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# Investigation of strength and dimensional movement of cement bonded board produced from tomato stem particles and coconut sawdust

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## ABSTRACT

**Aim:** The study was carried out to examine the use of coconut sawdust and tomato stem particles as wood at varying blending proportion to produce tomato particle based board.
**Method and Materials:** Boards of dimensions 350mm by 350mm by 6mm were produced from cement and wood (Coconut sawdust, tomato stem particles) at different blending proportion and addition of additive ($CaCl_2$ at different concentration). The physical properties which included water absorption and thickness swelling and mechanical properties which included Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) were investigated. Thickness swelling and water absorption were investigated at 24 and 48 hours.
**Results:** The results showed that boards exhibited mean values of 0.50% to4.16% and 2.12% to 7.00% respectively of thickness swelling at 24 hours and 48 hours respectively and 13.62% to 25.16% and 17.62% to 29.07% of water absorption at 24 hours and 48 hours respectively. The boards also exhibited means of 1.00N/mm² to 5.25N/mm² and 339.48N/mm² to 3425.73N/mm² for MOR and MOE respectively. Results showed that increase in the tomato particle content cause increase in water absorption, thickness swelling as it shows highest water absorption and thickness swelling values.
**Conclusion:** It was concluded that tomato stem and coconut sawdust can be used to produce cement bonded boards after pretreatment with hot water and preferably both sieved.

**Keywords:** Cement-Bonded Particle Board, Coconut Sawdust, Strength and Dimensional Movement, Tomato Stem.

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## Introduction

The traditional use of wood and demand for wood products are increasing in many part of the world, Nigeria. Large quantities of wastes are generated on daily basis from the agricultural sectors which has not been efficiently utilized but are burnt or allowed to decay in public places in the open air creating environmental pollution (Owoyemi et al., 2010; Olufemi et al., 2012; Shehrawat and Sindhu, 2012).

Odewumi, (2001) commented that, the pollution problems created by dumping and burning of agricultural residues, is linked with the concern for conservation of future resources such as forest, water among others, have developed interest in finding utilization outlets for Agricultural waste generated in the country.



However, waste generation is closely linked to population, urbanization and affluence observed which is connected with everyday living that cannot be avoided (Odewumi, 2001). Agricultural waste management is part of the ecological cycle in which everything is cycled and recycled such that an interdependent various possibilities of plant waste cycling, recycling and further relationship is maintained in the eco-system by waste management, all the plant wastes are placed at the right place and right time for the best utilization in order to convert into useful products and pollution control (Shehrawat and Sindhu, 2012). Thus by managing these crop wastes in a well-planned manner will enhance a healthy environment for man and all other living creatures.

In order to look for substitute for conventional wood and maximize the utilization of wood which is already in high demand and the most widely used raw materials, several research activities that prompted the discovery of some major material with close characteristics with wood among other has been on course. An area of utilization which is worth looking into is an attempt to further enlarge the scope of utilization of Agricultural waste is that of Wood - Cement Composite Board manufacture. (Ajayi, 2011; Papadopoulos, 2008; Ajayi and Badejo, 2005).

Wood - Cement Composite Board is a panel product made by compressing small particles of wood while simultaneously bonding them with an adhesive or binder. The many types of particleboard differ greatly in regard to the size and geometry of particles, the amount of adhesive used, and the density to which panels are pressed. The major types of particles used for particle board are: shaving, flake, chip, sawdust, sliver, excelsior. However, boards that appear similar may be quite different in strength and dimensional stability (Youngquist et al 1993). Cement-Bonded Wood Composites have the potential to provide a wide range of products for building applications by using a wide range of recycled wood materials (Ronald *et al.,* 1996).The major raw materials for cement boards consist mainly of wood, cement and water with or without a catalyst (Ajayi, 2005; Papadopoulos, 2008; Ajayi, 2011). The widespread distribution of local raw materials is the main reason why this product is generally acceptable.

Wood - Cement Composite Board products have many advantages such as no emission of toxic during their manufacture, low cost and ability to cure without applying high temperatures (Lima *et al.,* 2011). However, panels made from these composites have high versatility in terms of finishes (Matokoski, 2005). The product can be sawn, nailed, screwed, glued and towed; widely used as flat roofing, prefabricated structures, mobile homes, permanent formwork, cladding, sound barriers and paving, because they work as structural insulation panels (Karade, 2010).

