

# VEGETABLE WASTE PORTLAND CEMENT COMPOSITE

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## Abstract

*The scope of this work was to evaluate technically vegetable raw-material performance in the search of a wood-Portland cement composite. Wood process residues from five specie were mixed with two Brazilian Portland cement (type III and type V). Physical and chemical treatments were applied to wood particles as: natural, hot water extraction, lime and caustic soda solutions, additives (calcium chloride and aluminum sulfate) and coating process (water glass and aluminum sulfate solutions). Composites performance were evaluated by non-destructive method (ultrasonic speed wave propagation) and by compression test. Results showed the influence of wood chemical compounds and cement type in composite performance.*

**Keywords:** waste, composites, Portland cement, NDE.

## Introduction

Recycling materials nowadays is one of most important problems in today's society. Agribusiness generates considerable amount of waste, and in most of the cases this residues carry out environmental negative impact. In the other hand minerals (sand and gravel) exploitation. for construction's purposes strongly contribute to environmental degradation.

Vegetable fibers has been used as matrix reinforcement since long time ago. Egyptians employed this materials in brick fabrication when they looked for reducing cracks propagation across adobe. Nowadays several Brazilian laboratories developed Agave (*Agave sisalana*) and coconut fibers applications, mainly as matrix reinforcement [1].

Vegetable fibers are very useful for engineering purposes as they present several properties such as: availability of raw-material, matrix performance modification after occurring cracks, and thermal and acoustic insulation [2].

However, this advantages can be completely lost by a phenomenon known as chemical incompatibility between vegetable raw-material and the binder. This fact led several researchers to try to find solutions against deleterious effect caused by raw-material substances in binder hydration reaction.. Even though any vegetable raw-materials can combined with cement, as a general rule, chemical treatments must be done searching for an adequate chemical compatibility between the two materials. This treatments can be summarized in two kinds of procedure:

- 1 Chemical substance immobilization through a protective skin recovering (oil or salt substances); and
- 2 Substance extraction by water solutions (temperature, time and pH effects).

Chemical incompatibility can be analyzed by the matrix focus. In other words, it can be search a most adequate binder type, or less sensitive, to chemical substances present in wooden particles. So, it can be used, for instance, a very quick setting cement type (Brazilian standard type V). Others researchers suggest pH matrix reduction to enhance composite durability [3].

For a preliminary study it is very important to analysis natural raw-material behavior and, afterwards, to look for chemical treatment, or binder replacement, searching for a better composite performance.

## Development

Raw-material was obtained from five sources: *Eucalyptus grandis*- International Paper- Mogi Guaçu – SP. Particles from a bottom of a 3 years old tree; *Eucalyptus tereticornis*- residue from a 30 years old tree from Taubaté – SP; *Bambusa vulgaris* – particles from a stem 5 years old from Campinas University Campus; *Pinus caribaea* –Faber Castell Industry, São Carlos – SP. Residue from a 30 years old tree from Prata – MG; and *Dinizia excelsa* – residue from a 50 years old Amazonian tree from Brotas – SP.

Raw-materials was chopped and it was selected the particles smaller than 2.4 mm. Chemical treatments were applied to wooden particles to enhance their performance in composite properties such as: natural (control), additives (calcium chloride and aluminum sulfate– 3% in relation to the cement mass), washed (hot water – 2 h at 80 °C, lime and sodium hydroxide solutions at 5% concentration) and mineralized (water glass at 5% e aluminum sulfate at 20% concentration).

To evaluate the raw-material performance in two binder types (CP-III-40-RS and CP-V-ARI) binder consumption was fixed as 680 kg/m<sup>3</sup>. This cement amount is excessive but some raw-material could be inhibitory to cement setting. and chemical treatments often can not overcome this deleterious substance effects. Mixture ratio in weight was 1:0.375:0.75 (cement : wooden particles : water). Three replications of cylindrical samples (100 mm height and 50 mm diameter) were produced for each treatment. After 24 hours samples were removed from the mold and placed in plastic bags during 7 days and air dried during more 7 days.

