Chapter

Potential, Challenges, and Application for Wood–Plastic Composite Fabricated with Several Additives

Amit Prem Khare, Nidhi Dwivedi and Shamsul Haq

Abstract

The expeditious transformation of the atmosphere and economy is pushing researchers from various fields to do more by using a lesser amount of resources. Especially, in the field of forest-based resources, such as the utilization of wood resources for different utility purposes in wood industries. It is meant to say that, the wood estate should be used as an efficient means or expedient. It is also the necessity of world atmosphere, according to the point of view ecosystem or global warming condition. Thus, we will need to sustainably use forest-based resources as major sources of wood materials and reuse the underutilized woods and waste wood in any form. Further, it will require the reuse of the underutilized wood material and present wood waste material in an environment with the assistance of the latest and newer growing technology. In general, for improving the performance of wood-based materials, additives may be used for performing different functions, such as lubricants, pigments, colorants, anti-microbial agents, antioxidants, UV stabilizers, fire retardants agents, coupling agents, or stabilizers, in the wood industry.

Keywords: WPC (wood–plastic composites), MOE (modulus of elasticity), MOR (modulus of rupture), MAPP (maleic anhydride poly-propylene), NFC (natural fiber composites), RPP (recycled polypropylene), LDPE (low-density polyethylene)

1. Introduction

Most wood items incorporate added substances. They might be additives to safeguard the wood opposition natural debasement or opposition fire, coatings for insurance or to offer the wood a better stylish look, other than wood materials to work on the exhibition of the item and conquer shortcomings in the wood material, or plastics in blends with wood deposits to make new kinds of wood–plastic composites. The worldwide wood manufacturer is, for instance, the biggest client of adhesives; around 80% of all timber and timber-based items include some type of holding and 70% of the total quantity of adhesives created are consumed in the carpentry business. Wood can consequently be seen as a composite containing lumber-based materials got together with various materials to shape the complete material. A model is a compressed wood, in which facades are gotten together with glue to frame a level board. Different sorts of wood composites incorporate different board items, primary composite lumber, and furniture and joinery parts, all counting some type of holding with adhesives. This present circumstance clearly impacts the manner by which we ought to connect with wood items and their natural influences. This part gives a cutting edge and shows that various added substances are now being utilized in wood items. These data are fundamental for additional concentrates on the impact, that is, these added substances have on the assistance life and ecological viewpoints, and the constraints which they might force on the use again, updating of wood items.

Wood and wood-based composites are key designing materials that can be effectively planned and fabricated with foreordained double-dealing properties, making them reasonable for a wide scope of utilizations and end utilizes. Outstandingly, wood-based composites can be designed to meet explicit execution pre-requisites, which make them a practical answer for lessening the utilization of strong wood. The logical objective of this distribution is to give the peruse of new data on late practices in pressed wood research. Indeed, pressed wood is certainly back. Toward the finish of the twentieth hundred years and the start of the twenty-first hundred years, there was a reasonable decrease in pressed wood research. Be that as it may, its unforeseen expansion underway and the development of its application likewise caused an expansion in research work [1]. Ecological sources of info can work fair and square of development by interconnecting them with customary sources of info in regards to the properties of materials and processes as a vital eco-plan system. High-level designed polymer composites are expected to meet the different necessities of clients for elite execution auto, development, and items that all the while expanding the supportability of woodland assets. In the ongoing work, wood polymer composites (WPCs) are examined to advance long-haul asset manageability and to decline ecological effects compared with those of existing items. A progression of polypropylene wood–fiber composite materials having 20, 30, 40, and 50 wt% of wood filaments were arranged utilizing a twin-screw extruder and infusion shaping machine. Tractable and flexural properties the not entirely set in stone. Polypropylene (PP), as a lattice utilized in this study, is a thermoplastic material, which is recyclable. Reasonableness of the pre-arranged composites as an economical item is examined [2, 3] (**Figure 1**).

Wood–plastic composite (WPC) is emerging in the market. A portion of the great qualities of this material is biodegradability, recyclability, low assembling cost, high compound resistivity, high solidarity to weight extent, imperviousness to fire, and high firmness to weight extent. WPC is the better alternative for virgin wood and plastics, therefore, finds application in various fields, such as aircraft, automobile industry, electrical, sports, wrapping, and furniture. Wood–plastic composite is an eco-friendly material that also reduces the exhaustion of petroleum resources and also reduces the emission of CO_2 [4].

