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Potentials of Wood Plastic Composite Boards from *Funtumia africana* (IRE) Sawdust with Recycled Polyethylene Terephthalate (PET) Chips for Building Applications

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Abstract: *The study is designed to evaluate the physical and mechanical properties of Wood Plastic Composite Boards from Funtumia Africana Sawdust with Recycled Polyethylene Terephthalate (PET) Chips using locally fabricated extruding machine at temperature of about 170⁰C - 200⁰C. The production variables investigated were pre-treatment of sawdust with cold water for 2 days in order to eliminate water soluble extractives which could inhibit the strength properties and proper formation of WPC. The wastes generated were dried to about 5% moisture content, wood waste content at five plastic replacement levels (50%, 40%, 30%, 20% and 10%) and plastic wastes content at five wood replacement levels (2%, 4%, 6%, 8% and 10%) respectively. The wood plastic composite (WPC) were tested for Water absorption (WA), thickness swelling (TS), density (ρ), noise absorption (NL), specific gravity (SG), modulus of elasticity (MOE), modulus of rupture (MOR) and impact bending strength (IB). The water absorption ranged between 0.20% to 8.33%, TS (0.09% to 4.55%), Density (0.9 x 10^3 Kg/m^3 to 1.2 x 10^3 Kg/m^3), NA (65 dB^A to 70 dB^A), SG (0.78 to 1.17), MOE (624 N/mm^2 to 281 N/mm^2), MOR (1.85 N/mm^2 to 4.5 N/mm^2) and IB (7.06 J/m^2 to 56.44 J/m^2). The results revealed that physical properties such as water absorption and thickness swelling increases as the wood content increases, while; density, noise absorption and specific gravity decrease with increase in wood content. Strength properties of WPC such as impact, MOE and MOR decreases as the wood content increases.*

Keywords: *Density; Funtumia africana; Modulus of Elasticity; Modulus of Rupture; Noise absorption; Thickness swelling; Water absorption.*

INTRODUCTION

Wood plastic composite (WPC) is a product which could be obtained from plastic and wood. WPC is a composite with a rapid growing usage consisting of a mixture of wood waste and polymeric material (Soury, *et al.,* 2009). Several worldwide attempts have been adopted; especially in the developed countries, to take advantage of these types of waste especially with the raised need for alternatives to virgin materials (Winandy, *et al*., 2004). WPC has become currently an important address of research that gained popularity over the last two decade especially with its properties and advantages that attracted researchers which include high durability, low maintenance, acceptable relative strength and stiffness, fewer prices relative to other competing materials, and the fact that it is a natural resource (Bengtsson and Oksman 2006) and

(Winandy, *et al.,* 2004). Other advantages are the resistance in opposition to biological deterioration especially for outdoor applications where untreated timber products are not suitable, the high availability of fine particles of wood waste is a main point of attraction which guarantees sustainability, improved thermal and creep performance relative to unfilled plastics where it can be produced to obtain structural building applications including: profiles, sheathings, decking, roof tiles, and window trims (Wechsler and Hiziroglu 2007). On the other hand, WPCs are not nearly as stiff as solid wood; however, they are stiffer than unfilled plastics. In addition, they do not require special fasteners or design changes in application as they perform like conventional wood (Clemons and Caufield 2005). Although considerable work on optimizing the interface has been performed, much less work has been done on developing a consistent analysis for WPC using advance methods (for example FEM), especially experimental test methods. Until now no standard test methods for evaluating fracture behaviour of WPC have been developed.

The term strength applied to a material such as WPC refers to its ability to resist external forces tending to change its shape (Desch, 1981). Also, according to Nurudeen *et al* (1982), the physical and mechanical properties, which are present in wood plastic composite, decide purpose to which WPC can be sustainably put. During utilization, when external forces such as heavy loads are applied to a given sample of wood plastic composite, internal forces generated within the WPC which resist changes size and alteration in shape. These forces are called stress. The changes in size and shape are known as deformations, strains. If the stress is small, the deformation is small, and when the stress is removed there is a complete or partial recovery to the original size and shape, depending on the elasticity of the wood plastic composite (Geoffrey, 2002). The equilibrium condition at which every stress applied has a noticeable corresponding strain or deformation on the wood plastic composite; this point is called the limit of proportionality. Beyond this point of proportionality, deformation or strain increases rapidly than the stress applied, when the stress is removed, recovery is not complete, and that is, the initial shape, size and orientation of the wood plastic composite cannot be regained. If the stress applied exceeds the forces of cohesion between the tissues a rupture or failure occurs (Wagner and Howard, 1996). Furthermore, the right and efficient use of wood plastic composite therefore demands full knowledge of its physical and mechanical properties, which can only be obtained through research. An estimate on the types of loads acting on the various constructions to which WPC is subjected during their working life is also considered necessary.

