PHYSICAL-MECHANICAL EVALUATION OF MINERALIZED PARTICLES BAMBOO - PORTLAND CEMENT COMPOSITE

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SUMMARY

In this work was presented physical and mechanical evaluation of composites made from natural or washed mineralized bamboo particles and Brazilian Portland cements. It was utilized a bamboo specie (*Bambusa tuldoides*) and two Brazilian Portland cement: type II (CP II E 32) and type V (CP V ARI - a high initial strength cement). Mineralization was realized with two salt solutions: sodium silicate (water glass) and aluminum sulfate. Changes in the weight particles after mineralization and the moisture content of the samples were evaluated. It was accompanied the structural sample changes by means of non-destructive evaluate test (NDE). Despite NDE can evaluate, at early ages, changes in the samples structure, ultrasonic speed wave die not allow a good correlation with density or with compression strength.

INTRODUCTION

Bamboo is the most employed raw material in developing countries for a lot of purposes. Bamboo has many important characteristics, like a renewable material and its availability in many countries. Bamboo can be utilized directly or combined with other materials (clay, concrete, plastics and metals) for building constructions. Particles from bamboo culms also can be used for resin-bonded boards fabrication. However, technical informations about bamboo-inorganic bonded materials are very scarce in literature.

Wood-cement bonded boards are known at earlier 30's. Several researches showed the importance of this composite for building construction. At the same time it was detected serious problem with Portland cement and some wood species. Complex chemical reactions are developed when wood particles are added to the Portland cement paste. Sometimes cement setting is delayed. In other cases setting cement failed.

Accelerators (chlorides, sulfates and aluminates) are generally utilized to overcome wood-cement chemical incompatibility. For a particular wood specie there is a more efficient accelerator. Among the accelerators calcium chloride is the most used in fabrication of particle wood-cement bonded boards.

Theoretical wood-cement chemical compatibility can be evaluated by means of analyses of the composite hydration curve (time against temperature), according Moslemi & Lim (Ref.1). Other possibilities are the compression strength of the samples (Lee & Hong, Ref. 2) and by nondestructive evaluate method (Beraldo, Ref.3).

Setting and hardening of a lignocellulosic-cement composite can be improve by mineralization technique. Impermeable layer envelop vegetal parties, and then it can restrain the displacement of non desirable substances onto particles surface.

According Furuno et al. (Ref.4) mineralization can also reduce the wood hygroscopicity and enhance its fire performance.

Non-destructive evaluating test (NDE) was initially proposed to detected defect in metals and alloys. Results obtained were normally reproducible and the modifications founded were due to the internal cracks. For concrete is very interesting to find a relationship between ultrasonic speed wave and compression strength of the samples. For the same aggregate and the same ratio of the constituents, the modifications is ultrasonic speed wave can indicate changes in the cement past structure.

DEVELOPMENT

Physical bamboo particles: bamboo particles smaller than 2.0 mm were washed in water (during 2 hours at 80'C). It was utilized 0.1 kg of bamboo particles by 1 liter of water. After washing-up, bamboo particles were dried in natural condition during one week.

Mineralization: natural or washed particles were treated with two types of chemical solutions: sodium silicate (2 and 4% concentration) and aluminum sulfate (10,20 and 30% concentration). This procedure was adapted from Furuno et al. (Ref.4).

Samples fabrication: samples (three replication by treatment) were made with natural and washed bamboo particles (both mineralized). Two types of Brazilian Portland cement were employed: type II (CPII E 32 - NBR 11578) and type V (CP V ARI - NBR 5733 - a high initial strength cement). For three cylindrical samples (0 50 mm and 100 mm height) were used 300 g of cement and the mass from 150 g of the original bamboo particles. Water amount ranged 250 to 400 ml.

Primarily it was realized a mix cement-bamboo particles. Water was added to the mix, then the mix was placed into the cylindrical moulds. After 24 hours the samples were removed from the moulds. Mass of the samples was measured during 44 days. Compression test was conducted in a Versa Tester apparatus for about 3 minutes.

Non-destructive evaluate: ultrasonic speed wave was utilized to survey changes in the structure of the composites. A surgical gel was utilized to enhance the surface contact of the samples with the probes. A Steinkamp BP-5 apparatus was utilized (sensibility of 0.1 us). Measurements were conducted during 14 days.

RESULTS

Natural bamboo particles are very inhibitory to the cement setting (Beraldo, Ref.3). So, it was utilized, as reference, the sample made with washed bamboo particles. It was adopted **N**-for Natural bamboo particles and **W**-for washed ones.

Mineralization treatments were represented by **A/B**, where **A** and **B** denotes, respectively, the concentration of **sodium silicate** (%) and **aluminum sulfate** (%).

At the same moisture content the mineralization treatment increase the weight of the bamboo particles. Values ranged from 14% (treatment N2/10, i.e. natural bamboo particles mineralized with 2% sodium silicate concentration and 10% aluminum sulfate concentration) to 58% (treatment N4/30).

