# *Pinus caribaea* wood-Portland cement mortar composite for roofing tile fabrication

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**Abstract**

Pencil manufacture generates a large amount of wastes. These residues do not have an useful destination. They are usually burned provoking air pollution and energy loss. However, these wood residues could be used as a raw material in cement based products. A studied composite demonstrated advantageous characteristics as lightweight and thermal insulation. The objective of this work was the development of an adequate wood/cement ratio using *Pinus caribaea* residues from Faber Castell Industry, to be used in tiles production. Chemical compatibility between *P. caribaea* residues and Portland cement was evaluated by means of the hydration curve method. Result shows the inhibitory effect of the raw-material when mixed with cement paste. Compression strength of cylindrical specimens was also evaluated. Results show the influence of several parameters as Brazilian cement type (CP V-ARI and CP II-E-32), wood/cement/sand/water ratio, chemical treatments (calcium chloride and aluminum sulphate), cure type (humid and steam), and raw-material type (sawdust and wax coated particles). Absorption capacity and swelling were also evaluated. Mix was selected after physico-mechanical evaluation for tiles fabrication in a Parry Associates device. Two series of tiles were produced, one with coated wood particles and the other with sawdust material. Both tiles were compared with the micro-concrete tiles reference. Tiles composite by-products presented characteristics to be used for construction, mainly in rural areas.

**Keywords**: composite, wood residues, tiles

## 1 Introduction

Environmental problems originated from the extraction and commercialization of products based on asbestos are reopen the discussion regarding possible substitutes of that mineral raw-material. On the other hand, several industrial processes generate important amounts of residues that could be supposed to substitute the asbestos in the fabrication of building components.

The exploitation of forest resources requires considerable areas and the generated by-products could supply industries dedicated to the building sector.

The objective of this work was to verify the possibility of utilization of residues from the processing of *Pinus caribaea* wood in the fabrication of undulated roofing tiles based on mortar of Portland cement and sand.

Composites prepared with lignocellulosic materials and inorganic binders are known since a long time. These materials present important advantages, such as lightweight and impact strength. But some vegetable resources cannot be directly mixed the Portland cement. Complex chemical reactions take place and culminate with the complete absence of the binder setting in specific situations. As a consequence, most of the researches aimed the solution of that problem, which can limit the use of certain vegetable raw materials. Amongst the proposed alternatives, the most used ones focused the choice of an efficient matrix, or appropriate curing methods or vegetable raw material with a chemical constitution less troublesome to the Portland cement setting (PIMIENTA et al., 1994).

## 2 Material and Methods

The pencil producer Faber Castell, located in São Carlos, SP, Brazil, provided two types of vegetable residues used in the experimental work. The first one is denominated sawdust (S) and comes as a by-product of the sawmill. The second is called paraffined (P) and it is derivate of other phase of the pencil fabrication in which the processed wood is impregnated with the paraffin.

The composites used two types of binder: Portland cement with a blend of blast furnace slag (CP II-E-32- Brazilian Standards NBR 11578) and Portland cement with quick set (CP V-ARI- NBR 5733). Both cements also received accelerating additives: calcium chlorate (CC) and aluminum sulphate (SAP) (3% by mass of cement). The CP V-ARI used another aluminum sulphate (commercial product - SAC) as well.

The specimens received wet or steam curing. In the second situation the de-moulding process was anticipated.

The different formulations provided cylindrical specimens (NBR 7215), cured during seven days and then dried in the laboratory environment by additional seven days, until the date of compression test.

The statistic analysis helped with the evaluation of test results. The formulation with best behavior followed to the fabrication of undulated roofing tiles using a Parry Pantile machine and the recommendations of SKAT (1989). The elements were simply submitted to wet curing.

The bending test evaluated the mechanical strength of the roofing tiles in the saturated condition at 28 days. The universal testing machine EMIC model DL 30000 equipped with a load cell of 5 kN performed these tests. The software M-Test v.1.01/96 monitored the tests.

The method provided by Brazilian Standards NBR 13858-2 accessed the tightness of the undulated tiles.

## 3 Results and Discussion

The method of linear regression related the compression strength with: cement type, wood origin, curing type and chemical treatment. As these factors were qualitative, indicative variables were used to identify the levels (categories) of each variable as presented in the Table 1. The Table 2 presents the variable chemical treatment with four categories. These categories are indicated by the combination of the variables T1, T2 and T3. For example, the treatment N (natural) corresponds to T1=1, T2=1 and T3=1.

Table 1- Codification of variables

| Variable | Category | Code |
|---|---|---|
| Cement | CP II | 1 |
| | ARI | 0 |
| Nature | Sawdust | 1 |
| | Waxed | 0 |
| Cure | Humid | 1 |
| | Steam | 0 |

Table 2- Treatment codes

| Category | T1 | T2 | T3 |
|---|---|---|---|
| N | 1 | 1 | 1 |
| SAC | 1 | 0 | 0 |
| SAP | 0 | 1 | 0 |
| CC | 0 | 0 | 1 |

The linear model showed to be well adjusted to the experimental data ($r^2$=0.897). The analysis of variance (ANOVA) presented a P value very close to zero (Table 3), which leads to the rejection of the hypothesis of nullity of all the model parameters.

Table 3- ANOVA

| | gl | SQ | QM | F | P value |
|---|---|---|---|---|---|
| Regression | 6 | 191.304129 | 31.88402157 | 35.05402 | 9.94E-11 |
| Residue | 24 | 21.8296369 | 0.909568204 | | |
| Total | 30 | 213.133766 | | | |

The calculation of compressive strength adopted:

The maximum value of compressive strength is obtained by: cement = 0 (ARI); origin = 1 (sawmill) and cure = 1 (wet); in the combination of treatments the calcium chlorate was the most favorable (T1 = 0, T2 = 0 and T3 = 1). Undulated roofing tiles (8 mm thick) employed this formulation. Tests also used the paraffined material as the water absorption of the composite could present a reduction.

The tiles developed ductile rupture. The average energy absorbed during the tests was of 0.56 and 0.38 $N.mm/mm^2$ for tiles based on sawdust and paraffined material respectively. The energy absorption of tiles produced with conventional mortar was equal to 0.25 $N.mm/mm^2$. The averages of the maximum loads supported by tiles based on sawdust (535.34 N) and on paraffined material (494.48 N) were slightly superior to the GRAM et al. (1994) recommendation (425 N). The conventional material presented the better results (745.52 N).

The water tightness of tiles was acceptable according the NBR 13858-2 specification although some specimens containing sawdust showed wet marks in the inferior surface.

## 4 Conclusions

The material originated from the mechanical processing of the *Pinus caribaea* wood showed to be adequate to the fabrication of undulated roofing tiles. The results indicated the better formulation as the one using ARI cement, residues of sawmill, calcium chlorate as accelerating additive and wet cure.

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