1.1 Challenges for improved or new innovations can be distinguished along the entire wood supply and cycle chain

1.1.1 Wood supply

Woodland material is being crushed between developing requirements (counting quickly, developing interest for timber as a power transporter) and natural limitations. This will open the unrefined substance distribution to semi-regular backwoods,

Figure 1.
Application of wood waste product [2].

timberland estates, agroforestry, and farming assets and new preparation ideas for wood assets. This new unrefined substance range, including the rising utilization of reused material, will immensely affect wood innovation and material plan also.

1.1.2 Timber manufacture

Wood is an exceptionally incorporated and streamlined unrefined substance from the earth with load-bearing capacities as one of the principal functionalities. Involving wood as lumber in development comes close to the normal highlights of wood; however, man actually can work on the technician execution of wood by legitimate evaluating and barring regular example and developing designed material designs. Material and building part models and recreation will turn into a significant device to comprehend and work on the materials and parts (**Figure 2**).

1.1.3 Material engineering

Designed wood composite materials and designs on every single progressive level (from nano to macrostructures) are as of now a fundamental area of innovation examination and will turn out to be significantly more significant to make wood materials more cutthroat. A solid spotlight on assets and environmentally friendly materials, including unrefined components from any sustainable sources, will lead us to "Green Composites" as visualized.

1.1.4 Wood attractiveness

Design and composition including the different extractives make an incomparable exterior of wood, particularly with the different hardwoods. Tragically the shade of

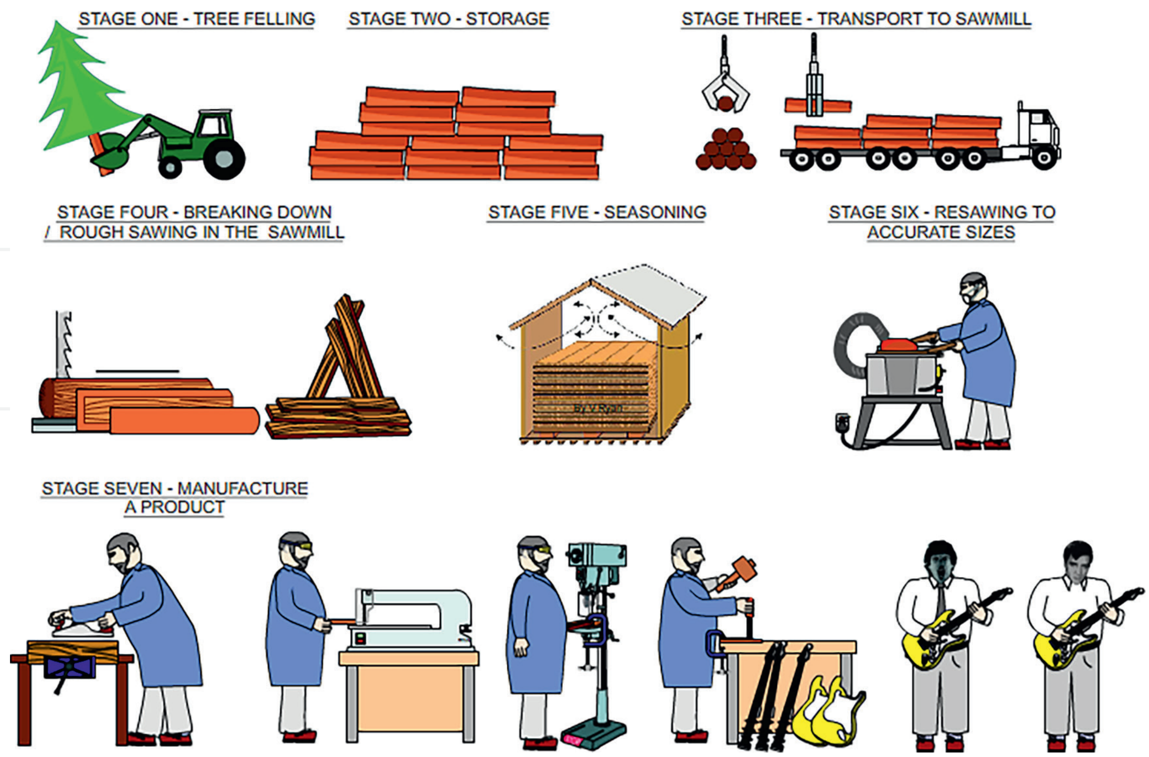

Figure 2.
Processing natural wood from logging to manufacturing a product [5].

wood is not ultraviolet is a fundamental test to forestall blurring and staining to a further effective and reasonable utilization of wood surface (facade and strong wood) in interior and exterior application in contest with specialized surface designs.