In addition, used plastic bottles and wood wastes such as sawdust are contributing nuisance to the environment, adding values and turning these wastes to wealth is highly essential. WPC had very high strength and physical properties which depict its ability to withstand loads applied on its ends and also show ability to resist defects such as durability test, cupping, splitting etc. WPC because of moderate strength and high physical properties could find its use in house decking, strip flooring, cabinet making, railings, fences, landscaping timbers, siding, park benches, molding and trim, window and door frames, panels and indoor furniture (Omoniyi and Oladejo).

Methodology

This study was carried out in the Department of Agricultural and Environmental Engineering, Faculty of Technology, University of Ibadan, Ibadan, Oyo State, Nigeria. It was aim at compiling information on strength factor parameters. The sawdust was generated from ***Funtumia africana*** through circular saw machine. Plastic bottles were also collected in large quantities and chipped into smaller sizes. Pre-treatment of sawdust was done by soaking into two drums for about 96 hours (4 days) in other to eliminate the water soluble extractives. Soaked sawdust was later air-dried and subsequently dried in an oven at 102 ± 2°C for 12 hours to a moisture content of about 5% and sieved with 1mm iron mesh sieve to remove the impurities and over sized particles as depicted in plates 3, 4 & 5. Clean consumer drinking water and beverages bottles were ground in a locally fabricated grinder in order to get the recycled PET chips. The PET chips were screened to remove the oversized chips. The PET chips were then sun dried in order to remove additional moisture acquired by the chips during grinding process, as illustrated by the flow chart in figure 1. Blending and mixing of PET chips and sawdust was achieved by dry mixing the wastes thoroughly with a mixer to enhance homogeneity of the material and it was mixed in the ratio presented in table 1.

Table 1: Wpc Research Design Formulation Based on Weight

Sawdust Content (%)	Pet Content (%)
2	50
4	40
6	30
8	20
10	10

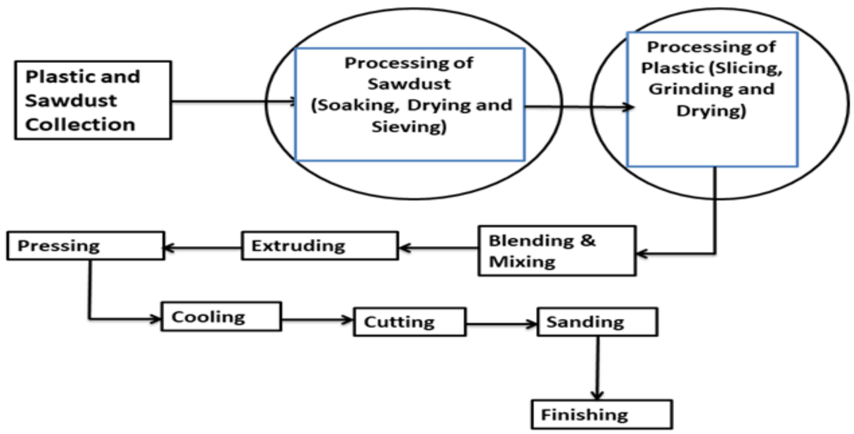

Figure 1: WPC Production Processes

The mixed particles were later extruded using a locally fabricated extruder and were later cooled, cut, sanded and finished as shown from plates 1 to 10 respectively.

Plate 1: Sawdust Collection

Plate 2: Plastic bottles collection

Plate 3: Soaking of sawdust (Ire)

Plate 4: Drying Process

Plate 5: Sieving Process

Plate 6: Locally Fabricated Extruding Machine

Plate 7: mould Fabrication Processes

Plate 8: Locally Fabricated Moulds with Cover

Plate 9: Grinding of Plastic Bottles in a Locally Fabricated Grinder

Plate 10: Pet Chips From Transparent Consumer's Plastic Bottles

Plate 11: Samples of Wood Plastic Composite (WPC)

