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Strength and dimensional stability of cement-bonded wood waste-sand bricks

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Abstract: Conservation of trees which belong to renewable natural resources in developing countries through judicious utilization in building industry has been seriously left unattended to over the years. The utilization of this unprocessed wealth materials which could serve as one of the alternative constituents in construction materials is now a global concern. Therefore, the needs to investigate the strength and water sorption property of wood waste as a partial replacing material in brick production for building construction arise. Sawdust, sand and cement were mixed together at three different mixing ratios of 1 : 1 : 1, 1 : 1 : 2 and 1 : 1 : 3. The brick samples were replicated three times and subjected to water absorption, density and compressive strength tests. The results show that the effect of the equal volume of sand and sawdust with a subsequent increase in the cement portion at each mixing ratio level gave compact bricks without sudden fracture, reduced unit weight of bricks and subsequent lower water sorption properties of the bricks. The bricks show potentials to be used for wall partitioning. The introduction of sawdust also serves as partial sand replacement in concrete brick making.

Keywords: wood waste; bricks; mixing ratios; compressive strength; water sorption response; building industries

Wood wastes are residues from wood derived during various wood conversion processes. These residues are in form of edgings, trimmings, slabs. These wastes are generated in large quantities in the sawmill and some other wood based industries. The non-challant attitude of saw millers had been attributed to increases in the wastage of wood in sawmills since saw millers find it difficult to maintain their machines according to the manufacturers' prescription (Oyinloye 2004). Over the years, wood wastes have been a menace to our environment and health. They constitute environmental pollution and health hazard through the emission of poisonous gases during the burning method of disposal. According to the report of Badejo (1990), he opined that the bulk of wood wastes generated in Nigeria was estimated to be 1.72 million m^3, it rose to 2.3 million m^3 by 1988 and still this number has been increasing yearly without means of controlling and mitigating it.

Overtime, construction industry has been found to be responsible for the current consumption of 25% of wood and 40% of aggregates, 16% of water and 40% of the energy annually spent (Braganca et al. 2002). It is also worth knowing that locally sourced building materials particularly in Nigeria which could have facilitated sus-

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tainable development and growth in this sector had remained underdeveloped to a socially and economically acceptable level due to the low level of development of the economy (Adedeji 2007). In most developed countries, Ghosh (2002) from his study, verified that the traditional and conventional technologies used for construction and maintenance of buildings had been inefficient and resource wasteful due to an enormous amount of resources consumed.

In order to meet future challenges in wood product needs and in building construction which is now becoming scarce in the tropical forest, one strategy is to convert various wood wastes into value added products that could meet up with the properties of wood as building and structural materials. One out of many strategies that could be employed in meeting this challenge is the production of valuable wood products from wood residues such as sawdust, wood powder, wood shavings, wood flakes, etc. Application of any of these residues as a partial replacement of sand in brick production will also go a long way to produce a lightweight mortar and reduced bulkiness attributed to sand and cement in building construction.

Naghizadeh et al. (2012) and Faria et al. (2013) stated that incorporating wood waste into cement-bonded composite could serve as a welcome development. These researchers were of the opinion that while waste wood is vulnerable to biological degradation and environmental weathering, addition of cement could significantly reinforce the strength performance, reduce water absorption properties and structural durability of such wood composite. Cement-bonded wood has been studied over a century, but the mass utilization of this cement-bonded particleboard began in the early 1930s. Studies have shown that most of modernization was concluded prior to the 1940s. Cement-bonded wood was stimulated by problems associated to asbestos (Moslemi 1999). Also, the paucity of stocks as a whole is a sensation that limits the application of reprocessed wood (Wei et al. 2003). Many composites have emerged in many decades, for example, cement-bonded wood wool boards (CBWW), cement-bonded particleboards (CBPB), and fibre-reinforced cement boards (Frybort et al. 2008).

The need for locally manufactured building materials has been emphasized in many countries of the world because of their easy availability and low cost. Not long ago a few inventions for construction applications turned out to be produced as highlighted by some researchers, namely cement-bonded Oriented Strand Board (OSB) (Ntalos, Papadopoulus 2006; Papadopoulus et al. 2006), cement strand slab (Miyatake et al. 2000), or cement-bonded composite beams (Datye, Gore 1998; Bejó et al. 2005). For many applications, cement-bonded composites have been known to be competitive when in most cases compared to reinforced concrete they are used because of their relatively low density (Bejó et al. 2005). Bricks, a major construction material, have been regarded as one of the longest lasting and strongest building materials used throughout history. Ordinary building bricks are made of a mixture of clay and water, which is subjected to various processes, differing according to the nature of the material, the method of manufacture and the character of the finished product (Parashar, Parashar 2012).

