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INFLUENCE OF PRE-TREATMENTS ON THE COMPATIBILITY OF MAIZE COB CEMENT MIXTURES

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ABSTRACT

The effects of pre-treatments: aqueous extraction, addition of 3% calcium chloride ($CaCl_2$) and combination of aqueous extraction and 3% $CaCl_2$ on maximum hydration temperature (T_{max}), setting time (t_{max}) and time ratio indices (t_R) of locally sourced maize cobs mixed with Portland cement were investigated. Aqueous extraction reduced the t_{max}, T_{max} and t_R while chemical treatment and combination of aqueous extraction and chemical treatment reduced t_{max} and t_R but increased T_{max} of the maize cob-cement mixes. Generally, untreated maize cobs were moderately suitable for cement bonded composites production. Pre-treatment with 3% $CaCl_2$ improved the compatibility of maize cobs with cement than either aqueous extraction or combined treatment with aqueous extraction and addition of 3% $CaCl_2$. The results of this work showed that utilisation of maize cob for composite production can serve as avenues for creation of waste to wealth and thus cushion the over-exploitation of timber resources.

Keywords: Maize cobs, Cement composites, Maximum hydration temperature, Setting time, Time ratio index

INTRODUCTION

The increasing demand for wood and wood products due to the ever increasing world population has culminated into the constant depletion of wood in the forest with an attendant scarcity of timber supply (Ajayi, 2002; Adefisan, 2010). Therefore in order to meet future wood products needs, it is imperative to utilise readily available agricultural residues such as banana stem, coffee and groundnut husks, maize cobs etc. for the production of value-added products by combining them with Portland cement as binder (Ajayi, 2002; 2006). This is more so since the use of agricultural residues can increase material supplies for construction, create job opportunities, increase food production, increase farmers' income and alleviate poverty and reduce pressure on other forest resources (Ajayi, 2006). Most agricultural residues are fibrous tissues having comparatively attractive cellulosic properties similar to wood. Their incorporation in cement composites for building construction is believed to be able to offset wood shortage and can augment the development of durable low-cost housing materials in developing countries adaptable for both internal and external purposes (Xu *et al.*, 2004).

Maize is one of the major crops grown in large quantities in Oyo state, Nigeria. An estimated cob residue of 3299.2 kiloton per year is generated which are sometimes used as fuel but most times litter the ground on street, inside drainage channels and in market places in both urban and rural areas at different stages of decay especially during harvesting season from February to September (Olorunnisola, 1999). A means of curtailing this menace is in the production of environmentally friendly cement based composites for use in structural and non-structural purposes. This could serve as building components to the Nigerian populace in need of affordable construction materials and also cushion the existing timber demand.

However, a major limitation to the development of cement based maize cob composites is the incompatibility existing between lignocellulosic materials and cement. This is attributable to presence of sugars and extractives which impair the formation of strong crystalline bond. Therefore, pre-treatment measures such as aqueous extraction (cold or hot water) and / or application of chemical accelerators such as calcium chloride ($CaCl_2$) which remove or partially remove soluble inhibitory components that may hinder formation of strong crystalline bond are employed in the production line (Badejo, 1989; Olorunnisola *et al.*, 2005, Ajayi, 2006; Olorunnisola, 2008).

The first step in determining the compatibility of a particular lignocellulosic with cement is to compare its hydration characteristics with that of cement. The more similar the hydration of the candidate furnish is with that of cement, the more compatible is the material (Semple *et al.*, 2002; Semple and Evans, 2004). Also, various compatibility indices have been used over the years in the classification of lignocellulosics for cement bonded composite (CBC) manufacture (Hachmi, *et al.*, 1990; Karade *et al.*, 2003;

Pereira *et al.*, 2006 etc.).While Jorge *et al.*, (2004) noted that the maximum hydration temperature (T_{max}) and the time to attain it (t_{max}) are the two predictors of the general inhibitory properties of lignocellulosics when used for CBC production, Olorunnisola (2008) reported that the deployment of time ratio index (t_R) due to its ease of use could enhance productivity in composite production.