1.1.5 Wood adjustment

Much accentuation has been placed on wood change somewhat recently to make it more tough and steady and so on. Creating new processes in the wood surface will be important to make another wood execution, which is prepared to support brilliant materials.

1.1.6 Fractionizing wood

Different mechanical deterioration and compound decay processes are deeply grounded to separate and fractionize the natural substance of wood and to re-organize and yet again engineer it into stuck parts, wood boards, paper sheets, and so forth, nonetheless, improved and totally new cycles of crumbling must be conceived.

1.1.7 Making and processing

Wood handling has worked on a ton somewhat recently (e.g., high limit sawmills, consistent presses for wood boards, and superior execution wood machining), yet new cycle advances, fabricating ideas (mass customization, fitting of items, and so on) must be created. Asset and eco-proficient cycles must be conceived in wood enterprises through improved and new cycle examination and creating the executive frameworks, which thus are important for an idea of information-based creation.

1.1.8 Wood refinery

Thermo-synthetic cycles, and progressively, biotechnology are utilized to separate lignocellulosic raw material to their structure blocks being compound and power industry. The expressions "incorporated biomass innovations" and "wood biorefinery" turned into catchphrases inside the rise of another modern area of renewable-based advancements. Today we are in a maze of various; however, aggressive ways to deal with unfastening lignocelluloses to their structure impedes so they can be utilized for additional cycles. Despite the fact that pieces of that idea now exist, a broad monetary advancement is yet absent.

Figure 3.
Recycling of wood waste [6].

1.1.9 Recycling

Indeed, even as most timber items are considered as standard and big items, expanded utilization of wood develops a colossal optional feedstock to be utilized as a material as well as an energy transporter. The material, modern, and building plans must be coordinated to an upcoming obliterating of utilized structures and the recuperation of wood. Wood innovation turns into a significant job in the idea of a cascading utilization of wood (**Figure 3**).

1.1.10 Technology education

Wood innovation as a scholastic discipline must be additionally evolved (and examined inside the wood science and innovation local area) enveloped by thorough scholarly educational programs to give a significant innovation schooling to the understudies, which needs to make the scholarly spine of the upcoming timberland-based ventures and a knowledge-based society too [7].

2. Role of additives in the wood industry

2.1 Zinc Stearate

It was observed that the mechanical and physical properties were improved using lubricant (ZnSt) in the WPC composition. It was added in a ratio of 0–3% [8]. Structure TRO16 acts as a coupling agent, anti-microbial agent (1RGAGUARD F 3510) as a fungicide, ultraviolet filter casting (TINUVIN1235), blue pigment (irgalite) were used as an additive in the manufacturing of WPC panels. In this concentration, a portion of the significant properties is tentatively made WPC is not entirely set in stone. Example having 60 and 80% molecule and fiber of radiata pine (Pinus radiata) were blended in with polypropylene (plastic) and four various added substances, to be specific Structure TR 016 which is coupling agent, CIBA anti-microbial agent (IRGAGUARD F3510) as fungicide, UV filter coating (TINUVIN 123S), blue pigment (irgalite), and their blends. Given the underlying finding of this work, static twisting properties of the examples upgraded as above synthetics were added into both molecule- and fiber-based samples. Thickness swelling was likewise improved with having added substances on the boards. Micrographs taken on SEM uncovered that coupling agent and pigment brought about the same combination of wood and plastic together. Twin surface harshness boundaries average roughness (Ra) and maximum roughness (Rmax) used to assess surface qualities of the tests showed that molecule-based samples had more rough surface qualities than those of fiber-based ones. No critical impact of synthetics included the samples was found on surface roughness upsides of the samples made from molecule and fiber of radiate pine [9]. Two different additives were added, that is, glycerol acts as a plasticizer and MAPP acts as a compatibilizer to improve the mechanical and thermal properties of the composites [10]. The aim was to examine the impacts of material structures on the mechanical properties of WPC made by injection molding. Utilizing a proportion of wood floor, plastic, MAPP, zinc stearate of 47:47:3:3, the modulus of rupture (MOR), and tensile strength of WPC made with LDPE. Notwithstanding, differentiating discoveries were gotten when the polymer grid was ABS (acrylonitrile-butadiene-styrene). In contrast with the mechanical properties of recycled polypropylene itself, the modulus of rupture increased furthermore, the tensile strength decreased for WPCs produced with RPP [11]. Wood–plastic composite (WPC) is a naturally progressive approach to consolidate reused plastics and wood floors. The composite regularly comprises four significant components: wood flour, thermoplastics, coupling agents, and lubricant. The mechanical and physical properties of WPC exceptionally rely upon the material plane, and the ideal material structure is a fundamental subject of momentum research. This concentrate on exploring the impacts of changing material arrangements on the mechanical and physical properties of WPC. The concentration on WPC was expelled shaping WPC made utilizing recycled polypropylene (RPP) plastics and wood floor. The review assessed four boundaries: (a) wood floor particle size, (b) coupling agent dosage, (c) oil content, and (d) the mass proportion of wood and RPPs. The outcomes showed that utilizing better wood loor can work on the controlled and strength of WPC, and lessen the enlarging because of water adsorption. The ideal grouping of the lubricant and coupling agent in WPC were both 3%. Adding the legitimate measure of coupling agent can work on the mechanical properties and essentially diminish the swelling, however, over-dosing the oil fundamentally increases swelling and decreases all the mechanical properties of the WPCs. Keeping up with wood content at half or less delivered the best mechanical properties, what's more, wood content above around half brought about a decrease in all mechanical and physical properties of WPCs. The review exhibited the connection between water absorption to thickness swelling. Decrease in thickness swelling and water absorption was encountered (**Figure 4**) [9].