However, supplementing sand with wood waste (sawdust) for producing bricks must be critically studied and emphasized as this will help us address the problems of compatibility and imbalance between the expensive conventional building materials in tandem with depletion of traditional building materials. Hence, there is a need to shift our attention from a conventional way of producing bricks which are expensive and bulky to focusing on low-cost alternative building materials.

In assessing physical and mechanical characteristics/performance of any composite, the product design mix could also play a major role. Many reported cases of the structural collapse of reinforced concrete buildings due to progressive deterioration of the various components forming the structural unit were found to be a result of an improper mixing ratio or ignorance in the use of locally available fine aggregate (Olusola, Akintayo 2009). Alexander and Mindess (2008) ascertained that mixing ratio can affect the strength and stability of a reinforced concrete structure just as the size, the shape and the grading of the aggregate will do.

This study therefore was designed to develop cement-sand building bricks reinforced with sawdust for construction with the possibility of obtaining light bricks with higher compressive strength when compared with traditional bricks while estimating their response to moisture and mechanical properties at different mixing ratios.

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MATERIAL AND METHODS

Procurement of materials

The materials used for this study included wood waste (sawdust) of *Gmelina arborea* Roxb, river sand and Portland cement. Other materials included manual brick moulder of dimensions 150 × 150 × 150 mm and water. The sawdust was procured from a sawmill section of the Department of Forest Products Development and Utilization, Forestry Research Institute of Nigeria, Ibadan, Oyo State, while the sand was collected from a stream located in Forestry Research Institute of Nigeria, Ibadan, Oyo State. Ordinary Portland Cement (OPC) was procured from the Lafarge Cement Company, Eleyele, Ibadan, Oyo State, Nigeria, which conformed to the British Standards Institution (1996a) requirements. The water used was cleaned and freed from any visible impurities, which conformed to British Standards Institution (1996b) requirements.

Raw materials preparation

The collected sawdust was pre-treated in hot water at about 80 °C for a soaking period of 1 hour. This was done in an aluminium bath. This pretreatment was carried out in order to facilitate the removal of water-soluble sugars and other extractives present in the raw materials which may possibly retard or completely inhibit the setting and curing of the cement binder and also to produce workable cement mixtures during brick formation (Gil et al. 2017). At the end of the soaking period, the hot water was drained off while the sawdust was washed in cold water for ten minutes and air-dried to a moisture content of 12% prior to use. This was done in accordance with the procedure used by Ajayi (2000).

The sand was sieved to remove stones and other unwanted materials and to have uniform particle size with sawdust. The stream sand was thoroughly washed and flushed with water to reduce the levels of impurities and organic matter. The sand was later sun-dried which conformed to British Standard 882 (1992). The water used was clean and free from any visible impurities, which conformed to British Standards Institution (1996b) requirements. The wooden mould used was cleaned and lubricated. The lubrication was necessary for easy demoulding after brick formation.

Brick formation

Water requirement. Water required for a workable mixture was determined using the Equation (1) applied by Adefisan (2007).

$$Rq = 0.35C + \left(0.30 - M\right) \times W \quad (1)$$

where:

Rq – water required (L);

C – weight of cement (g);

M – percentage moisture content of sawdust on dry basis;

W – oven dry weight of sawdust ($kg \cdot m^{-3}$).

Blending of materials and brick formation. The quantities of the materials used for the production of bricks were calculated and measured out according to the levels of combinations in the experiment. The sawdust, river sand and cement were calculated based on the sawdust/sand/cement ratio of the three components, while the nominal density was estimated to be 1 500 $kg \cdot m^{-3}$. Production of bricks was based on mixing ratios of sand/wood/cement at 1 : 1 : 1, 1 : 1 : 2 and 1 : 1 : 3 by weight.

A mould of 150 × 150 × 150 mm made with a wooden frame was used. The quantity of sawdust, river sand and cement were measured and poured inside a plastic bowl. These materials were thoroughly mixed until they were well blended. Water was then added followed by thorough blending until a lump-free furnish was obtained. The mix was manually dispensed into a locally fabricated mould followed by hand compacting in a pestle and mortar mode to increase the quantity of the mix in the mould.