A significant problem however, when these products are manufactured, is the compatibility of wood with cement. The term compatibility, when applied in the area of wood-cement composites, refers to the degree of cement setting after mixing with water and with a given wood in fragmented form. Generally, if the chemical process of cement hardening is undisturbed by the presence of wood, it is considered that cement and wood are compatible. On the other hand, if cement hardening is impaired by the presence of wood, then cement and wood are referred as incompatible (Nazerian. 2011).

The production of Particleboard from Agricultural wastes like Tomato stem with cement as a binder may provide a suitable alternative to low density sawn timber which will also reduce the demand for wood and wood products for other board production as they are available in large quantity, thereby reducing pressure on forest and ensures sustainable forest management.

## Materials and Methods

*Preparation of Tomato Stem*

The tomato stems were collected from CSP Farm, at The Federal University of Technology, Akure (FUTA). The stems were turned into particles using hammer mill, treated in hot water to remove extractive capable of hindering the setting and curing of cement then dried to aid its adhesion to the binder. The particle obtained was sieved to obtain particles of uniform size which was used for the production of the tomato stem based board. Thereafter the particles were dried to 12% moisture content in a laboratory environment.

The coconut sawdust was obtained from wood workshop of FWT, FUTA. It was sieved using a 2mm aperture sieve to obtain uniform sawdust sizes. It was then pre-treated using hot water to remove soluble extractive that may possibly hinder its binding with cement.

*Materials Formulation and Board Formation*

The material contents comprising tomato stem particles and sawdust were weighed using blending proportion 0:100, 75:25, 50:50, 25:75, and 100:0 for varying Additive concentration (1.5%, 2.5%, and 3.5%). The density of the board produced is 1200kg/m$^3$ and the size of 200 x 200 x 6mm. The cement and wood were weighed into the mixing bowl in an appropriate quantity based on the blending ratio of the materials and mixed thoroughly without any lump and spread into the mould for mat formation. The cold pressing machine was used to densifythe materials in the mould thereafter the formedboard was removed from the mould and stored inside a conditioned environment. The boards were then cut into experimental sizes.

*Testing*

This study examined the material's Thickness Swelling, Water Absorption, Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) of the tomato stems based Cement Particle Board. The cement based boards were cut into test specimens according to a modified ASTM 1998 (American Standard Testing Method) with specified Samples of 50 x 50 x 6mm which was used to conduct the Thickness Swelling and Water Absorption while 200 x 50 x 6mm sized samples were used for MOR and MOE determination.

*Water Absorption*

Water Absorption (WA) is the percentage of the increase in weight of board over original weight or initial weight. This test was carried out to determine the dimensional stability of produced board. Test specimens were soaked in water (at room temperature) for moisture uptake for 24 hours, and then the weight was recorded. The percentage water absorption for the test samples were calculated using:

$$WA(\%) = \frac{W_1 - w_2}{W_1} \times \frac{100}{1} \ldots\ldots\ldots 1$$

Where;

WA = Water absorption (%)

$W_1$= Initial weight (g)

$W_2$= Final weight (g)

*Thickness Swelling*

The same procedure was used to determine the thickness swelling, using the same samples at the same water soak period. The thickness of the cement based boards were measured using veneer calliper before and after water soak. The thickness swelling was expressed as the percentage of increase in thickness of the cement based board over the original thickness as expressed below:

$$TS\ \% = \frac{T_0 - T_1}{T_1} \times 100 \ldots\ldots\ldots 2$$

Where

TS = Thickness swelling (%)

$T_1$ = is thickness of the board after water immersion (mm)

$T_0$ = is the initial thickness of the board (mm).

*Strength Properties*

The Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) were evaluated by subjecting a sample of 200 x 50 x 6mm to a force/load on the Universal Testing machine at wood Testing Laboratory of FWT/ FUTA. The samples were supported by metal bearing plates to prevent damage to the beam at the point of contact between specimen and reaction support. The forward movement of the machine leads to gradual increase of load at the middle of the span until failure of the test specimens occurred. At the point of failure, the force exerted on each sample that caused the failure was recorded; thus, MOR and MOE were calculated using the equations 3 and 4, respectively:

$$\mathbf{MOR} = \frac{3PL}{2BH^2} (N/mm^2) \ldots\ldots\ldots 3$$

$$\mathbf{MOE} = \frac{PL^3}{4bd^3D} \ldots\ldots\ldots 4$$

Where; L = Span of board sample between the machine supports (mm)

b = Width of the board sample (mm)

H = Thickness of test specimen (mm)

d = thickness of the board sample (mm)

P = Ultimate failure load (N)

D = Deflection

*Experimental Design*

The experimental design for this study is Randomized Completely Block Design, the tomato stem particles and sawdust ratio (100:0, 75:25, 50:50, 25:75, 0:100) being the treatment and the additive concentration $CaCl_2$ representing the block.