Figure 4.
Replacement of glass by wood [12].

2.2 Biocides

Wood impregnation is carried out in order to preserve WPC from biological decay like resistance to rot and dipping plants, protection against mold and blue stain fungi, and resistance toward destructive organisms. Some of the dipping agents used are water-soluble fluoride agents and phenolic agents, and copper sulfate solution also used in parts for impregnating railway sleeper coaches. Impregnation with creosote in the future will become a somewhat common impregnation method. Impregnation salt that contained some arsenic, zinc, and chromium was also used in open tank plants. In early 1970, oil soluble protective agent was used for the impregnation of window frames. Open container impregnation is utilized for the impregnation of telephone poles. The wood is lowered into a tub with a hermetically sealed cover. Steam is driven into the tub and after 8–12 hours, the wood is warmed. After this warming, a chilly impregnation arrangement is taken care of into the tub and the cooling prompts an under pressure, because of which the arrangement is sucked into the wood. This piece of cycle takes 30–35 hours. The boliden impregnation salt is typically utilized in this strategy. Different impregnation methods that were used for WPC are Fuel-cell/ Bethell method and the Lawry method. In pressure impregnation, creosote is used as the main agent.

2.3 Fire retardants

Inorganic salts are mainly used as a fire retardant to protect WPC products against fire so that they cannot catch fire easily. Fire retardants impact the scorching rate, ignitability, fire speed, smoke improvement, and mechanical properties. Some fire retardants affect the properties of the wood, such as mechanical strength, shade, and paint ability. Inorganic salts are used as fire retardants and they contain ammonium sulfate, zinc chloride, boric acid, mono ammonium phosphate, etc.

Flame retardants are classified as intumescent and non-intumescent substances. The Intumescent formulation includes a char former, blowing agent, and

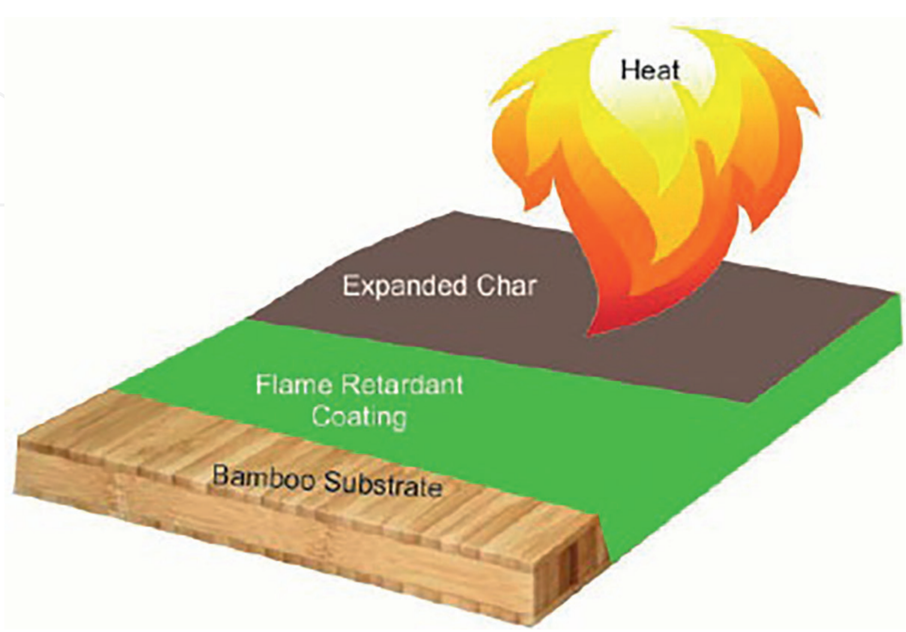

Figure 5.
Schematic diagram of fire protection by IFRC [14].