Pressing and curing. The pre-compacted mix was followed by manual pressing using a minimal hold-down pressure press to allow the mixture to compact and initially set. Pre-pressing of the mixtures was necessitated by the low density of sawdust in the mixture. The pre-pressed bricks were then taken to a manual pressing machine, pressed in the mould with a pressure of 1.23 $N \cdot mm^{-2}$ for 15 min to 20 min to compress the mix to achieve good compaction after which they were removed from the mould which conformed to Sadiku (2015). The formed brick samples were carefully removed from the mould so that no damage occurred on the bricks while demoulding. All the bricks were marked appropriately for easy identification. The brick samples were allowed to cure at room temperature for 28 days. This was followed by air drying of the bricks until a constant weight was achieved.

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Testing

Three tests were carried out on the bricks. These include:

Mechanical property – Compressive strength. This test was carried out using a universal testing machine in the Structures Testing Laboratory at the Department of Civil Engineering, Faculty of Engineering, The Polytechnic of Ibadan, with attention focused on the maximum load causing failure. The test pieces of dimensions 150 × 150 mm were placed between a supporting base and a flat steel plate above it, onto which a plunger that applied a compressive load rested. The maximum load (newtons) was recorded per test specimen and the compressive strength was calculated as maximum load applied per unit area [Equation (2)].

$$C = \frac{F}{A} \quad (2)$$

where:
C – compressive strength;
F – maximum load applied;
A – cross-sectional area of the bricks.

Physical properties – Water absorption and unit weight test. This test was carried out according to ASTM C 67-03a (ASTM 2003). The brick samples were taken out of the curing tank and allowed to be drained by placing them on a metal wire mesh as described by Turgut (2007). The residual surface water was also removed with a dry cloth and immediately weighed. The water absorption of saturated and surface dried weight of samples was calculated using the following Equation (3):

$$WA = \left(\frac{W_2 - W_1}{T_1}\right) \times 100 \quad (3)$$

where:
WA – water absorption (%);
W_1 – initial/dried weight (g);
W_2 – saturated weight (g).

For the unit weight, the bricks were placed into an oven at 102 °C and dried until a constant mass was observed for a period of 26 hours. The bricks were then taken out from the oven and weighed at room temperature. The brick samples are cooled at room temperature and their unit weights were obtained by dividing the mass of the bricks by their overall volume.

The unit weight was then calculated using the Equation (4):

$$D = \frac{M}{V} \quad (4)$$

where:
D – density;
M – mass of the bricks after drying;
V – volume (size of the bricks).

RESULTS AND DISCUSSION

Compressive strength. The compressive strength of the bricks increased with an increase in the ratio of cement from 1 : 1 : 1 to 1 : 1 : 3 as shown in Figure 1. Bricks with lowest compressive strength were recorded from an equal ratio of wood waste to sand and with the lowest cement ratios (1 : 1 : 1). The compressive strength dramatically increased with an increase in the cement ratios to other materials (sand and sawdust). The highest mean value recorded was 12.80 ± 0.59 N·mm^{-2} at a mixing ratio level of 1 : 1 : 3 which were lower than what was recorded by Gong et al. (1993) but higher than what was recorded by Sadiku (2015). Gong et al. (1993) reported that the compression values required for materials to be used as pavements range from 20 N·mm^{-2} to 25 N·mm^{-2} while those for beams range from 20 N·mm^{-2} to 35 N·mm^{-2} and up to 65 N·mm^{-2} for reinforced concrete depending on the expected loads.

The low compressive strength recorded in this study may be due to the presence of fibre in the mix. This observation is corroborated by a similar finding of Elinwa and Ejeh (2005) where at higher sisal fibre content there is a reduction in the volume of the mix thereby leading to a reduction in the compressive strength of concrete. However, the compressive strength was greater in bricks with the highest cement