*Statistical Model*

$Y_{ij} = \mu + T_i + B_i + \varepsilon_{ijk}$

$Y_{ij}$ = Individual Observation,

$\mu$= General Mean

$T_i$ =Treatment Effect, which is the three different mixing ratio

Bi = Block effect, additive concentration

$\varepsilon_{ijk}$ =Experimental Error

*Data Analysis*

Microsoft Excel was used for the basic statistical analyses. Descriptive statistic was presented as mean and standard deviation values. The statistical analysis was represented in graphs, tables and charts.

## Results and Discussion

*Physical properties*

The mean values of water absorption and Thickness swelling are represented in figure 1 to 4. The mean values ofwater absorption and thickness swelling at 24 hours ranged from 13.62% to 25.16% and 0.5% to 4.16% respectively with the lowest value showing the least board weight and thickness as shown in Fig. 1& 3. The mean values of the Water absorption and thickness swelling at 48 hours ranged from 17.62% to 29.07% as shown in Fig. 2& 4. The weight and thickness of samples increases as the proportion of tomato stem particles increases.

*Water Absorption*

It was observed that during the period of immersion in water, the amount of water absorbed by the boards increase as the tomato stem particles increase (Fig. 1 & 2). It was also observed that the lowest mean values of water absorption of 24 and 48 hours was 13.62% and 25.16% respectively which were obtained at the highest tomato stem particle content and highest additive concentration of 3.5%while the highest mean values at 24 hrs and 48 hrs at 25.16%, and 29.07% respectively were obtained at the lowest tomato stem particle content and lowest additive concentration of 1.5%.This is in accordance with previous research carried out such as Nadzri, et al. (2012); Ajayi (2002) where water absorption of cement and coconut sawdust produced boards increased as soaking time increase and water absorption of coconut fiber which might have been influence of coconut sawdust only.

Results of analysis of variance showed that the concentration of $Cacl_2$ and wood blending proportion (BP) has no significant effect on water absorption after 24 hours and 48 hours of immersion (Table 1). It showed that board produced with pure tomato stem particles and cement is the best when water absorption is considered, the absorption reduces as quantity of tomato stem particles reduces.

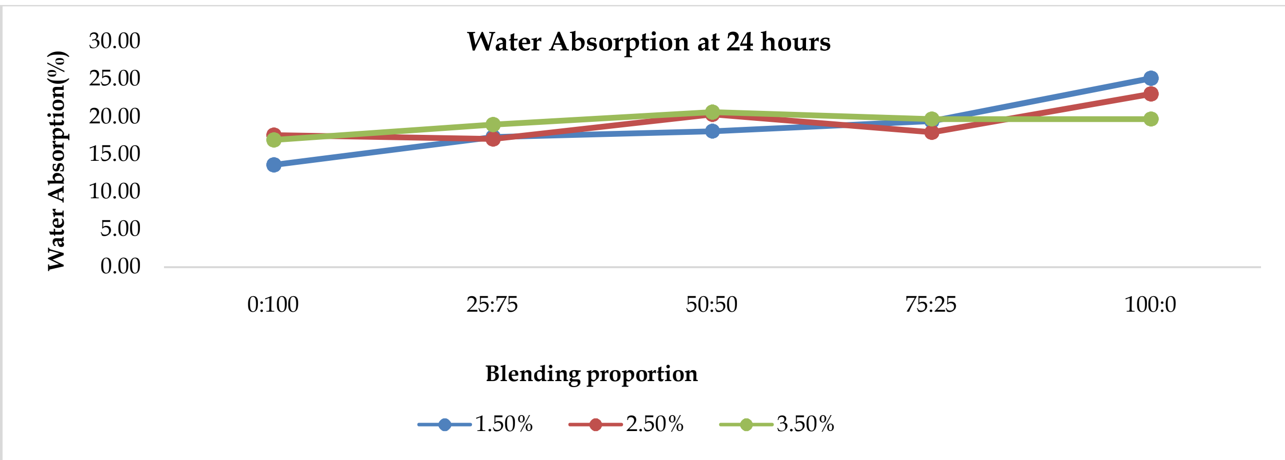


Fig. 1: The effect of variables on water absorption for boards exposed to water for 24 hours