Drying curves of composites show different behavior for mineralized or not mineralized particles (fig.1 and 2). It can be observed that the moisture content of a reference composite (WO/O-without mineralization) decreased faster than others composites made from mineralized particles. This prove that mineralization modify the structure of the composites.

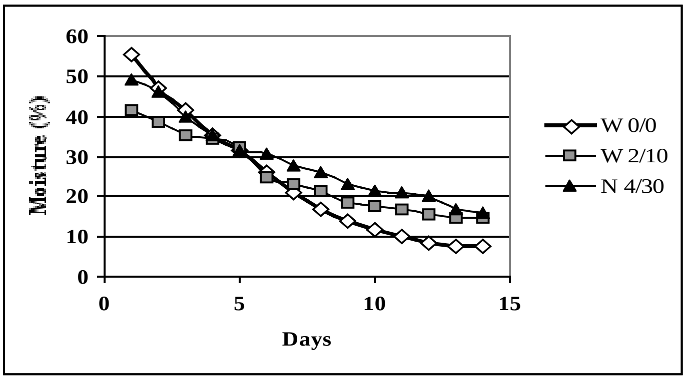

Fig.1 - Drying curves for CP VARI

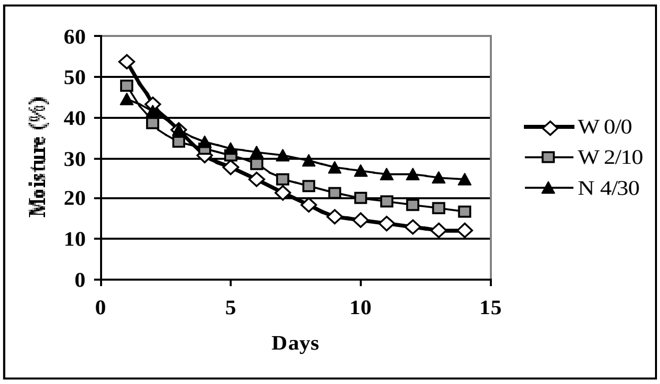

Fig.2 - Drying curves for CP II E 32

Mineralization could overcome the inhibitory effect of the substances enclosed in natural bamboo particles. Setting and hardening of Portland cement were enhanced. However, this procedure was very sensible according to the mix constituents, mainly the water amount. Table 1 show the results of the compression strength of the samples.

For type II Portland cement the composite compression strength of washed and mineralized particles (**W**) were increased, when compared with a composite from natural mineralized particles (**N**) utilization. For type V Portland cement it was observed an adverses effect. Cement type II is then more sensible to the harmful substances in natural bamboo particles.

Table 1 - Compression strength (MPa) for bamboo mineralized-Portland cement composite. N (natural particles), W (washed particles).

Treat.	CP II				CP V			
SA/SS	SS 2		SS 4		SS 2		SS 4	
(%)	N	W	N	W	N	W	N	W
SA10	3.7	6.6	3.6	4.9	10.4	6.4	9.9	5.3
SA20	3.8	4.4	3.7	4.7	6.7	5.0	8.0	4.1
SA30	2.2	2.6	2.2	3.1	2.8	2.6	4.6	2.9

Greater salts concentration produce smaller composite compression strength. This unexpected fact can be explained by an occurrence of a very quick exothermic reaction between cement and other chemicals. When water is added to the dry mix, temperature raise suddenly (15'C in 5 minutes for N4/30). Increase in the mix temperature avoid composite workability, and this fact can damage the structure of the material.

It was not necessary utilize a high salt concentration for a composite fabrication. Better results were obtained for 2/10 treatment. However, the results obtained must be considered with precaution because the changes in water amount reduces drastically the mix workability. Table 2 show the compression strength for two kind of treatments (N2/30 and N4/30).

Table 2 - Compression strength (MPa) of natural mineralized bamboo-cement composite.

Particles treatment	Water amount (ml)	MOR (MPa)	
		CP II	CP V
Natural	250	2.2	2.8
SS 2	300	3.0	4.4
SA 30	400	-	4.2
Natural	250	2.2	4.6
SS 4	300	2.1	4.2
SA 30	400	1.6	2.2

For a 2% sodium silicate concentration compression strength of the samples increased with amount of water, while for a 4% concentration the effect was adverse. For both matrix employed compression strength of the samples was smaller than 5.0 MPa.

Non-destructive evaluation: composites surface was very irregular and there was not a good coupling with the samples and the probes. Ultrasonic speed wave across the composites increased during the first days and mainly, during the first hours. After a variable time (5 to 8 days) there was a stabilization in ultrasonic speed wave.

An exponential relationship between ultrasonic speed wave and the time can be proposed:

$$V = V_{max} (1-\exp(-kt)) \qquad (1)$$

Where V_{max} = maximum ultrasonic speed wave (at is supposed constant) k = rate of speed increase by time.

Figure 3 and 4 show the ultrasonic speed wave value across the specimens.