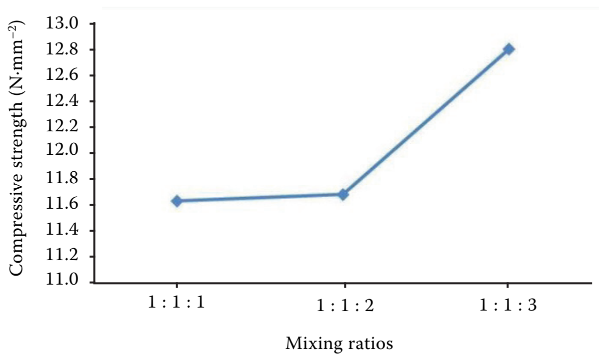

Figure 1. Effects of mixing ratios on compressive strength

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ratios, i.e. sawdust/sand/cement ratio (1 : 1 : 3). It is also good to note that the lowest compressive strength value (recorded in this study) is higher than the minimum compressive strength of normal bricks of 3.50 N·mm^{-2} as stated by Kumar et al. (2018). Hence, this makes these bricks suitable for construction purposes. The bricks where a low compressive strength was recorded may also be a result of wetting by up to 25% to 40% of dry strength (Figure 2).

The compressive strength increased with the density of bricks. This work is also in agreement with the conclusions of Wolfe and Gjinolli (1996) that at high density indices, a material is more compact in the lattice structure and thus it is able to withstand stress to a level before crumbling. However, the wood fibre presence in the bricks assisted in bridging the void and pore spaces created by the sand, thereby reducing the deformation and overall crumbling of the bricks when subjected to load. This observation was corroborated by the work done by Corinaldesi et al. (2016) on lightweight mortars containing wood-processing by-product waste. The analysis of variance (ANOVA) revealed that the three mixing ratios have a significant effect on compressive strength of the bricks produced (Table 1).

Water absorption. Figure 2 shows the mean values for percentage water absorption (*WA*). The mean values for *WA* ranged from 24.62 ± 0.16% to 39.69 ± 0.31%. The result shows that an increase in cement content to sand and sawdust caused a decrease in *WA*. The lowest water sorption values were obtained from the bricks produced at a mixing ratio of 1 : 1 : 3 (wood waste/sand/cement) (Figure 2). The highest water absorption recorded was 39.69 ± 0.31% at a ratio of 1 : 1 : 1. However, the ratio of 1 : 1 : 3 produced more dimensionally stable bricks with the lower sorption rate of 24.62 ± 0.16%

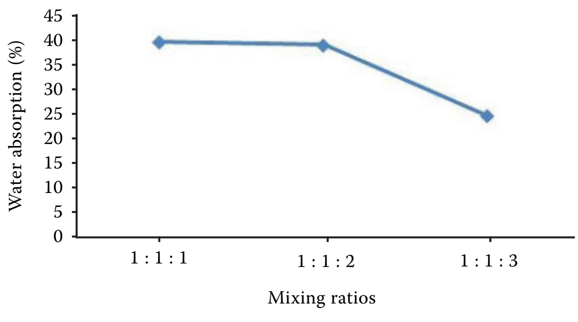

Figure 2. Effect of mixing ratios on water absorption

Table 1. Analysis of variance (ANOVA) on the influence of mixing ratios on compressive strength, water absorption and density of bricks produced from wood waste and sand

VAR	*SV*	SS	*DF*	*MS*	*F*
Compression	between groups	2.35	2	1.17	30.61*
	within groups	0.23	6	0.04	–
	total	2.58	8	–	–
Water absorption	between groups	359.20	2	179.60	1 228.82*
	within groups	0.88	6	0.15	–
	total	360.07	8	–	–
Density	between groups	23 171.35	2	11 585.67	190.22*
	within groups	365.45	6	60.91	–
	total	23 536.79	8	–	–

*significant ($P \leq 0.05$); VAR – variables; *SV* – source of variation; *SS* – sum of squares; *DF* – degrees of freedom; *MS* – mean of squares; *F* – *F*-tab (signifance)

(Figure 2). This result was lower than 46.70% recorded by Babatola et al. (2011).

Bricks with a mixing ratio of 1 : 1 : 1 were found to be more porous and absorbed more water faster. This phenomenon could be a result of the void spaces created by a small quantity of cement to an equal volume of sawdust and sand available to bind and coat the sand and the wood fibres which are hydrophobic in nature. Consequently, these void spaces were easily stocked with the penetrating water thus increasing the brick absorption rate after soaking. This observation is in accordance with Zhou and Kamdem (2002) and Hachmi et al. (1990), who in their studies reported a low water absorption rate at a higher cement/fibre ratio, leading to lower water penetration of the void spaces and complete coating of particles with cement gel. It could also be observed that the greater compression ratio of bricks due to the equal level of sand to sawdust and higher proportion of cement in bricks was responsible for higher stability properties obtained at this level.