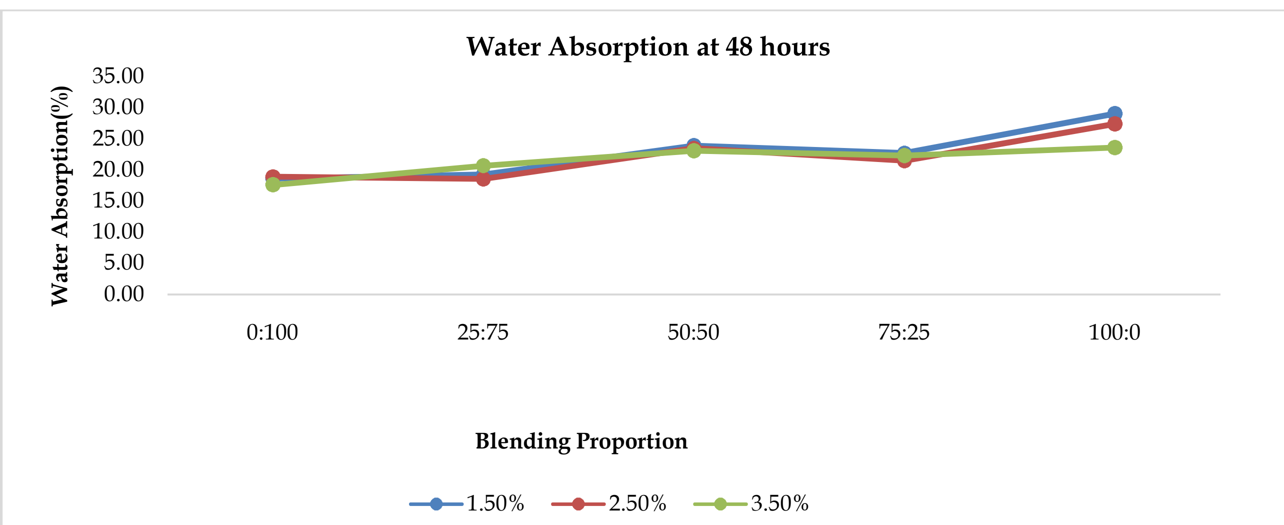


Fig 2: The effect of variables on water absorption for boards exposed to water for 48 hours

Table 1: The results of ANOVA conducted for water absorption of cement bonded particle boards

| Properties | period | Source of variance | Sum of Squares | df | Mean Square | F cal. | Sig. |
|---|---|---|---|---|---|---|---|
| Water absorption | 24 hrs | Blending Proportion (BP) | 144.322 | 4 | 36.081 | 10.720 | 0.000* |
| | | CaCl | 1.557 | 2 | 0.779 | .231 | 0.796ns |
| | | MR * CaCl | 62.329 | 8 | 7.791 | 2.315 | 0.077ns |
| | | Error | 50.485 | 15 | 3.366 | | |
| | | Total | 258.693 | 29 | | | |
| | 48 hrs | Blending Proportion (BP) | 262.396 | 4 | 65.599 | 39.516 | 0.000* |
| | | CaCl | 7.905 | 2 | 3.952 | 2.381 | 0.126ns |
| | | MR * CaCl | 32.346 | 8 | 4.043 | 2.436 | 0.065ns |
| | | Error | 24.901 | 15 | 1.660 | | |
| | | Total | 327.548 | 29 | | | |

*Thickness Swelling*

The mean values of thickness swelling at 24 hours ranged from 0.50% to4.16% with the lowest value showing the least swollen board as shown in Fig.3. The mean values of the thickness swelling at 48 hours ranged from 2.12% to 7.00%. The thickness swelling decreased as the quantity of tomato stem particles decreases, this could be attributed tohighcement content which makes the cement crystals grow and develop from the cement particles during the hydration process so that they push themselves against the fibre surfaces and penetrate into the available void spaces for anchorage. Therefore, the greater the amount of cement present, the stronger the interlocking between the cement crystals and fibres, resulting in a strong fibre–cement composite product. This result agrees with the findings of Tuico (1994). She found that boards with highercement: coconut coir dust ratio absorbed less water than boards with a lower ratio.