Ultrasonic speed wave propagation across the samples was measured daily by an Ultrasonic Tester BP – 7 device (Steinkamp). Exponential section transducers with 45 kHz resonance frequency was applied. After 14 days samples were submitted to a compression test in a Solotest device according to Brazilian standard NBR 7215 [4].

## Results and Discussion

Raw-materials were named as **DE** (*Dinizia excelsa*), **BV** (*Bambusa vulgaris*), **ET** (*Eucalyptus tereticornis*), **EG** (*Eucalyptus grandis*) and **PC** (*Pinus caribaea*) and the cement as type **III** and type **V**. Figure 1 show Pinus-cement composite pattern. Despite the wooden particles mass be responsible for only 1/3 of overall mixture, it was observed that the wood particles were found predominantly in the surface (and in the volume), enhancing thermal insulation composite properties. ANOVA of composite compression strength is presented in Figure 2. Cement type was significant at  $\alpha=0.01$  (except for **DE** and **BV** species) and mainly treatment kind.

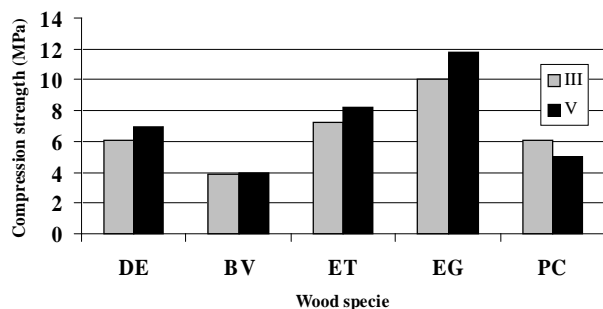


**Figure 1.** Pinus-cement composite pattern

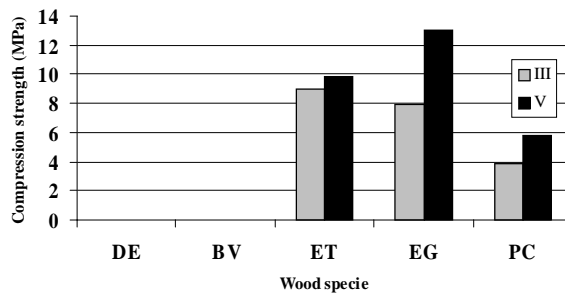
Source	DE	BV	ET	EG	PC
Cement	ns	ns	s	s	s
Treatment	s	s	s	s	s
Cement*Treatment	s	s	ns	s	s

**Figure 2.** ANOVA – Compression strength

Overall cement types analysis results could not point to the best treatment for all wood species (Figure 3). So, results were presented according to cement type, wood specie and chemical treatment. Two natural raw-materials were highly inhibitory to cement setting. Composites from bamboo (**BV**) and a wood specie (**DE**) did not present a minimal structure; ultrasonic wave propagation was completely disturbed by chemical substances presented in this vegetable particles. In the other hand two Eucalyptus species produced better results in compression strength, mainly *E. grandis*(**EG**) when it was combined with type V Portland cement. *P. caribaea* (**PC**) was lightly inhibitory to a type III Portland cement setting (Figure 4).



**Figure 3.** Cement types overall compression strength



**Figure 4.** Raw-material influence

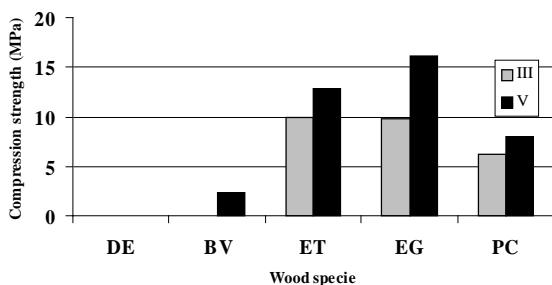
### Additives effect

#### Calcium chloride- DE

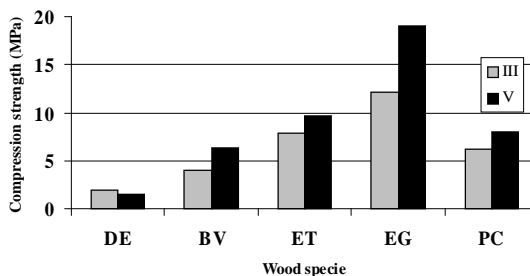
The wood still highly inhibitory for two cement types setting.. Bamboo (**BV**), even so sensitive to calcium chloride action when it was combined with type **V** cement still not allowing adequate compression strength (Figure 5).