Figure 3 shows the relationship between water absorption and unit weight across all samples examined. In relating to this figure under international standards and previous studies, the highest value of the water absorption (39.69 ± 0.31%) may seem low while compared with that of widely used light-

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weight building materials, such as autoclaved aerated concretes (60%) reported by Ozdemir (2002). The ANOVA (Table 1) revealed that there are significance differences in water absorption properties between the three mixing ratios.

Density. The nominal brick density from this study was estimated to be 1 500 kg·m^{-3}, but from the results, the observed density ranged between 1 300 ± 10.82 kg·m^{-3} and 1 420 ± 4.10 kg·m^{-3} across the three mixing ratios. From the result, the lowest density (1 300 kg·m^{-3}) was observed in brick samples made from a mixing ratio of 1 : 1 : 1, while the highest density 1 420 ± 4.10 kg·m^{-3} was produced from a mixing ratio of 1 : 1 : 3. The result clearly shows that the equal volume of sawdust to sand with an increase in the quantity of cement resulted in an increase in the density of bricks as shown in Figure 4. The greater bonding quality and cohesive strength inherent in the bricks produced from the high cement/wood/sand ratio must have probably accounted for their increased density.

The response of the bricks to production variables shows that an increase in the cement to wood waste ratio (1 : 1 : 1 to 1 : 1 : 3) caused an increase in the density of bricks produced. High dense bricks were produced as they show the greatest improvement and resistance to loading at this level. High bond in bricks was improved due to an increase in the quantity of available and increased surface contact area between the bricks to withstand the load applied. The greater bonding quality and cohesive strength inherent in the bricks from high cement to the equal ratio of wood to sand must probably account for their increased density as represented graphically in Figure 4. All these observations are similar to the results obtained

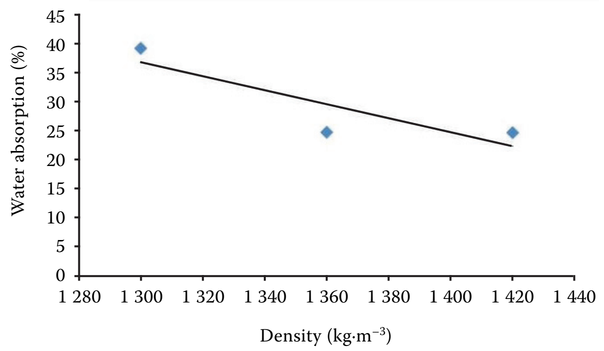

Figure 3. Relationship between the unit weight and water absorption

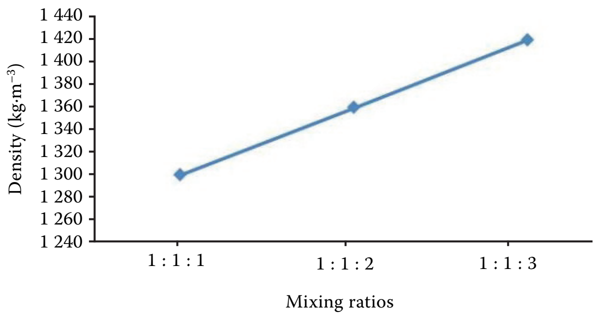

Figure 4. Brick density with respect to mixing ratios

by Babatola et al. (2011), Badejo et al. (2012) and Lohani et al. (2012). All the bricks with equal fibre content to sand were found to have a density below 1 680 kg·m^{-3} which is categorized by ASTM C90 (ASTM 2000) as lightweight concrete blocks.

The ANOVA table (Table 1) showed that the density of the bricks responded differently to varying mixing ratios used in this study.

CONCLUSION

In this study, bricks were successfully produced using conventional sand supplemented with sawdust. Three mixing ratios of sand, wood waste and cement at 1 : 1 : 1, 1 : 1 : 2 and 1 : 1 : 3 were used in relation to the volume of each component used. Both mechanical test (compressive strength) and physical properties (water absorption and density) were carefully examined. Bricks containing the mixture of an equal ratio of sand to sawdust and at 3% cement content (1 : 1 : 3) performed better in terms of water sorption properties, density and compressive strength, as bricks produced at this level proved to be dimensionally stable, moderately denser and with good response to loading/force during tests. Although the dimensional stability of the bricks was affected by the mixing ratio (wood/sand/cement), however, an increase in the mixing ratio from 1 : 1 : 1 to 1 : 1 : 3 could be attributed to a decrease in water absorption and increase in density and compressive strength of the bricks produced. The reduction in the strength properties of the bricks from the other two mixing ratios (1 : 1 : 1 and 1 : 1 : 2) might be due to water sorption rate at these levels, sawdust type and method of production. The addition of sawdust also improves the filling of the void spaces and acts as granular skeleton in the bricks. The replacements of sawdust

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as aggregate in the tested samples also help in reducing the unit weight of the bricks.