Results of analysis of variance showed that the blending proportion of Tomato particle to coconut sawdust, concentration of $CaCl_2$ and their interaction had no significant effect on thickness swelling after 24 hours and 48 hours immersion in water (Table 2).

Results of analysis of variance showed that there is no significant different in the effect of different blending proportion, $CaCl_2$ and their interaction on the thickness swelling of boards after 24 hrs and 48 hrs of water immersion (Table 2).

**Mechanical properties**

*Modulus of Rupture (MOR)*

It was showed that the mean values of MOR obtained for this study which ranged from 1.00N/mm$^3$ to 5.25N/mm$^3$ for all the blending ratio and additive concentration (Fig. 5).

The results of the analysis of variance showed that strength properties of the board are greatly influenced by blending ratio (Table 3).

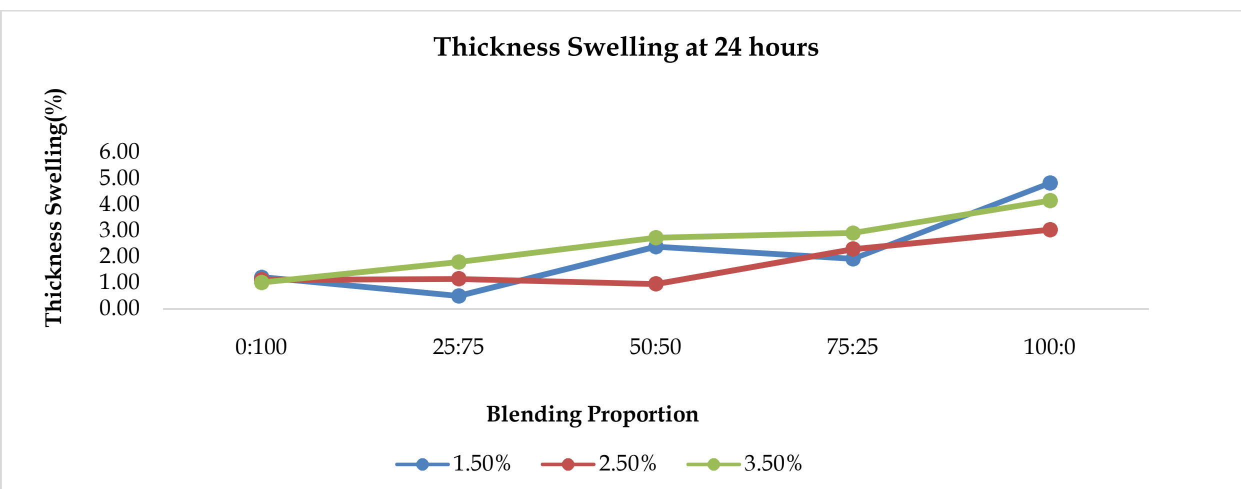


Fig 3: The effect of variables on thickness swelling for boards exposed to water for 24 hours