Plate 12: Weighing the Test Sample

Plate 13: Noise metre

Table 2: Physical and Mechanical Properties of Wpc

Treatments (Wood/Plastic Ratio)	Water Absorption (%)	Thickness Swelling (%)	Density (Kg/m^3)	Noise Absorption (dB^A)	Specific Gravity	Impact (J/m^2)	MOE (N/mm^2)	MOR (N/mm^2)
I_1	0.20	0.09	1,174.43	70.00	1.17	56.44	624.00	4.50
I_2	2.35	0.15	1,124.32	69.32	1.12	42.33	535.00	3.21
I_3	4.45	1.03	997.97	68.40	0.98	28.22	436.00	2.25
I_4	6.56	4.17	984.29	67.95	0.92	14.11	344.00	1.96
I_5	8.33	4.55	924.26	65.00	0.78	7.06	281.00	1.85
Mean	**4.38**	**1.99**	**1,041.05**	**68.13**	**0.99**	**29.63**	**444.00**	**2.75**

Key:

I_1 = (2% wood and 50% Plastic)

I_2 = (4% wood and 40% Plastic)

I_3 = (6% wood and 30% Plastic)

I_4 = (8% wood and 20% Plastic)

I_5 = (10% wood and 10% Plastic)

Results and Discussions

Physical Properties

Water absorption: The results from table 2 showed that the higher the wood content in the WPC, the higher the water absorption, which may be due to the hydrophilic nature of the wood and the other fibres. The behaviour of the produced composites was similarly reported by Bledzki *et al.*, (1998), that the presence of hydroxyl groups inside the cellulose and hemi celluloses attract the water molecules and form hydrogen bonding. More-over due to the porous structure of wood fibres, the WPC with higher wood content absorb more water which penetrates into the pores according to the principle of capillary flow.

Also, as the plastic content in the composites increases, the wood content were more encapsulated by the plastic content which has no affinity for water absorption which shows the hydrophobic nature of thermoplastics. The finding from this study is similar to the earlier report by Aina *et al.* (2013) on the properties of wood plastic composites. The variation in water absorption also conforms to Donaldson and Frankland (1997) submission that when water enters the cell wall, it occupies spaces between the micro-fibrils, so if the micro-fibril angle is large, there is more swelling along the grain as water is added. The reverse applies as water is removed from the cells. This property confirms effectiveness of WPC for exterior use.

Thickness swelling: The results of thickness swelling percentage of wood plastic composites are presented in table 2 and fig. 2 respectively. Thickness swelling percentage of wood plastics composites boards produced increases as the wood content in WPC increases. This shows that the more the quantity of the plastic content in the composite, the more resistant the board to water uptake and vice-versa, which is proportional to thickness swelling (Omoniyi and Oladejo, 2015). Similar observations have earlier been reported on the effect of wood/plastic ratio on WPCs (Bledzki, 1998 and Aina *et al.*, 2013). As wood is hydrophilic and plastic is hydrophobic, therefore the higher the quantity of plastic and the lesser the quantity of wood, the better the dimensional stability of wood plastic composites.

Density: The results from table 2 and figure 3 showed that as the wood content in the WPC increases, the density decreases which conforms to Winandy (2004), which speculate that variations in cell wall thickness, the proportion of late versus early wood, and the prevalence of fibres, ray and plastic specific gravity are among the anatomical characters that correlate with density.

Noise Absorption: It was observed that WPC noise level tends to decrease as the wood content increases. I_1 records the highest noise level with 70.00dB^A, followed by I_2 with value 69.32dB^A while the lowest is I_5 of 65.00dB^A as depicted in figure 4. Bahrambeygi *et al*, (2013) speculates that due to formation of this fine morphology, more paths for passing sound waves can be created and also higher absorption of sound energy, because of higher created friction between sound waves and internal cell walls, can be dissipated. On the other hand, nano-sized fibres would also lead to extra vibrations, which results in more dissipation of sound energy (Yang and Li, 2012). The analysis of variance reveals that the noise level is significant.

Specific gravity: The results of specific gravity decreases slightly with increase in wood content. 1.17 is the highest specific gravity for wood-plastic ratio I_1, followed by 1.12 for I_2 and I_5 has the lowest with value 0.78 as found in figure 5. Therefore, as the wood content in WPC increases, specific gravity also increases. According to Winandy (2004), variations in cell wall thickness, the proportion of late versus early wood, and the prevalence of fibres, ray and plastic density are among the anatomical characters that correlate with specific gravity.

