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Review on Manufacturing and Testing processes of Wood-Plastic Composites

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Abstract: Now-a-days everyone is aware of the disadvantage of Plastic and its various products. Around 300-400 tonnes of plastic waste is generated every year. This also results in man environmental pollution as well as human health issues. But, this doesn't mean that we completely don't need plastic. It has much application in the field of composites which is trending as well as a good alternative of wood. Composite materials have significant strength as well as stiffness. They are also light in weight and long lasting. But, its application is limited to some fewer areas. On the other hand, wood have high straight compare to composite materials but come with disadvantage like hydrophobic material, on-fireproof, on-termite resistant. But when you mix plastic and wood we get wood-plastic composite eliminating many disadvantages of plastic as well as wood. Here, we have manufactured WPC considering different composition of composite as well as wood (60-40%, 70-30%, and 80-20%). Composites used are High-Density Poly-Ethylene (HDPE), Low-Density Poly-Ethylene (LDPE), Polyvinyl Chloride (PVC).Further after manufacturing of WPC testing of WPC was carried out. Different Types of Mechanical, Physical and chemical test were carried out.
Keywords: Composite Materials, wood-plastic composites, HDPE, LDPE, PVC, Natural bamboo fibres, On-termite resistant.

Introduction:

Virgin thermoplastic materials are majorly used in WOOD PLASTIC Composites manufacturing industries. As same as virgin plastics, any recycled plastic can be melted and processed below the degradation temperature of wood or other lignocellulosic fillers (200C) is usually essential for manufacturing WPCs [1]. Researchers had worked on recycling the post-consumer plastics in order to reduce the environmental impact and usability of virgin plastics. Plastics are one of the major volumes of global municipal solid waste (MSW) and present a promising raw material source for new value-added
products (WPCs) thanks to their large amount of daily generation and low cost [1]. Approximately 100 million tons per annum of plastic production is done worldwide [2], resulting in a significant proportion in MSW. For example, in 2006, the total quantities of MSW in Tehran (capital of Iran) added up to 84.2 $\times 10^3$ tons, generated by the population of 7.728 million. The amount of plastics in MSW reached 9.4×10^3 tons, comprising 11.2% of the waste stream by weight. High-density polyethylene (HDPE) plus polypropylene (PP) was the largest component, followed by polyethylene terephthalate (PET), polystyrene (PS), and low-density polyethylene (LDPE) [3]. This creates a substantial amount of polyolefin that can potentially be recovered for PC manufacturing. There are many number of researched studies on the reinforcement of virgin HDPE, LDPE, and PVC with wood fibre in regard to the resulting mechanical properties, dimensional stability, interfacial bonding and durability [2-6]. However, studies on wood plastic composites based on recycled HDPE are very limited [1,3]. This study aims to explore the use of recycled HDPE for the production of the wood fibre composites. The effect of the fibre loadings and compatibilizing agent on the dimensional stability and mechanical properties is also investigated. Polyethylene is considered the most used

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thermoplastic material in the manufacturing of WPCs because of its high percentage volume within the amounts of waste and its high resistance to atmospheric and biological agents.
An increasing number of researchers have produced studies suggesting the conversion of plastic waste to a valuable product [7]. The properties of recycled high-density polyethylene were found to be near to those of virgin high-density polyethylene and the two could hence be used for different uses, and recycled high-density polyethylene is certainly much cheaper than virgin high-density polyethylene [8]. A wood–plastic composite (WPC) is a common term referring to wood-based elements such as lumber, veneer, fibres, or particles that are combined with polymers to create a composite material. It is a broadly used term, and as such, wood elements can be combined with either thermosetting or thermoplastic polymers. The term wood–plastic composite is used interchangeably with wood–polymer composites, and the wood composites made from either thermoplastic or thermos-setting polymers are often categorized as separate material types [9].

Manufacturing processes of wood-plastic composites:

Injection Molding process - The parts which contain complex geometry and require no finishing steps can be produced by injection molding process of wood-plastic composites. A post cap for guard rail structure is the perfect example for WPC Injection molding part. Research specifically targeting the injection molding process for WPCs is limited compared to extrusion processing, but topics tend to be similar and focus on material compositions and properties [10]. There have also been reports examining injection molding (IM) to produce WPC microcellular foams [11, 12] as well as IM of WPC made with biopolymers [13].