Furthermore, different lignocellulosic materials react differently to varying levels of pre-treatment due to their chemical composition (Alberto *et al.*, 2000). While some were found amenable to cold aqueous extraction, others required hot water treatment. However, the incorporation of chemical additives such as calcium chloride ($CaCl_2$) to remove or reduce cement inhibitory components is one of the commonest pre-treatment measures employed in composites production (Badejo, 1989; Olorunnisola, 2005, 2008). This work therefore examined the influence of aqueous extraction (cold and hot water), treatment with 3% calcium chloride ($CaCl_2$) and combination of aqueous extraction (hot or cold) and 3% $CaCl_2$ on the compatibility of maize cob mixed with cement.

MATERIALS AND METHODS

The study area and methods of data collection

Maize cobs were sourced from two local markets (i.e. Bodija and Sanngo) in Ibadan, Oyo state, south west of Nigeria. The cobs were air dried for two weeks and hammer milled. The milled particles were sieved using a set of 1.18 mm, 0.85 mm and 0.60 mm sieves. Particles that passed through the 0.85 mm sieve and were retained in the 0.60 mm sieve were collected and dried to 10% moisture content.

Laboratory analyses and testing

Particles retained on the 0.60 mm sieve were divided into three sets with the first set mixed with cement 'as is'(i.e. without pre-treatment), the second set was soaked in ordinary de-ionised water for 30 minutes, the third set was soaked in hot de-ionised water at 80°C for 30 minutes, drained and dried to 10% moisture content. The fourth set consist of samples (i.e. three samples measuring 15 g each) from the untreated particles and those treated with cold and hot water were later mixed with 3% $CaCl_2$.

Hydration Test

For the hydration tests, 15g of both treated and untreated maize cob particles, 200g of ordinary Portland cement and 93ml of de-ionized water were mixed in a polyethylene bag to form homogeneous slurry as in Adefisan and Olorunnisola (2007). The neat cement was mixed with 90 ml of de-ionised water. The tests were performed in a set of well insulated thermos flasks. Temperature rise was monitored for 24 hours using a T-type thermocouple. Three replicates of each mixture were prepared. The compatibility of maize cob with cement was assessed using the compatibility indices shown in Table 1.

Table 1: Cement compatibility assessment schemes

S / No.	Parameters	Classification Index	Reference
1	Setting time (time to reach maximum temp., t_{max})	Suitable (<15hr) Unsuitable (> 20hr)	Hofstrand *et al.* (1984)
2	Maximum hydration temp.	Suitable (T_{max} > 60°C) Intermediately Suitable (T_{max} = 50 - 60°C) Unsuitable (T_{max} < 50°C)	Sandermann and Kohler, (1964)
3	Time ratio (t_R): ratio of setting time of wood/cement mix to neat cement i.e. $t_R = t_{WC}/t_{NC}$	$1 \leq t_R \geq 1.5$ (Suitable) $1.5 < t_R \geq 2.0$ (Acceptable) $t_R > 2.0$ (Inhibitory)	Olorunnisola (2008)

Method of data analysis

The results of the hydration test were subjected analysis of variance (Anova) at 5% level of probability at the following levels:

Pre-treatments: none, cold water, hot water, 3% chemical additives
Replicates: 3
This translates to a 4 x 3 factorial experiment

RESULTS

The results of the hydration tests are shown in Table 2

Table 2: Hydration parameters of maize cob-cement mixes

Pre-Treatment	Setting Time (tmax,h)	Maximum Hydration Temperature (Tmax, °C)	t_R
None	9.9[A] (0.35)	44.6[C] (0.71)	1.4[A] (0.08)
3% $CaCl_2$ + Untreated Cold Water Treated Cobs	4.8[B] (0.0)	63.1[A] (0.45)	0.7[B] (0.02)
3% $CaCl_2$ + Cold Water Treated Cobs	7.1[B] (3.29)	37.7[D] (0.9)	1.0[B] (0.49)
	5.4[B] (0.25)	61.0[B] (1.32)	0.7[B] (0.02)
Hot water treated Cobs	5.0[B] (0.0)	35.9[E] (0.49)	0.7[B] (0.02)
3% $CaCl_2$ + Hot Water Treated Cobs	5.5[B] (0.29)	60.5[B] (0.62)	0.8[B] (0.02)
Neat Cement (Control)	7.2	61.0	1.0

Means with the same letters in the same column for each of the rattan species are not statistically different.
Standard deviation in parentheses

The setting time of the maize cob cement composites without pre-treatment was 9.9 h. The equivalent time for neat cement (without maize cob) was 7.2 h. While the application of aqueous pre-treatment to maize cob particles resulted in t_{max} that ranged between 5.0 to 7.1 h, the setting time of composites treated with 3% $CaCl_2$ was 4.8 h (Table 2). The maximum hydration temperature of the maize cob cement composites (T_{max}) was 44.6°C while untreated and ranged between 35.9 to 63.1°C when subjected to varying levels of pre-treatments. However, the time ratio indices (t_R) of the maize cob cement mixes were 1.4 while untreated and ranged between 0.7 and 1.0 when subjected to varying levels of pre-treatments (Table 2).