This study is an eye opener as regards further investigations on efficient utilization of wood that has been lying as waste in sawmills. The mechanical properties (compressive strength) of the bricks at a mixing ratio level of 1 : 1 : 3 are an absolute proof of their suitability for structural purposes for internal panelling and demarcation.

REFERENCES

Adedeji Y.M.D. (2007): Materials preference options for sustainable low-income housing in selected cities in Nigeria. [Ph.D. Thesis.] Akure, Federal University of Technology.

Adefisan O.O. (2007): Cement-bonded composite boards as constructional building materials. International Journal of Composite Materials, 26: 131–134.

Ajayi B. (2000): The strength and dimensional stability of cement – bonded flake board produced from *Gamelina arborea* and *Leucaena leucocephala*. [Ph.D. Thesis.] Akure, Federal University of Technology.

Alexander M.G., Mindess S. (2008): Aggregates in Concrete. London, Taylor & Francis: 435.

ASTM (American Society for Testing and Materials) (2000): Standard Specification for Load Bearing Concrete Masonry Units. Philadelphia, ASTM: 3.

ASTM (American Society for Testing and Materials) (2003): Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile. Philadelphia, ASTM: 12.

Babatola J.O., Sadiku N.A., Idowu A.O., Oladipupo K.S. (2011): Suitability of wood waste as reinforcement in the production of building bricks in Nigeria. In: Popoola L., Ogunsanwo K., Idumah F.O. (eds): 34th Annual Conference of Forestry Association Nigeria, Osogbo, Dec 5–10, 2011: 104.

Badejo S.O.O. (1990): Sawmill wood residues in Nigeria and their utilization, invited paper. In: Proceedings of National Workshop on Forestry Management Strategies for Self-Sufficiency in Wood Production, Ibadan, June 12–15, 1990: 5–14.

Badejo S.O., Baiyewu R.A., Adejoba O.R., Adelusi E.A. (2012): Dimensional stability of building blocks produced from wood waste and sand. In: Onyekwelu J.C., Agbeja B.O., Adekunle V.A.J., Lameed G.A., Adesoye P.O., Omole A.O. (eds): Proceedings of the 3rd National Conference of the Forest and Forest Products Society of Nigeria: De-reservation, Encroachment and Deforestation: Implication for Future of Nigerian Forest Estate and Carbon Emission Reduction, Ibadan, Apr 3–6, 2012: 174–178.

Bejó L., Takáts P., Vass N. (2005): Development of cement bonded composite beams. Acta Silvatica et Lignaria Hungarica, 1: 111–119.

Braganca L., Almeida M., Mateus R., Mendonca P. (2002): Comparison between conventional and MBT constructive solutions from an economic and environmental point of view. Case study. In: Ural O., Abrantes V., Tadeu A. (eds): XXX IASH World Congress on Housing, Coimbra, Sept 9–13, 2002: 959–966.

British Standard Code of Practice 882 (1992): Specification for Aggregates from Natural Sources for Concrete. London, British Standards Institution: 15.

British Standards Institution (1996a): British Standards Code of Practice 12: Portland Cement (Ordinary and Rapid Hardening). London, British Standards Institution: 38.

British Standards Institution (1996b): British Standards Code of Practice 3148: Methods of Test for Water for Making Concrete (Including Notes on the Suitability of the Water). London, British Standards Institution: 11.

Corinaldesi V., Mazzoli A., Siddique R. (2016): Characterization of lightweight mortars containing wood processing by-products waste. Construction and Building Materials, 123: 281–289.

Datye K.R., Gore V.N. (1998): Innovative designs of wood-bamboo-brick composite. In: Natterer J., Sandoz J.-L. (eds): 5th World Conference on Timber Engineering, Montreux, Aug 17–20, 1998: 526–533.

Elinwa A.U., Ejeh S.P. (2005): Characterization of sisal fiber reinforced concrete. Journal of Civil Engineering Research and Practice, 2: 14.