dehydrating agent. The Non-intumescent coating includes formulation of water-soluble salts, such as diammonium phosphate, ammonium, and borax [13]. The fire retardancy conduct of wood–polypropylene composites containing different fire retardants, such as ammonium polyphosphate (APP), zinc borate, and melamine, has been examined with the calorimetry procedure. The impact of ammonium polyphosphate (APP) in blend with graphite has been likewise examined with a calorimeter test. The fire properties estimated in the cone calorimeter are discussed, including the total heat release, heat release rate (HRR), ignition time, effective heat of combustion, smoke production, specific extinction area, and mass loss rate. The consequences of the review show that zinc borate decreases the heat release rate (HRR) productively. Based on the review, it is apparent that melamine has next to no impact on the combustibility of a wood–plastic composite, however, it lessens smoke formation. APP, utilized alone, has increased smoke creation altogether, whereas the development of smoke, as well as other fire properties, have been altogether improved when both ammonium polyphosphate (APP) and graphite have been added to the composite (**Figure 5**) [15].

2.4 Thermal modification

Thermally treated wood is used in order to improve resistance against fungi and insects, mechanical properties, dimensional stability, and also properties such as odor, color, coating performance, and gluability. Thermal treatment of wood is done in order to improve resistance to biological degradation and dimensional stability [13]. The effect of steam exploded (SE) wood floor added to wood–plastic composite was inspected utilizing wood such as Japanese cedar, red meranti, and beech, and three sorts of thermoplastic polymer: polyvinyl chloride, polymethyl methacrylate, and polystyrene. An increase of steam exploded wood floor increased the water resistance and fracture strength of the composite board to a degree subject to the polymer species and the structure of wood polymer composite. In any case, water resistance diminished with the rising extent of steam exploded wood when red meranti was added to the mixture. Effects of the steam-treated wood species on the properties of resulting board were small. An increased dampness content of steam exploded wood floor expanded the variety of board execution [16].

2.5 Surface treatment

Surface treatment of wood is carried out using paints and lacquers or varnishes in order to protect the surface and to look decorative. The main components of a coating include pigments, binders, fillers, solvents, and additives. The binder combines the pigment particles to each other and also to the wood as a protective shield. Typical binder includes alkyd resins, nitrocellulose, acrylates, amino resins, and polyester resins. With the addition of solvents, the coating has a viscosity so that it can be applied to the wood easily. Common solvents are white spirit, water, turpentine, and alcohol. Fillers are used to modify the gloss of the coating, the color strength, and the extent to which the coating covers the substance. Additives in the coating may include alcohols or glycerol, fungicides, in order to prevent mold growth, accelerate the drying process, make the color drip free, improve adhesion, and to regulate certain properties of the finish such as consistency, gloss, flow, wetting, sand ability, and blister prevention [13]. Additives, such as dolomite, lingo sulphonate, potato floor and peel, starches, and some motor and vegetable oil are used as additives for wood pallet production.

Additives used act as a lubricant and they decrease energy consumption and increase the production rate. Starch additives minimize the final moisture content more than lingo sulphonate additives. Additives such as corn starch, motor oil, urea, sodium carbonate, dolomite, and vegetable oil decrease the wood pallet particle density. All types of starch increase the mechanical durability of wood pallets. Ligno sulphonate increases SOx emission. Vegetable oil and motor oil when used as additives increase the calorific value of wood pallets. Dolomite additives increase ash formation. Corn starch and dolomite additive increase carbon emission [17].