DISCUSSION

Setting time (t_{max}) of Maize Cob Cement Composites
Based on the classification of Hofstrand *et al.* (1984), the untreated maize cob particles were compatible with cement having t_{max} less than 15 h. The setting times of composites treated with aqueous extraction (hot or cold water) with the addition of 3% $CaCl_2$ were very similar (5.5 and 5.4). The greatest improvement in setting time was recorded for composites treated with 3% $CaCl_2$. What this implies is that the application of 3% $CaCl_2$ was more effective in removing / reducing the inhibitory components in maize cob particles than aqueous extraction or combination of aqueous extraction and chemical additive.

Analysis of variance (Table 3) revealed that pre-treatments had significant effects ($P < 0.05$) on the compatibility of the maize cob composites. However, no significant effect existed in the setting times of composites subjected to varying levels of pre-treatments. This implies that the varying levels of pre-treatment did not influence the setting times of maize cob composites.

Table 3: Analysis of variance of setting time, maximum hydration temperature and time ratio index of maize cob cement composites

Source	Df	Mean Square Values t_{max}	T_{max}	t_R
Pre-treatment	5	468.27*	11.26*	0.218*
Error	12	0.648	1.847	0.041

* Significant at 5% Level of Probability

Maximum Hydration Temperature (T_{max}) of the Maize Cob Composites

According to Sandermann and Kohler (1964) classification, the untreated maize cobs were unsuitable to CBC production having T_{max} less than 50°C. While the application of aqueous extraction (hot and cold water) reduced the maximum hydration temperature (35.9 – 37.7°C) resulting in composites unsuitable for CBC manufacture, pre-treatment with 3% $CaCl_2$ recorded the greatest improvement in T_{max} (41% increment). This may again indicate that $CaCl_2$ was more effective than aqueous extraction in removing / reducing the inhibitory components of maize cobs particles thereby increasing the T_{max} of the composites. This observation is similar to those reported by Olorunnisola *et al.*, (2005) that the addition of 3% $CaCl_2$ increased the T_{max} of some cement based composites. Further, the incorporation of aqueous extraction and 3% $CaCl_2$ improved the compatibility of maize cob cement mixes resulting in T_{max} in the range of 60.5 and 61.0°C. What can be inferred from the foregoing is the application of 3% $CaCl_2$ alone can improve the compatibility of maize cob-cement mixes.

Statistical analysis (Anova) revealed that pre-treatments had significant effects ($p < 0.05$) on the compatibility of maize cob composites (Table 3). While no significant difference existed in the T_{max} of composites treated with combinations of aqueous extraction and 3% $CaCl_2$, the T_{max} of composites treated with 3% $CaCl_2$, cold and hot water were significantly different from each other (Table 2). This may suggest that the different pre-treatments had different effects on the T_{max} of the maize cob composites. This observation is in line with those of Alberto *et al.* (2000) that different lignocellulosic materials require different pre-treatment depending on their constituents.

Time Ratio Indices of the Maize Cob-Cement Composites

Based on Olorunnisola (2008) criterion, the untreated and pre-treated maize cob composites were suitable for cement bonded composites production. Pre-treatments significantly ($p < 0.05$) improved the t_R indices of the maize cob composites as against the untreated samples (Table 2). However, no significant difference existed in t_R indices of composites subjected to varying levels of pre-treatments. What this implies is that varying levels of pre-treatments employed did not influence t_R of the pre-treated composites (Table 2).

CONCLUSIONS

The following conclusion can be deduced from this study.

i. maize cobs are suitable for cement bonded composites production.

ii. pre-treatments improved the compatibility of maize cobs with cement.

iii. the application of 3% calcium chloride improved the compatibility of maize cob with cement than either aqueous extraction or combination of aqueous extraction and 3% $CaCl_2$.

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