Extrusion process – The core profile processing system of WPC is extruder, and the basic purpose of extruder is to heat and melt the polymer and mix it with additives and wood in a process referred to as compounding. In addition, the extruder conveys the compounded wood–polymer mixture through the die. The extrusion systems used to process WPC profiles are basically divided in two parts which are, Single screw extruder and counter-rotating twin screw [9, 14].

1) Single screw extruder process :

A single-screw fibre composite extruder is the simplest extrusion system for producing WPC profiles. A typical single screw extruder will have a barrel length to diameter (L/D) ratio of 34:1. It will employ two stages, melting and metering, and a vent section to remove volatiles. The material form for the single-screw extruder will be pre-compounded fiber-filled polymer pellets.
A dryer may also be required to dry the pellets. The material feed method is usually by gravity hopper. The melting/mixing mechanism is barrel heat and screw shear. Advantages of the single-screw extruder are that it is a proven technology and this method has the lowest capital acquisition cost. Disadvantages include high raw material cost, lower output rates, drying system required, polymer is melted with the fiber with greater risk of fiber thermal decomposition, high screw speed (rpm) with greater risk of burning at the screw tip, and inability to keep melt temperature low with higher head pressures.

2) Counter-rotating twin screw :

Counter-rotating twin-screw extruders excel in applications where heat-sensitive polymers like rigid polyvinyl chloride (PVC) are utilized, low temperature extrusion for fibres and foams, non-compounded materials like powder blends, materials that are difficult to feed, and those materials that require degassing. The counter-rotating twin screw can either have parallel or conical screw configurations.
The fibre/flour and polymer are in the same polymer size, usually 250 to 400 μm. Material preparation includes fibre drying followed by high intensity blending with the polymer and additives. The material feed method usually utilizes a crammer feeder. The melting/mixing mechanism is barrel heat and screw mixing. Screw mixing is accomplished through screw flight cut-outs and gear mixers. Moisture removal is through vacuum venting.

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Wood truder - The Wood truder includes a parallel 28:1 L/D counter rotating twin- and a 75-mm single-screw extruder, a blending unit, a computerized blender-control system, a die tooling system, a spray cooling tank with driven rollers, a traveling cut off saw, and a run-off table. As processing begins, ambient moisture content wood flour is placed into the unit's fibre feeder and dried within the twin screw. Meanwhile, separate from the fibre, the plastics are melted. The melting/mixing mechanism includes barrel heat and screw mixing. The separation of wood conveying and plastic melting ensures that fibres will not be burned during plastic melting and that the melted plastic will encapsulate the fibres completely. These materials are then mixed, and any remaining moisture or volatiles are removed by vacuum venting.

Compression molding or Thermoforming - Compression molding or thermoforming of wood–plastic composites has been researched for many years and has been used extensively in the manufacture of automobile composite parts [15]. The use of continuous belt presses for producing WPC panels and glass-reinforced WPC panels has also been demonstrated [16, 17]. Techno Partner Samtronic GmbH, Goppingen, Germany can produce continuous WPC sheets up to 1.3 m wide and 13 mm thick on a continuous basis.

Testing of Wood Plastic Composites:

Durability test – Great overview of WPC durability in various aspects can be seen in Stark and Gardener and Morrell et al [18]. There are two board categories of wpc durabilities: structural durability and aesthetic durability. Example of WPC durability categories are listed below in the table 1.

Durability categories	Material properties impacted
Aesthetic	Weathering (color fading), biological attack (mold, mildew), food stains
Structural	Mechanical properties (strength and stiffness, thermal (fire), creep) physical properties (swelling, shrinkage, warping), biological degradation (decay)

Table 1. Categories of wood–plastic composite durability and material properties impacted

from a safety standpoint for building structures made using WPCs, structural durability is most important key factor but aesthetic durability can be as important to consumers and problems as WPC appearance have led to a number of class action law suits for WPC decking in particular [19]. Mold and mildew and color fading of WPCs tend to be the durability issues that factor in the promulgation of class action law suits. Most recent research on WPC durability focuses on studies to better understand the mechanisms contributing to various degradation issues as well as methods to improve durability.