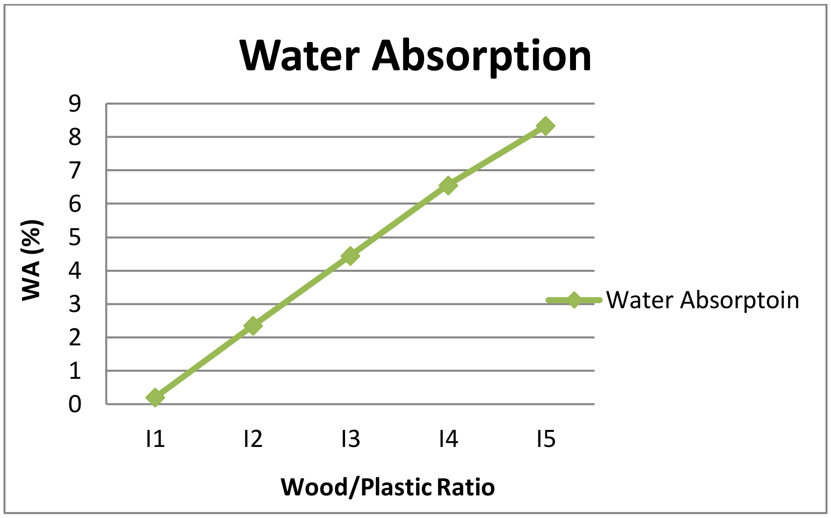

Figure 2: Water Absorption vs Wood/Plastic Ratio

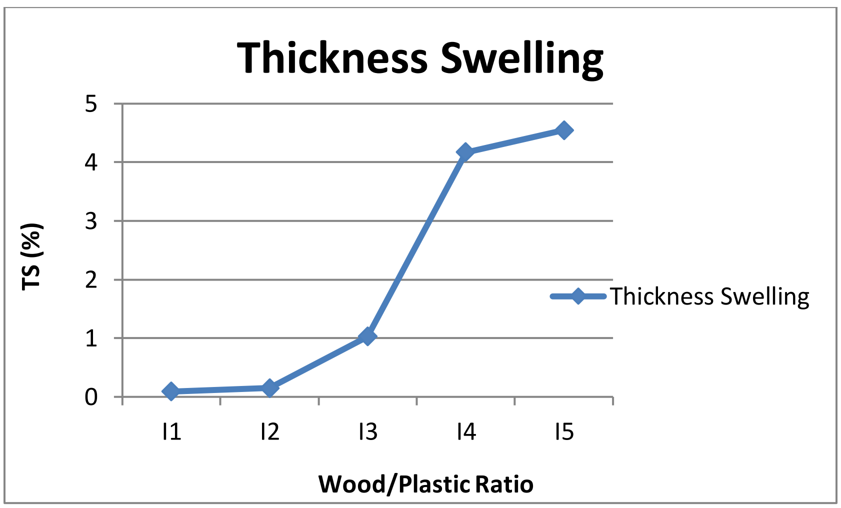

Figure 3: Thickness swelling vs Wood/Plastic Ratio

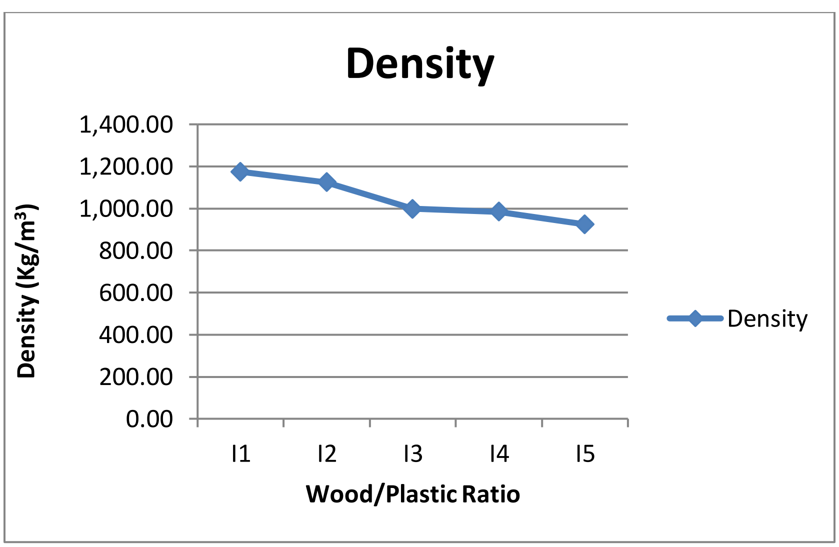

Figure 4: Density vs Wood/Plastic Ratio

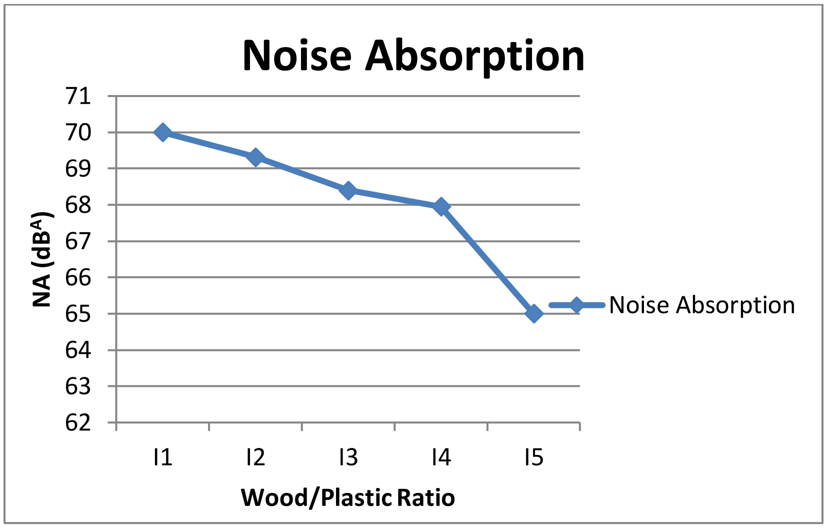

Figure 5: Noise Absorption vs Wood/Plastic Ratio

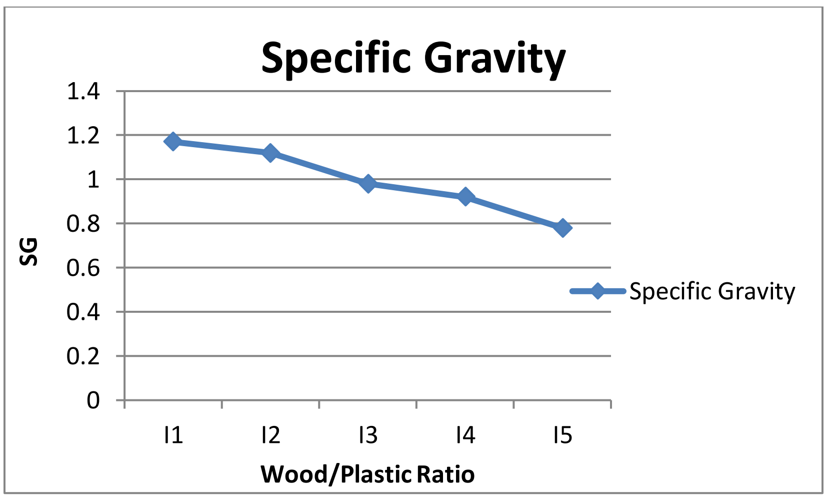

Figure 6: Specific Gravity vs Wood/Plastic Ratio

Mechanical Properties

Impact Strength: Also, it was observed that the impact bending strength of WPC tends to decrease as the wood content increases. The value ranges from 7.06 to 56.44 J/m^2 with mean 29.63 J/m^2 respectively. I_1 is the highest (56.44 J/m^2), followed by I_2 (42.33 J/m^2) and the least is I_5 (7.06 J/m^2) as shown in figure 6. The variations in the impact bending strength agrees with (Woodcock and Shier, 2002) submission that impact bending varies as a result of change in density.

Modulus of Elasticity: The results showed that Modulus of elasticity tends to decrease as the wood content increases. It ranged between 281.00 and 624.00 N/mm^2 with mean 444.00 N/mm^2 which shows that WPC has a consistent trend in MOE with I_1 being the highest, followed by I_2 and I_5 is the lowest as shown in figure 7. The stiffness determined for both formulations using this method is within ten percent of results from previous research in determining apparent modulus of elasticity for WPC material (Lockyear, 1999).

Modulus of Rupture: It was also observed that MOR of WPC tends to decrease as the wood content increases. It ranged between 1.85 and 4.50 N/mm^2 with I_1 being the highest of 4.50 followed by I_2 of 3.20 N/mm^2 each, while the least is I_5 of 1.85 N/mm^2 as demonstrated in figure 8. Previous comparisons of modulus of rupture (MOR) showed similar differences between coupon and near full-size section test results (Paynter, 1998).

