12) days.

After every twenty-four (24) h, the panels were taken out of the water, cleaned carefully, and then weighed. This operation was repeated until the weight of the panel between two successive weighings hardly varied. The quantity of water absorbed was calculated for each panel and the mean value of the seven panels of each series was determined. Knowing the surface of contact of the panel with water (30 × 30 cm^2) and the duration of water absorption and assuming that the absorption is uniform over the entire surface of contact, the coefficient of permeability was calculated according to the following formula Eq. 1:

$$P_e = \frac{Q}{AD} \tag{1}$$

where, P_e is the coefficient of permeability (m/s); Q is the quantity of water absorbed (m^3); A is the surface of contact and D is the duration of absorption (s).

Tests Conducted on the Materials used

To characterize the sand, two tests were conducted: the particle size analysis according to the standard NF P 94056 and the test of the sand equivalent according to the standard NF P 94-054.

Results and Discussion

Results of Tests Conducted on the Sand

The granulometric curves of the different sands are presented in Fig. 13. As expected, the percentage of sand" passing through" the sieve increases while the modulus of fineness decreases.

The results of the different tests on sands are summarized in Table 1. The absolute density and the apparent density of the sands tested are quite similar. The Mf1 and Mf3 sand contain more fine elements than the Mf2 sand.

Amount of Water Absorbed and Coefficient of Permeability

The curves in Fig. 14 show the variation in the quantity of water absorbed by each series of panels as a function of the imbibition time. Those curves indicate that on the tenth day of imbibition, all panels of the three processed series are saturated with water. The untreated panels are saturated at the seventh and are completely immersed while the treated panels still float on the water. The results are presented in Table 2.

The total quantity of water is measured at saturation, i.e., on the seventh day for the untreated panels and the tenth day for the treated panels. Table 3 presents the different coefficients of permeability of the panels (Fig. 15).

Conclusion

This study shows an improvement of the system of roof coverings by introducing a new design of roof support. An alternative to classic roof coverings using roofing tiles directly laying on wood frames was proposed. The new technique proposed can guarantee the waterproofing of the roof support.

Table 1: Results of the different tests on sands

Parameters	Sand Mf1	Sand Mf2	Sand Mf3
Modulus of fineness (Mf)	2.90	2.40	2.00
The Equivalent of Sand (ES)	93.54	57.73	88.84
Absolute density γ_s	2.50	2.50	2.58
Apparent density γ_d	1.48	1.48	1.47

Table 2: Quantity of water absorbed (cm^3)

	Days											
	1	2	3	4	5	6	7	8	9	10	11	12
Untreated panels	122.71	162.57	184.29	199.00	218.140	226.86	233.86	273.71	295.43	303.0		
Treated panels (Mf = 2.9)	7.71	9.14	10.86	15.00	24.570	28.71	28.71	30.14	31.86	36.0	36.00	36.00
Treated panels (Mf = 2.4)	5.14	5.71	6.57	7.57	9.570	12.43	12.86	15.29	16.57	18.5	18.51	8.57
Treated panels (Mf = 2)	4.86	5.57	7.00	8.57	11.710	18.43	22.71	27.00	29.00	29.0	29.00	29.00

Table 3: Calculation of the coefficient of permeability of the panels

		Treated panels (with sand)		
Characteristics	Untreated panels	$Mf = 2.9$	$Mf = 2.4$	$Mf = 2$
The average amount of water absorbed Q_{moy} cm^3	303	36	18.57	29
Depth of penetration of water d (m)	3.4×10^{-3}	4×10^{-4}	2×10^{-4}	3×10^{-4}
Permeability of the panel's P_e (m/s)	1.31×10^{-8}	4.63×10^{-10}	2.31×10^{-10}	3.47×10^{-10}

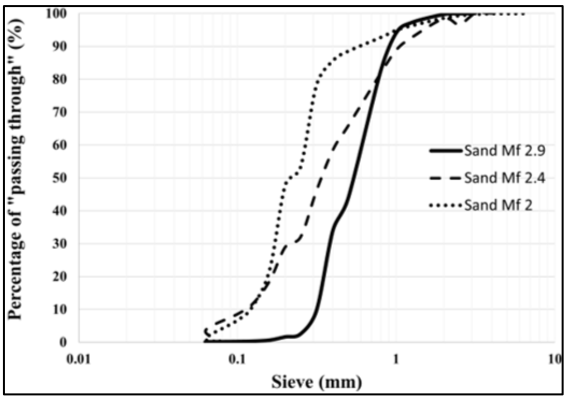

Fig. 13: Granulometric curves of the different sands

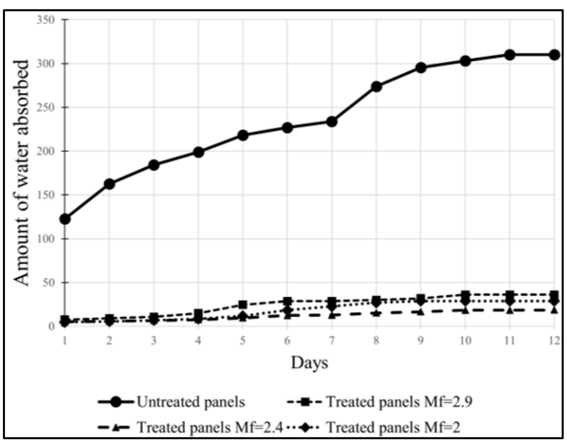

Fig. 14: Evolution of the quantity of water absorbed during days (cm^3)

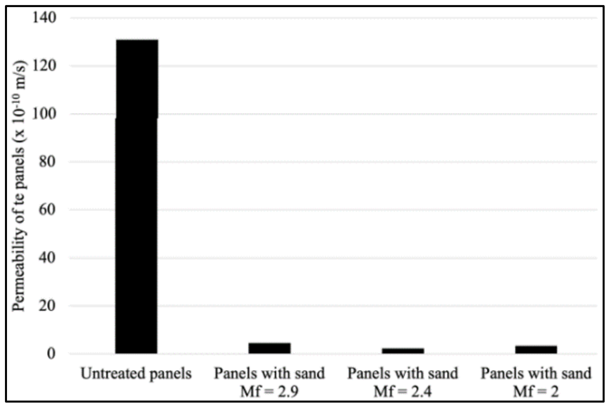

Fig. 15: Histogram of the permeability of the panels

A new composite material, bituminous plywood, was obtained by adding different layers of road bitumen (of grade 60/70), fabrics of fibers of cotton, and sand at specific modulus of fineness (2.9, 2.4, and 2) on plywood with fluidized bitumen. The new composite material was placed between the wood frames and the roofing tiles to form the new system of roof coverings. The test of water absorption conducted on the manufactured panels shows a permeability of about 3.47×10^{-10} m/s. These panels are then classified in the category of water-impermeable materials.

Bituminous plywood can be used as an alternative to slabs in the system of roof coverings, to strengthen the roof against water infiltration and to ensure the durability of the construction as well as a low-cost roofind system.

Acknowledgment

The authors sincerely thank the laboratory of the Centre Regional de Formation pour Entretien Routier´ (CERFER) and Laboratoire de mecanique des sols´ from the National Superior School of Engineers of the University of Lome. The authors also acknowledge their colleagues from various departments of Civil Engineering, Electrical Engineering, and Mechanical Engineering for their assistance.

Author's Contributions

Ouro–Djobo Samah and Sinko Banakinao: Research plan, experiments, data analysis, writing-original draft preparation.

Komlan Lolo: Experiments.

Kodjo Attipou: Writing, modification for the final layout.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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