Fig. 1 Durability test done on WPC sheet

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Decay Test- The effects of chemical preservative treatments in WPCs was researched by Ashori et al [20]. The untreated samples had less resistant than the Fungicide-treated WPCs. The influence of fungal decay on the physical and mechanical properties of WPCs was researched by Shirp and Wolcott [21]. They reported that WPCs can be designed to provide good fungal durability by controlling the ratio of wood to plastic in the composite formulation. Fabiyi and McDonald [22] studied the effect of wood species on property and weathering performance of WPCs. Among a number of wood species studied, hybrid poplar and ponderosa pine which are light-coloured woods exhibited better colour stability. Fabiyi et al. [22] also looked at the biodegradation of different species of WPC and Douglas-fir (Pseudotsuga menziesii) was found to be less susceptible to white rot. Kim et al. [23] studied the effect of wood species on water sorption and durability of wood–plastic composites. They reported that the use of durable wood species in WPCs resulted in improved durability performance.

Thermal Testing- Thermal treatment of wood refers to a process where wood fibers are conditioned with heat and moisture at a temperature around 230 °C to produce an inert surface and eliminate hemicellulose [21]. Andrusyk et al. produced WPCs using extracted wood flour and polypropylene [21]. The mechanical properties of the composite were enhanced significantly. Flamespread, specific gravity, and thermal expansion remained the same after the treatment. Similar results were found in Hosseinaei's research where southern yellow pine was hot water extracted at three temperature levels and made into WPCs with polypropylene [22]. Tensile strength and thermal stability were found to be increased by the extraction process. Water absorption and thickness swelling of the composites made by PP or HDPE and pine (Pinus ponderosa) were reduced after hot water extraction [23].

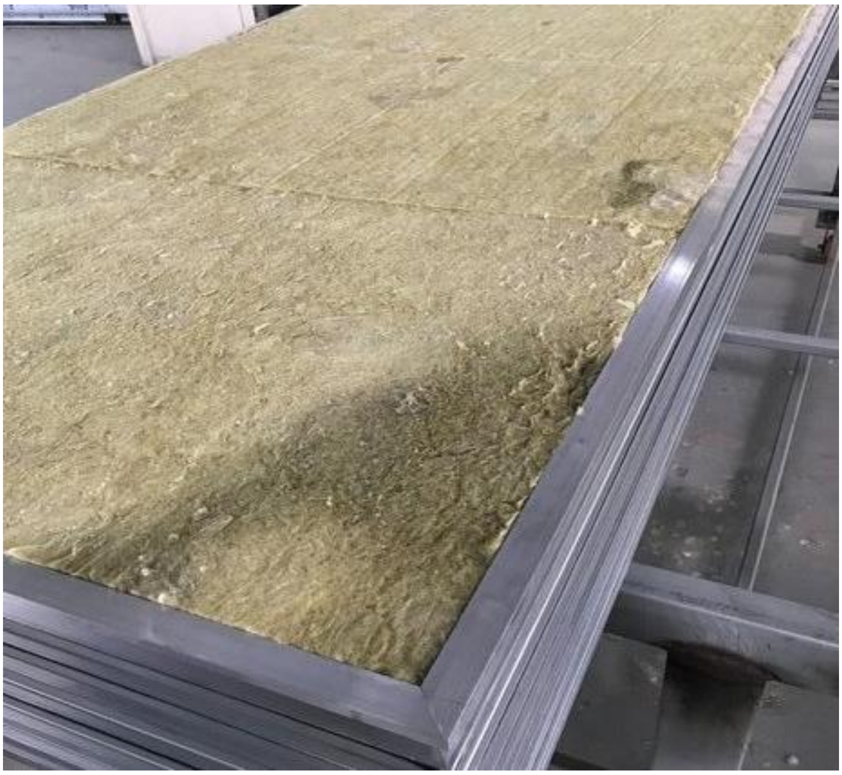

Fig. 2 Thermal test done on WPC sheet

Moisture Testing- Moisture is required for biological decay of wood. Air-dried wood should have no more than 20% moisture by weight to resist decay. If free water is added to attain 25–30% moisture content or higher, decay will occur in nondurable species. Wood can also be too wet for decay because there is not enough air for the fungi to develop. The overall uptake of moisture in WPCs is relatively slow compared to solid wood, and the amount of moisture absorbed by WPCs can vary widely as a result of the influences of the wood flour content, wood particle size, processing methods, and additives. However, moisture uptake in the outer 5 mm (0.2 in.) of WPC commercial products has

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been shown to be sufficient for fungal attack to occur. Water evaporation from the WPC is also very slow because the plastic inhibits moisture movement, thus providing an opportunity for biodegradation to occur. Laboratory research and field evaluations indicate that WPCs absorb moisture to the point where they can be degraded by fungi.