#### Aluminum sulfate- DE

The wood showed a non acceptable result, although, for the first time this composite presented small sensitivity to aluminum sulfate action, while *P. caribaea* (**PC**) was not affected by both additives (Figure 6).



**Figure 5.** 3% calcium chloride



**Figure 6.** 3% aluminum sulfate

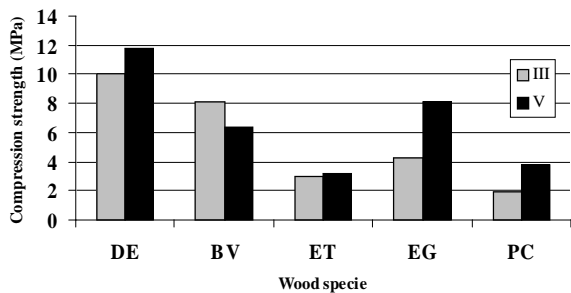
### Mineralization

Results obtained were statistically different. Bamboo (**BV**) and, mainly, **DE** wood increased compression strength, while exotic wood (*Eucalyptus* and *Pinus*) reduced them (Figure 7). The better combination *E. grandis* with type **V** cement, had 50% reduction when it was compared with additives products.

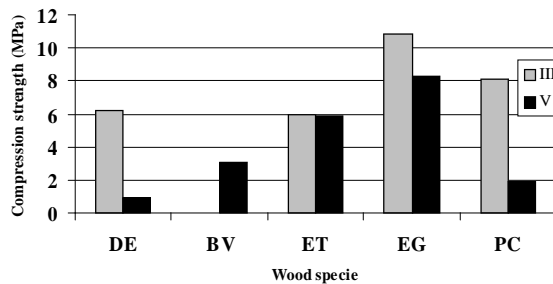
### Washing-up of wooden particles

#### Hot water

The washing-up allowed deleterious substance extraction. It is an alternative technique to enhance the behavior of an inhibitory raw-material, in this research, **BV** and **DE** species (Figure 8). By other hand for compatible or slightly inhibitory species this technique could be not adequate, because there was reduction in compression strength composite. Probably chemical substances can migrate to particle surface during washing-up reducing wood-cement reactions. This treatment was not capable to assure bamboo and type **III** cement composite good performance.



**Figure 7.** Mineralization



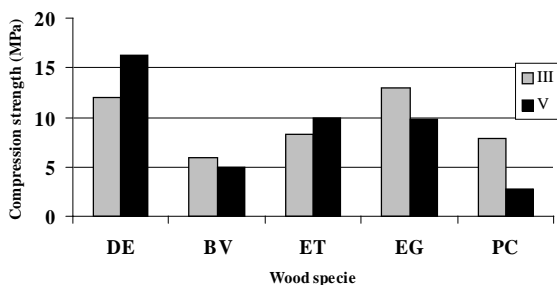
**Figure 8.** Washing-up

*Hot water extraction and calcium chloride- DE*

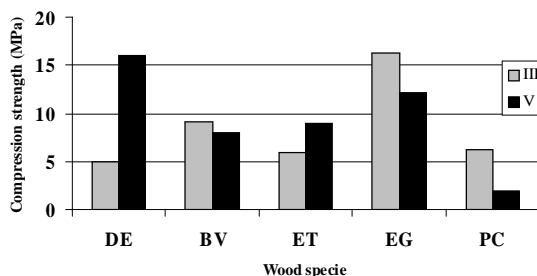
was very sensitive and gave the best compression strength when it was combined with type V cement. (Figure 9).