2.6 Fillers

Natural fibers composites (NFCs) are an emerging material that proved to have good sustainability credentials. Following the principles of recent research in material and design field, it was suggested that an existing low-esteem image of NFCs can be greatly enhanced by modifying sensorial aspects, form, and associated processing [18]. Wood from two assortments of insect-killed trees was used to create wood–plastic composites. Lodgepole pine and loblolly pine creepy crawly killed trees were de-fibrated thermo-mechanically into fiber. Fiber also, sawdust delivered from the trees were altered with potassium methyl siliconate (PMS) and injection molded into plastic composites. Alteration of fiber and sawdust with PMS worked on the similarity between ethylene plastic and lignocellulosic materials in the composites, bringing about decreased water absorption, increased layered dependability, and increased resilience to morphological varieties in the fiber and sawdust. Fiber-to-sawdust proportion also, size of sawdust particles impacted the time expected for immersion with water, as well as dimensional stability [19].

2.7 Coupling agents

Wood fiber built-up plastic composites at fiber content half by weight have been prepared. Various sorts of timber strands (softwood fiber, hardwood fiber, wood chips, and long wood fiber) were treated with a coupling agent (MAH-PP) to build the interfacial grip with the framework to work on the scattering of the particles and to diminish the water absorption properties of the composite. The current review examined the flexural, tensile, impact, and Charpy properties of wood fiber built up polypropylene composites as a component of coupling agent and fiber. From the outcomes, it was seen that wood chips polypropylene composites showed better elastic and flexural properties relative to the other wood–PP composites with an increase of 5% of MAH-PP, which is around 65% by weight and half for elasticity and flexural strength individually. Hardwood fiber and polypropylene composites showed improved effect trademark values relative to other wood–plastic composites with an increase of 5% of MAH-PP and damping index decreased to 60%. Charpy impact strength likewise increased up to 60% with the increase of 5% of MAH-PP for long wood fiber. Water retention and scanning electron microscopy of the composites are more over-explored [20]. There are a number of organizations creating wood–plastic composite for underlying applications. In any case, wood–plastic composite (WPC) requires addressing two significant limitations: strategy and detailing before their plan esteem for a primary application not set in stone. The study focused on tackling the two significant imperatives by utilizing the injection molding method to create WPC and utilizing different business accessible coupling agents at various levels to create WPC. The impact of wood-to-plastic proportion was likewise assessed on WPC delivered, utilizing the coupling agents that gave the most noteworthy bending properties. Commercial polypropylene wood floor and coupling agents were premixed in a mixer for 30 minutes before the extrusion process at a temperature of 190°C utilizing a 110 mm co-rotating twin-screw extruder. The WPC sheets with a size of 150 × 150 × 3mm were then formed by a 40-ton press molding machine. From the outcome, WPC created from coupling agents Exxelor PO 1020 at 4% fundamentally performed better in bending. Further concentrate on the impact of Exxelor PO 1020 rate and the wood-to-plastic proportion shows that, WPC with 65% wood floor performed altogether preferable in modulus of rupture (MOR) and modulus of elasticity (MOE) over another sort of wood–plastic composites. WPC with 60% wood floor had fundamentally lower water absorption and thickness swelling contrasted with those 65 and 70% wood floor WPC. Decisively, WPC with 65% wood floor is the ideal substance to deliver from the injection molding technique. A higher amount of coupling agent utilized in WPC formation gave higher bending properties [21]. The present study focused on the surface nature of wood-based materials used to produce furniture in Singapore. Different sorts of monetarily delivered composite boards, including particleboard, medium thickness fiberboard (MDF), and pressed wood notwithstanding 10 unique strong wood species that are generally utilized in furniture creation, were considered for the analyses. A pointer-type profilometer and 3D picture analyzer were utilized to decide the surface roughness of the samples. Medium