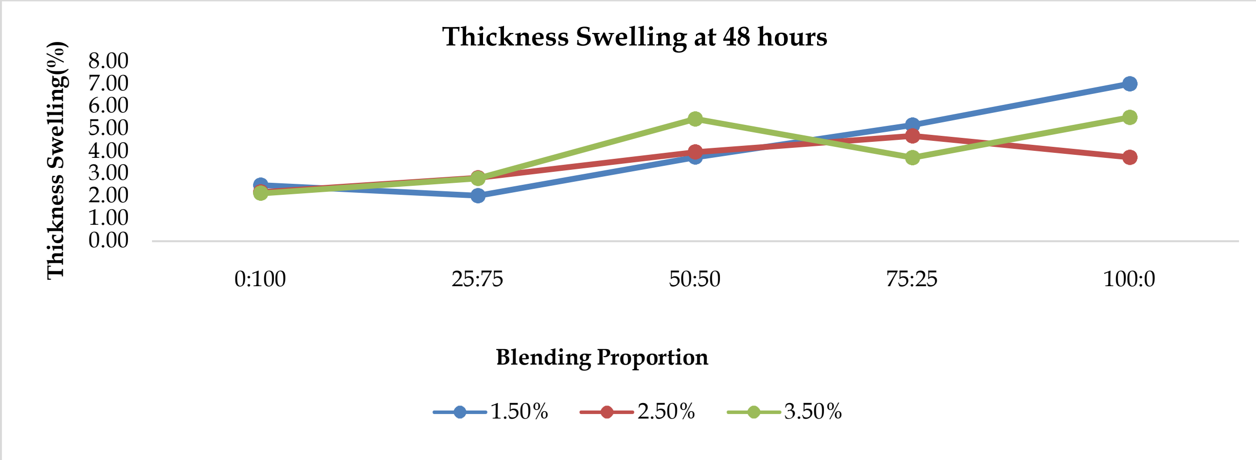


Fig. 4: The effect of variables on thickness swelling for boards exposed to water for 48 hours

Table 2: The result of ANOVA conducted for Thickness Swelling of cement bonded particle boards

| Properties | period | Source of variance | Sum of Squares | df | Mean Square | F cal. | Sig. |
|---|---|---|---|---|---|---|---|
| Thickness Swelling | 24 hrs | Blending Proportion (BP) | 33.616 | 4 | 8.404 | 2.525 | 0.085ns |
| | | CaCl | 3.326 | 2 | 1.663 | 0.500 | 0.617ns |
| | | MR * CaCl | 6.269 | 8 | 0.784 | 0.235 | 0.977ns |
| | | Error | 49.933 | 15 | 3.329 | | |
| | | Total | 93.143 | 29 | | | |
| | 48 hrs | Blending Proportion (BP) | 44.386 | 4 | 11.097 | 2.978 | 0.054ns |
| | | CaCl | 1.928 | 2 | 0.964 | 0.259 | 0.775ns |
| | | MR * CaCl | 15.343 | 8 | 1.918 | 0.515 | 0.827ns |
| | | Error | 55.895 | 15 | 3.726 | | |
| | | Total | 117.553 | 29 | | | |

ns = not significant, * = significant at 0.05% level of probability

There is significant difference between the blending ratio with board containing pure tomato being the highest which is in accordance with HanSeung Yang *et al.* (2004) that boards tend to be brittle whentheir modulus of rupture value is high and tend to be ductile or flexible when the value is low.

*Modulus of Elasticity (MOE)*

The mean values of Modulus of Elasticity ranged from 339.48N/mm² to 3425.73N/mm² which indicates that the MOE increased as the board density and mixing ratio as presented in Figure 6.The results of the analysis of variance of Modulus of Elasticity as shown in Table 3 showed that MOE was significantly affected by the board wood blending proportion at 0.05% level of significance, whereas the effect of additive concentration and the interaction between the blending proportion and additive concentration was not significant.

Table 3: The result of ANOVA conducted for Mechanical properties of Particle boards

| Mechanical properties | Source of variance | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Modulus of elasticity | Blending Proportion (BP) | 19648987.918 | 4 | 4912246.980 | 11.628 | 0.000* |
| | CaCl | 1881378.399 | 2 | 940689.200 | 2.227 | 0.142ns |
| | MR * CaCl | 2411098.252 | 8 | 301387.282 | 0.713 | 0.677ns |
| | Error | 6336756.921 | 15 | 422450.461 | | |
| | Total | 30278221.491 | 29 | | | |
| Modulus of rupture | Blending Proportion (BP) | 44.554 | 4 | 11.139 | 24.752 | 0.000* |
| | CaCl | 1.390 | 2 | 0.695 | 1.545 | 0.245ns |
| | MR * CaCl | 4.422 | 8 | 0.553 | 1.228 | 0.348ns |
| | Error | 6.750 | 15 | 0.450 | | |
| | Total | 57.117 | 29 | | | |

ns = not significant, * = significant at 0.05% level of probability.