*Hot water extraction and aluminum sulfate- BV*

and DE, both showed a good performance mainly DE when it was combined with type V cement. EG performance when combined with type III cement showed good results as well (Figure 10).



**Figure 9.** Washing-up and 3% calcium chloride



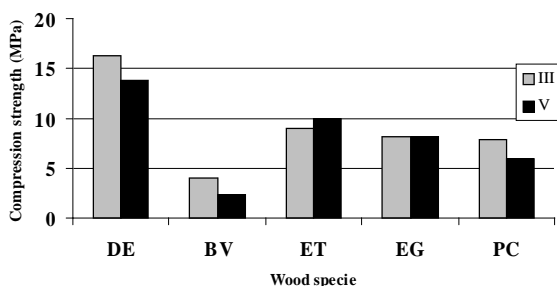
**Figure 10.** Washing-up and 3% alum. sulfate

*Lime solution*

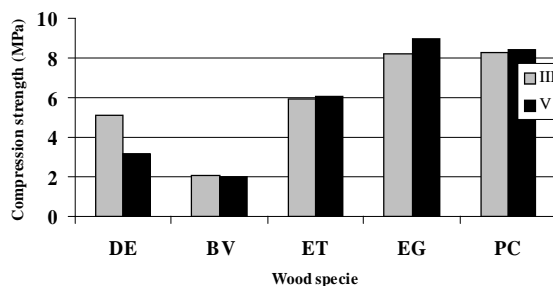
exotic woods presented an homogeneous behavior, their average compression strength was 8.0 MPa (Figure 11). (DE) average compression strength was 15.0 MPa, while for bamboo specie results were non satisfactory.

*Sodium hydroxide solution*

only two wood species (EG and PC) seemed to be sensible to this treatment (Figure 12). For the others woods this treatment was less satisfactory than others kinds of extractions (except bamboo presented in Figure 8).



**Figure 11.** Lime solution (5%)



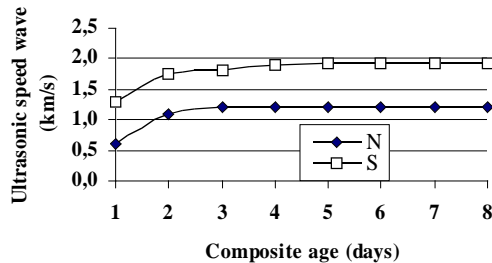
**Figure 12.** Sodium hydroxide solution (5%)

**Composite analysis by means a non destructive evaluating method (NDE)**

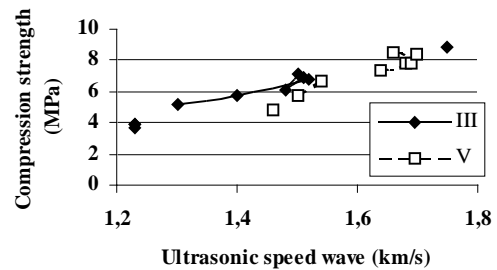
All of wood cement composites showed the same behavior. Ultrasonic wave propagation was presented only for two kinds of PC and type III cement composites. It was selected Natural (N) and

sodium hydroxide (S) treatments (Figure 13). In both cases it was observed that speed wave evolution across the time was very similar. Increase speed rate was large in the first days, becoming stable after a short period of time (6 to 7 days).

Compression strength could be predicted by speed wave propagation across the composite after stabilization. Mathematical models could be established when samples from three treatments (Natural, Natural and calcium chloride and natural and aluminum sulfate) were combined with two cement types (III and V).



**Figure 13.** Ultrasonic speed wave evolution



**Figure 14.** Compression strength vs. speed wave

## Conclusions

- Exotic woods (*Eucalyptus* and *Pinus*) produced more homogeneous composites when combined with two Brazilian Portland cement types (III and V);
- In most of the cases Portland cement type V (high initial strength) seemed to be less influenced by wood extractives;
- For each raw-material it was necessary search for a better combination with a specific cement type;
- Non destructive evaluating test (NDE) was useful to predict composite compression strength. This method allowed to verify composite hardening process.

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