thickness fiberboard (MDF) tests came about in the smoothest surface with an across the average roughness (Ra) value of 5.07μm, while comparing an incentive for pressed wood samples was 8.09 μm among the composite board tests. On account of strong wood tests, estimations brought and across the sand mark from the outer layer of the samples estimated by the pointer type profile meter, balau had the roughest surface with an average roughness (Ra) value of 9.85 μm across the sand mark followed by beech and pecan. Pine specimens alongside cherry, ash, and nyatoh brought about moderately smooth surface qualities. The relationship between estimations taken by two unique techniques, to be stylus and 3D scanning, showed a decent concurrence with one another. Given the discoveries in this work apparently, both techniques can be effectively used to assess and to get objective mathematical qualities on the surface nature of these examples so that such introductory information can be utilized as a quality control instrument to have a more powerful further assembling steps in furniture creation [22]. The present study examined the impacts of wood fiber content, coupling agent content, and wood fiber type on the mechanical properties of wood–plastic composites (WPC). This study embraced a reaction surface procedure of a 20-run optimal design for these three elements. The composite's modulus of elasticity was essentially impacted by wood fiber content, wood fiber type and ductile pressure at break relied upon wood fiber content, wood fiber type, and coupling agent content, though resist break was essentially impacted by wood fiber content and coupling agent content, yet not essentially impacted by wood fiber type [23]. The impact of maleic anhydride joined styrene-ethylene-butylene-styrene block copolymer (SEBS-g-MAH), and *in situ* joining MAHon dynamic mechanical and mechanical properties of wood–plastic composites were examined. Reused plastic like high-density polyethylene (HDPE), polypropylene (PP), and polystyrene (PS), were blended in with wood floor in a high-speed blender and afterward expelled by a twin screw extruder framework to shape wood–plastic composites. Results showed that the impact properties of the composites were further developed all the more essentially by utilizing SEBS-g- MAH compatibilizer than by utilizing the combinations of MAH and DCP by means of responsive mixing *in situ*. Notwithstanding, opposite results were noticed on the flexural and tensile properties of the comparing composites. In general, the mechanical properties of composites produced using recycled plastic mixes were mediocre compared to those produced using virgin plastic mixes, particularly in elongation break. The morphological review confirmed that the interfacial attachment or the similarity of plastic mixes with wood floor was improved by adding SEBS-g-MAH or *in situ* joining MAH. A superior interfacial holding between HDPE, PP, PS, and wood floor was acquired by *in situ* joining MAH than the increase of SEBS-g-MAH. *In situ* joining MAH can be thought of as a potential approach to increase the interfacial similarity between plastic mixes and wood floor. The elastic modulus and damping factor of composites were additionally portrayed through dynamic mechanical analysis (DMA) [24]. The blend of manufactured thermoplastic polymers and wood is regularly risky on the grounds that wood surfaces are hydrophilic while normal thermoplastic polymers are hydrophobic. A potential arrangement is to utilize block copolymer coupling agents. In this work, it was shown that the utilization of a possibly valuable manufactured strategy for delivering hydrophobic–hydrophilic block copolymers as hydrophobic coatings and coupling agents in wood polystyrene composites. Specifically, wood façades have been covered with water-based emulsions of hydrophobic–hydrophilic block copolymers from methacrylic corrosive and styrene. Dried-covered surfaces are displayed to become hydrophobic through unique contact point estimations. At the point when a wood floor is covered with the hydrophobic–hydrophilic block copolymer in view of acrylic and styrene corrosive, critical improvement in an ultimate tensile strength of composites shaped from covered wood polystyrene combinations is understood. Since no volatile organic compounds (VOCs) are utilized in covering wood surfaces, what's more, resulting composite creation, improvement in mechanical properties of thermoplastic/wood floor composites are displayed to happen in ecologically capable plans [25].