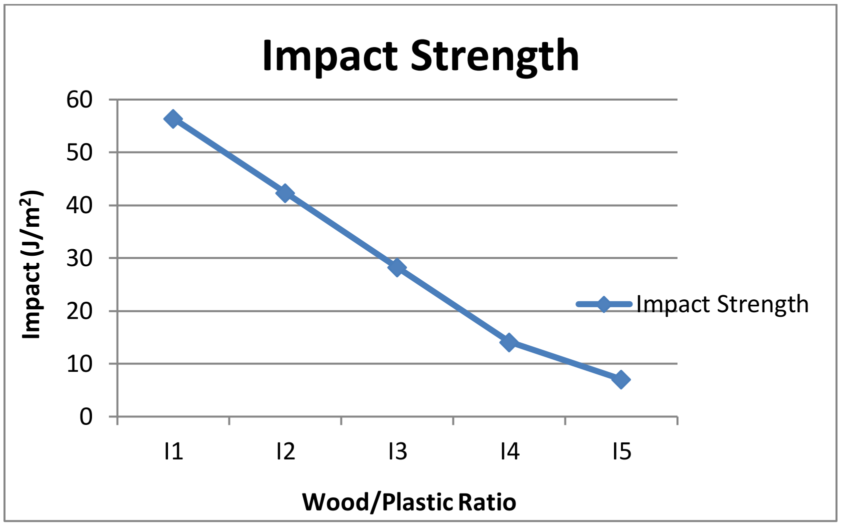

Figure 7: Impact Bending Strength vs Wood/Plastic Ratio

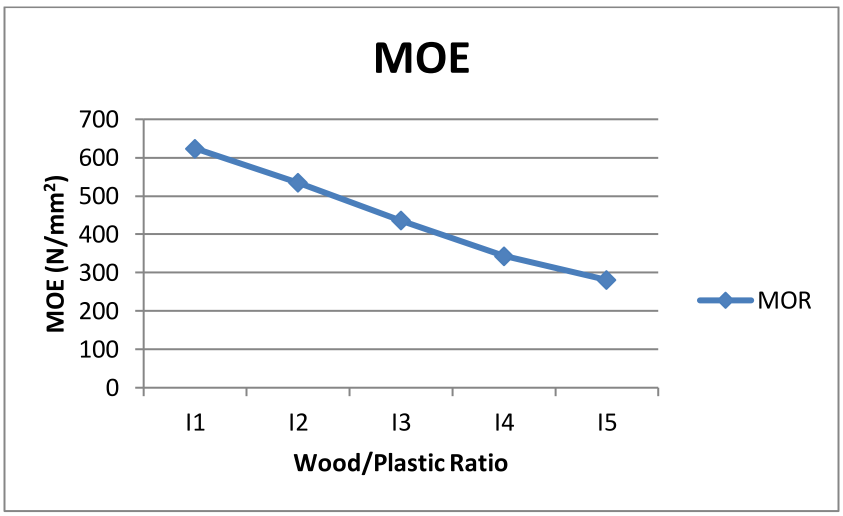

Figure 8: MOE vs Wood/Plastic Ratio

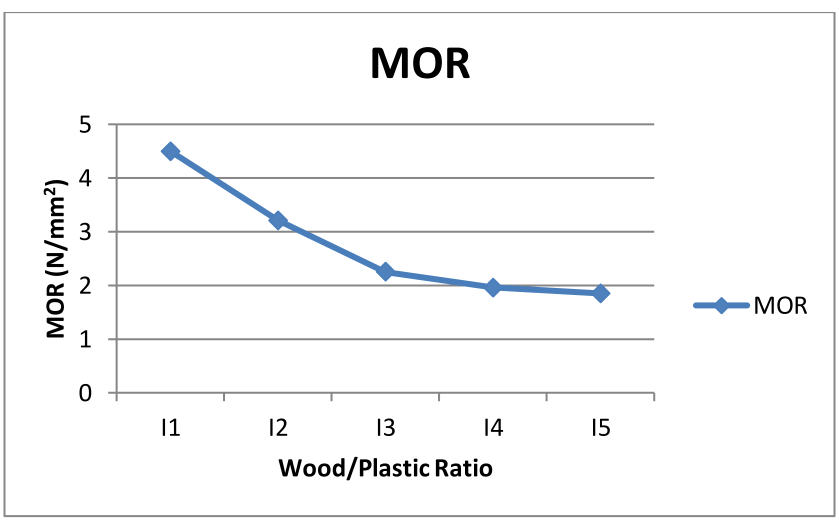

Figure 9: MOR vs Wood/Plastic Ratio

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