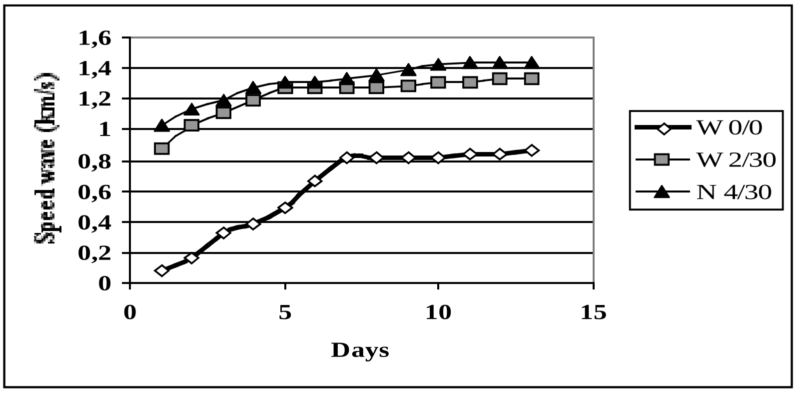

Fig.3 Ultrasonic speed wave for type II cement composite.

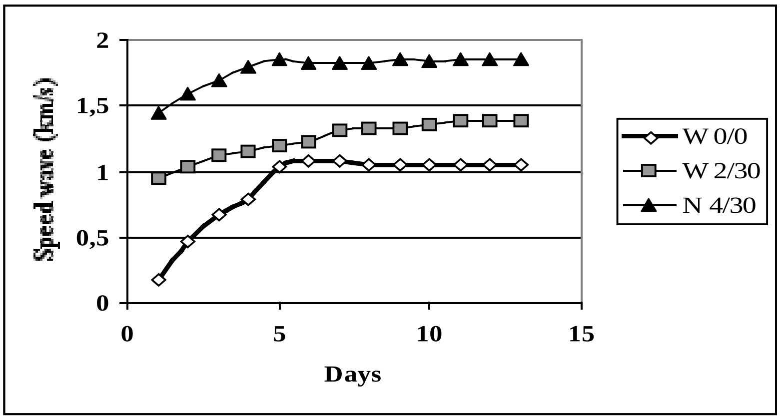

Fig.4 Ultrasonic speed wave for type V cement composite.

For type II cement maximum value ranged from 0.84 Km/s (WO/O) to 1.68 Km/s (W2/20). For type V cement maximum value ranged from 1.01 KM/s (WO/O) to 1.80 km/s (N4/30). The coefficient **k** was ranged from 0.31 to 0.44.

For many materials compression strength and ultrasonic speed wave are very dependent from density. Nevertheless, mineralization affect the density of the composite, by deposition of the substances into the bamboo cells. Probably, mineralization creates heterogeneous regions in the composite structure without provoking favorable modifications in terms of mechanical strength (table 2).

Table 2 - Physical - mechanical characteristics of mineralized particles bamboo - cement composite N (natural particles) W (washed particles)

Treatment	CP II			CP V		
SS (%) SA (%)	Speed (km/s)	Density ($g.cm^{-3}$)	MOR (MPa)	Speed (km/s)	Density ($g.cm^{-3}$)	MOR (MPa)
W 0/0	0.84	0.97	1.0	1.01	0.99	3.1
N 2/30	1.40	1.07	2.2	1.57	1.06	2.8
N 4/30	1.34	1.03	2.2	1.80	1.15	4.6
W 2/10	1.60	1.14	6.6	1.65	1.12	6.4
W 2/20	1.68	1.15	4.4	1.63	1.06	5.0
W 2/30	1.33	1.03	2.6	1.37	0.96	2.6
W 4/10	1.41	1.08	4.9	1.46	1.06	5.3
W 4/20	1.50	1.07	4.7	1.41	1.04	4.1
W 4/30	1.36	1.06	3.1	1.39	1.00	2.9

Statistical analysis indicates that ultrasonic speed wave depends strongly from the matrix employed. Speed average values was 1.48 Km/s (type V) and 1.38 km/s (type II0. For density average values were 1.05 g/cm^3 (type V) and 1.07 g/cm^3 (type II), while compression strength average values were 4.10 MPa (type V) and 3.52 MPa (type II).

Young's dynamic modules of the composites could be evaluated by means of the density and ultrasonic speed wave measures. For the composites reference (W0/0) values was 700 MPa (type II cement) and 1000 MPa (type V cement). For mineralized bamboo particles values ranged from 3700 MPs (N4.30, type V cement) to 1800 MPa (W 2/30, type II cement).

CONCLUSIONS

Natural bamboo particles are very inhibitory to the setting and hardening of the type II Brazilian Portland cement. Mineralization of the bamboo particles enhance the performance with cement paste. This procedure depends strongly of the water mix amount. For each mineralization treatment it was necessary optimize the water amount. Salts in small concentration were most indicate to composite fabrication. A non-destructive evaluating test (NDE) ultrasonic speed wave, can survey the matrix modifications in the early ages. However, ultrasonic speed wave cannot correlated with compression strength, mainly due to the different salts concentration during mineralization procedure. Young's dynamic modulus of particles bamboo-Portland cement composites ranged from 1800 MPa to 3700 MPa.

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