Faria C., Chastre C., Lúcio V., Nunes Â. (2013): Compression behaviour of short columns made from cement-bonded particle board. Construction and Building Materials, 40: 60–69.

Frybort S., Mauritz R., Teischinger A., Müller U. (2008): Cement bonded composites – A mechanical review. BioResources, 3: 602–625.

Ghosh S.K. (2002): Low-cost building materials. In: Ural O., Abrantes V., Tadeu A. (eds): XXX IASH World Congress on Housing, Coimbra, Sept 9–13, 2002: 811–814.

Gil H., Ortega A., Pérez J. (2017): Mechanical behavior of mortar reinforced with sawdust waste. Procedia Engineering, 200: 325–332.

Gong A., Hachandran R., Kamdem D.P. (1993): Compression tests on wood-cement particle composites made of CCA treated wood removed from service. In: Environmental Impacts of Preservative-Treated Wood Conference, Orlando, Feb 8–10, 2004: 270–276.

Hachmi M., Moslemi A.A., Campbell A.G. (1990): A new technique to classify the compatibility of wood with cement. Wood Science and Technology Journal, 24: 345–354.

Kumar K.S., Naziya S., Ganesh P., Kumar R.P., Reddy M.S.R. (2018): Limestone dust and wood saw as a brick material. International Journal of Engineering Trends and Applications, 5: 89–99.

https://doi.org/10.17221/98/2021-JFS

Lohani T.K., Padhi M., Dash K.P., Jena S. (2012): Optimum utilization of quarry dust as partial replacement of sand in concrete. International Journal of Applied Sciences and Engineering Research, 5: 391–404.

Moslemi A.A. (1999): Emerging technologies in mineral-bonded wood and fiber composites. Advance Performance Materials, 6: 161–179.

Miyatake A., Fiujii T., Hiramatsu Y., Abe H., Tonosaki M. (2000): Manufacture of wood strand-cement composite for structural use. In: Evans P.D. (ed): Wood-Cement Composites in the Asia-Pacific Region, Canberra, Dec 10, 2000: 148–152.

Naghizadeh Z., Faezipour M., Ebrahimi G., Hamzeh Y. (2012): Manufacture of lignocellulosic fiber–cement boards containing foaming agent. Construction and Building Materials, 35: 408–413.

Ntalos G., Papadopoulos A. (2006): Mechanical and physical properties of cement bonded OSB. In: Van Aacker J., Irle M., Olivier J. (eds): Cost Action E44-49 Wood Resources and Panel Properties, Valencia, June 12–13, 2006: 315–319.

Olusola B.S., Akintayo O. (2009): Assessment of failure of building components in Nigeria. Journal of Building Appraisal, 4: 279–286.

Oyinloye T.O. (2004): A Technical Report of Student's Industrial Work Experience Scheme Submitted to the Department of Wood and Paper Technology. Ibadan, Federal College of Forestry: 20.

Ozdemir A. (2002): Capillary water absorption potential of some building materials. Geological Engineering, 26: 19–32.

Papadopoulos A., Ntalos A.N., Kakaras I. (2006): Mechanical and physical properties of cement-bonded OSB. Holz als Roh- und Werkstoff, 64: 517–518.

Parashar A.K., Parashar R. (2012): Comparative study of compressive strength of bricks made with various materials to clay bricks. International Journal of Scientific and Research Publications, 2: 1–4.

Sadiku N. (2015): Utilizing wood wastes as reinforcement in wood cement composite bricks. Journal of the Faculty of Forestry Istanbul University, 65: 31–37.

Turgut P. (2007): Cement composites with limestone dust and different grades of wood sawdust. Building and Environment, 42: 3801–3807.

Wei Y.M., Tomita B., Hiramatsu Y., Miyatake A., Fujii T., Fujii T., Yoshinaga S. (2003): Hydration behavior and compressive strength of cement mixed with exploded wood fiber stand obtained by the water-vapor explosion process. Journal of Wood Science, 49: 317–326.

Wolfe R., Gjinolli A.E. (1996): Assessment of cement-bonded wood composites as a means of using low-valued wood for engineered applications. In: Gopu V.K.A. (ed.): Proceedings of the International Wood Engineering Conference, New Orleans, Oct 28–31, 1996: 74–80.

Zhou Y., Kamdem D.P. (2002): Effect of cement/wood ratio on the properties of cement-bonded particleboards using CCA-treated wood removed from service. Forest Products Journal, 52: 77–82.

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