There are different ways to produce WPCs. The three most common ways are extrusion, compression molding, and injection molding. WPC processing methods influence the moisture sorption, thus making them more or less susceptible to decay. Extruded composites absorb the most moisture, compression-molded ones absorb less, and injection-molded ones absorb the least (Fig. 1). A thin, polymer-rich surface layer forms in injection-molded composites. In addition, higher pressures are used in this process, resulting in the collapse of the wood fiber bundles, which makes a higher-density composite compared with extrusion and compression molding. The amount of moisture absorbed is also influenced by wood particle size and additives. Another variable is whether the WPC is extruded as a solid or a hollow profile. A hollow profile will create a larger surface area that allows for moisture sorption. Fig. 3 Effect of processing on the moisture sorption of WPCs containing 50% pinewood flour during water soaking.

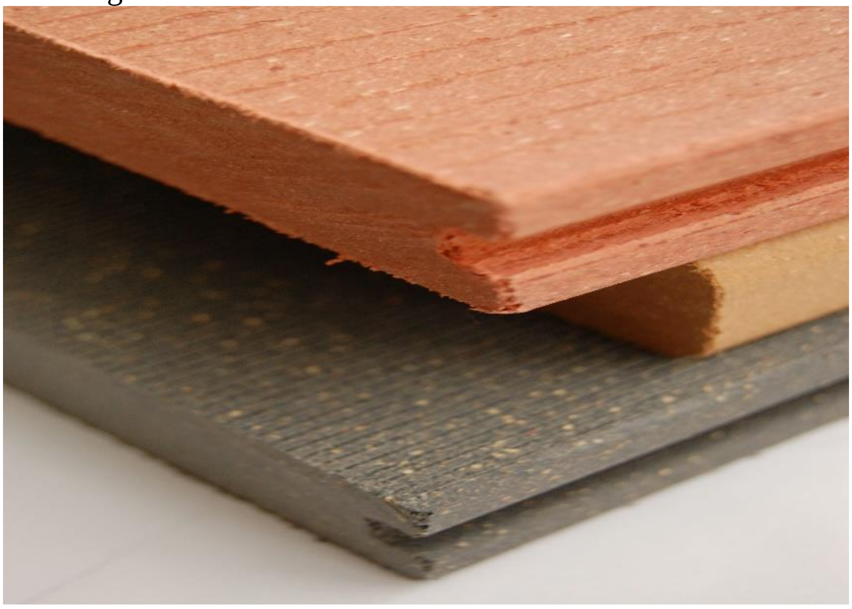

Fig. 3 Moisture test done on WPC sheet.

Conclusion:

Wood–plastic composite technology continues to mature with improvements being made in manufacturing processes (extrusion, injection, and compression molding); material advances in novel polymers matrices, treatments, and additives; profiles and parts for construction, automobiles, and furniture; durability from weather, fire, and biological attack; as well as the development of product standards for building construction. New developments are being made especially in the area of nano additives for WPCs including nanocellulose. Patent activity in WPCs continues to increase with the development of new product types and market application areas.

Wood composites are often used to replace steel for joists and beams in building projects. Their most widespread use, however, is in outdoor deck flooring, but they are also popular for railings, fencing, benches, window and door frames, cladding and landscaping work. The greatest advantage of WPC is its environmentally friendly approach of using waste wood and recycled plastic material. Wood composite plastics have low maintenance cost as compared to that of solid wood. One of the main reasons responsible for the fast growth of WPC is its low-life cycle cost. The greatest advantage of composite materials is strength and stiffness combined with lightness. By choosing an appropriate combination of reinforcement and matrix material, manufacturers can produce properties that exactly fit the requirements for a particular structure for a particular purpose.

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