2.8 Compatibilizer

Polypropylene (PP), a thermoplastic, enjoys a ton of benefits, for example, great handling properties, minimal expense, and so on. Nonetheless, PP has an unfortunate effect on opposition under high tests peed or low-temperature conditions. To further develop influence properties and low-temperature sturdiness of Polypropylene, the elastomer is frequently utilized in poly-propelene; elastomer adjustment of poly-propelene is known to cause a sensational decrease in both toughness and strength. The expansion of fortifications into poly-propelene can increase the strength and toughness, whereas it causes a decrease in fracture toughness. In this manner, to repay those downsides, an equilibrium in the durability and strength can be gotten by adding elastomer and support into PP. In this chapter, wood fiber as support was utilized to further develop firmness; furthermore, MA-SEBS was utilized as a compatibilizer and influence modifier (**Figure 6**) [27].

2.9 UV stabilizers

Four types of iron oxide pigments were added to wood floor/high-density-polyethylene composites (WF/HDPE) at three different concentrations. Then the effect of pigments on the color change and mechanical properties before and after UV accelerated weathering was determined. Wood fibers, HDPE, pigments, and other processing additives were dry-mixed in a high-speed mixer. The mixtures were extruded by a

Figure 6.
Wood-based material used in an exterior application [26].

S. No.	Additives used in wood based products	Efeect of additives on wood based products
1.	Coupling agent (MAPP) 3%	Increases mechanical properties like flexural and tensile strength,MOR, Storage modulus, decreases thickness swelling and damping peaks [8, 11]
2.	Lubricant ZINC STEARATE [ZnSt] 3%	Reduces physical and mechanical properties except MOR, increases thickness swelling [8]
3.	Additive STRUCTOR TR 016 CA	Promotes homogeneity, increases physical and chemical properties [9]
4.	CIBA anti-microbial agent	Protects against micro-organisms [9]
5.	UV filter coating CIBA (TINUVIN 1235)	Protect against UV radiations [9]
6.	Fungicides IRGAGUARD F3510	Protect against fungus [9]
7.	Pigment CIBA blue (Irgalite)	Avoids fading of structure [9]
8.	Plasticizer GLYCEROL	Increases thermal and mechanical properties, compatibility, and tensile strength [10]
9.	Fire retardant MELAMINE 30%	Reduces smoke formation, increases ignition time and total heat release [15]
10.	Fire retardant Zinc Borate 30%	Improves peak heat release rate[15]
11.	Fire retardant APP (Ammonium Polyphosphate) 20–30%	Increases smoke production by 20–30%, improves ignition time and total heat release, reduces peak heat release rate [15]
12.	Additive Lignosulphonate and starch	Improves mechanical durability, reduces the calorific value, increases SO_X emission [17]

S. No.	Additives used in wood based products	Efeect of additives on wood based products
13.	Additive Motor and vegetable oil	Increases the calorific value and CO emission, decreases the particle density [17]
14.	Additive Corn starch and Dolomite	Increases CO emission, reduces moisture content [17]
15.	Additive Wheat Starch	Reduces ash formation [17]
16.	PMS (Potassium Methyl Siliconate)	Improves compatibility, decreases water sorption, increases dimensional stability [19]
17.	Coupling agent MAH-PP 5%	Decreases water sorption, damping index and hygroscopicity, increases interfacial adhesion, charpy impact strength, tensile and flexural strength [20]
18.	EXXELOR PO 1020 4%	Improves bending properties, decreases water sorption [21]
19.	Compatibilizer SEBS-g-MAH	Improves impact strength, compatibility, tensile and flexural strength [24]
20.	MAH and DCP	Improves interfacial bonding and mechanical properties [24]
21.	Styrene-co-methacrylic acid	Improves ultimate tensile strength [25]
22.	Compatibilizer MA-SEBS 8%	Improves interfacial adhesion, impact strength, stiffness, toughness, and storage modulus [27]
23.	Pigment Iron Oxide 2.28%	Improves bending strength, avoid discoloration [28]

Table 1.
Effect of additives on wood-based products.

twin screw extruder. The color of the samples was determined according to CIE 1976 $L^*a^*b^*$ system by spectrophotometry. The bending properties were determined and the mechanical properties were evaluated before and after accelerated UV weathering. The result shows that the modulus of elasticity (MOE) of the composite did not change after incorporating the pigments, but the bending strength was improved. After accelerated aging for 2000 h, both mechanical properties and color were changed significantly. Red iron oxide and black iron oxide performed better than the other two pigments. It was also observed that the pigment dosage of 2.28% in the composites is favorable (**Table 1**) [28].

3. Conclusion

Wood-based products are an emerging material for wood industries nowadays. They have a number of applications, including window and doorframes, docks and railings, exterior and interior wall profiles, floors, stairs and hand rails, fencing, shelves, office furniture, garden furniture, soundproof cladding, and kitchen cabinet. Different types of additives are used to improve their efficiency and performance. Some of the additives are rheology control additives, lubricants, density reduction additives, UV stabilizers, product aesthetic additives, biocides, smoke suppressants, flame retardants, wax, colorant, foaming agent, blowing agent, fillers, etc. These additives are added to WPC according to the applications where they have to be used. Additives improve their efficiency, performance, durability, sustainability, and shelf life. Some of the benefits of using WPC instead of pure wood or pure plastic are high stiffness to weight ratio, high strength to weight ratio, more consistent, defects and distortion free, moisture resistant, highly durable, weather resistant, slip resistant, easy maintenance, recyclable and environment friendly, cost-effective, UV resistant, more shelf life, high insect and rot resistant, high MOR (Modulus of Rupture) and MOE (Modulus of elasticity). All the above-mentioned qualities of wood-based products encourage their manufacturing in wood industries rapidly nowadays. Wood-based product has almost replaced pure wood and pure plastic in a number of applications.

Author details

Amit Prem Khare[1], Nidhi Dwivedi[1] and Shamsul Haq[2]*

1 Mechanical Engineering Department, Madhyanchal Professional University, Bhopal, India

2 Mechanical Engineering Department, SAM Global University, Bhopal, India

*Address all correspondence to: shamsulhaq198615@gmail.com

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