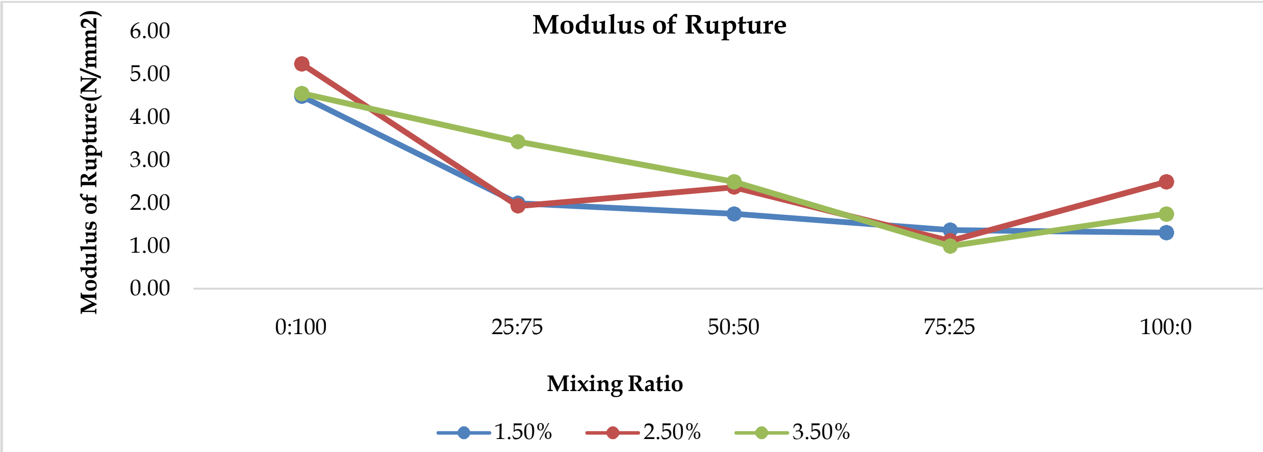


Fig. 2: The effect of variables on MOR of the boards.

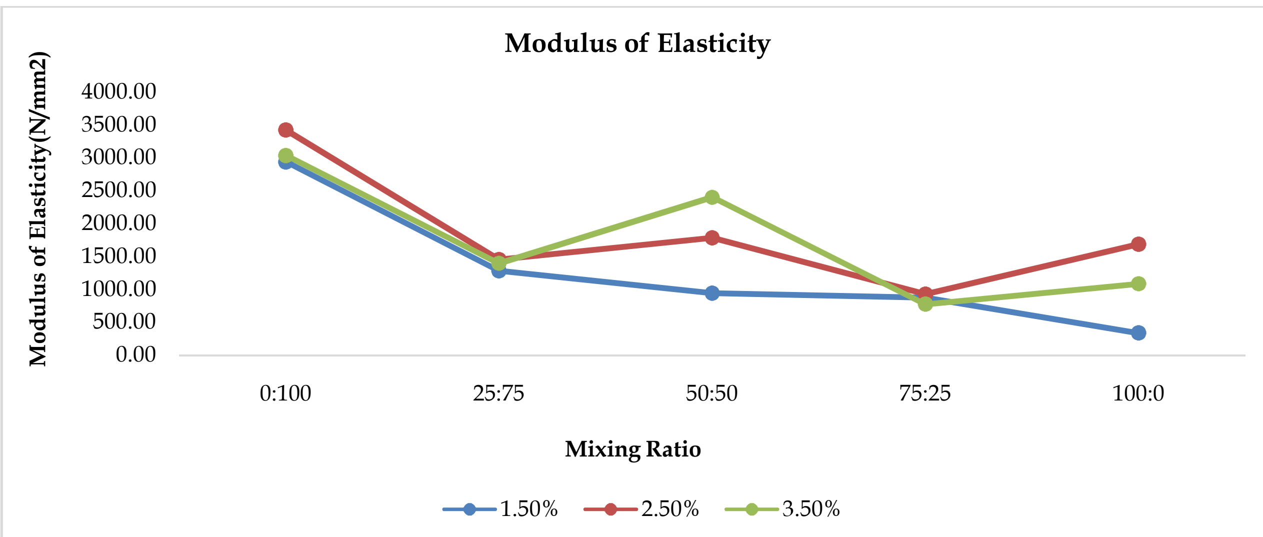


Fig. 6: The effect of variables on MOE of the boards.

## Conclusion

The blended Coconut sawdust and Tomato stem particles are suitable raw material for the production of cement bonded board. The best board with high strength properties and dimensional stability was shown to be produced with sawdust and cement only while the lowest appear to be boards with high tomato stem particle content. From this study, it is found that all the physical properties and mechanical properties of board with sawdust and cement is better that board with cement and tomato stem particles only; however 50:50 blending proportion is suitable.

*Recommendation*

Based on the above conclusions, the following recommendations are being made:

-Further research should be carried out to determine the effect of the sawdust size on the physical properties of the board.

-Further research should be carried out to examine the termite resistance of tomato wood cement boards.

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