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Editorial

Wood-Based Composites: Innovation towards a Sustainable Future

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The term wood-based composite (WBC) is used to define a wide range of products in which wood is bonded together with other wooden or non-wooden materials [1]. The bonding can be realized through natural (e.g., soybean) or synthetic (e.g., thermosetting) adhesive mixtures or binders (e.g., cement) [2]. WBCs are mainly manufactured for the following purposes, often simultaneously: (i) to effectively use small-diameter assortments, low-grade timber, and forest residues; (ii) to limit the amount of wood or other materials towards reducing the final costs or in case such components have limited availability; (iii) to obtain end products with improved properties and uniformity compared to those of their components; (iv) to obtain products whose performance fulfills ad hoc requirements (e.g., fire retardancy, improved durability, etc.).

WBCs are currently available on the market in a great range of typologies. This is because their constituent elements can have multiple configurations and be combined in a variety of compositions. The mere fact that the term wood-based is used to group such a wide category of products indicates that (i) the availability, ease of processing and versatility of wood make it suitable to the manufacturing of several types of composites; (ii) wood plays a relevant role in defining the properties of such composites, usually of importance at least equal to that of the other embedded materials.

The properties of WBCs depend upon several factors, including wood species and composition, size of the wooden elements, type of bonding, finishing, etc. The economic turnover of WBCs is relevant worldwide, as they are commonly used in many sectors, such as furniture, marine, building, transport, and packaging. The number of applications has increased over recent decades as a result of technological advancements that have enabled the manufacturing of new high-performing WBCs. In service, they exhibit, often at the same time, different properties that are also the subject of numerous scientific investigations: lightweight [3], mechanical strength [4], thermal insulation [5], sound absorption or insulation [6], durability [7], bonding quality [8], and flame retardancy [9], among others.

The present Editorial first provides an overview of different WBCs. Then, in order to determine a framework for these products from the perspective of the forest-wood sector, WBCs are considered in relation to the new European forest strategy [10], with particular reference to the goals concerning innovation and sustainability.

1. Overview on WBCs

Composite materials can be of natural or artificial origin. In fact, wood itself is a composite material, composed of cellulose fibers dispersed in a matrix of lignin.

The denomination wood-based composites can be confusing at times, since it refers to a wide range of products, of varying complexity, that are made by different elements. In fact, WBCs can be grouped according to several criteria, for example, configuration, density, bonding type, and end use.

In terms of structure, the less complex WBCs are made of two components namely wood and an adhesive mixture (which typically consist of a resin with further additives such as water, extenders, and fillers). Although belonging to the category of the so-called WBCs, such products are better referred to by specific denominations such as glue laminated timber (GLT), cross laminated timber (CLT), plywood, particleboard, fiberboards, or other wood-based panels. In this context, products in which wooden elements are assembled by point connectors (e.g., dowel or nailed laminated timber), and the chemically modified woods are not considered wood-based composites.

The abovementioned two-component WBCs are generally made of wooden elements of the same type that can, however, vary in terms of species, size, and/or orientation. An example of species variation is that of plywood made of veneers of two species alternated among the layers (combi) or in which one species is used for the faces and the other for the inner layers (twin) [11]; similarly, a mixed composition can be arranged in the production of other panels such as CLT or oriented strand board (OSB). An example of change in elements size is that of particleboard with progressive particle dimension from the surface to the middle line of the panel thickness, whereas examples of different elements orientation are those of plywood and OSB.

A further step in complexity is represented by WBCs made of two different materials and the adhesive mixture. In some cases, all the assembled elements are of wood (such as in blockboard, made of veneered faces bonded to a central layer of small sawn laths). Otherwise, one or more layers can be, for instance, of aluminum sheets used as vapor barrier or reinforcement. Some technical standards provide an actual definition for WBCs: e.g., EN 313-2 [12] defines composite plywood in this sense.

Of note, the above WBCs are often reported as engineered wood products, especially in the case of structural applications or when their technical features are particularly relevant. This is mainly because they can be manufactured through a controlled industrial processing aimed at optimizing their properties and to obtain more homogeneous and predictable performances compared to solid wood.

Of course, as the name suggests, wood plastic composites (WPC) also fall within the category of two-component WBCs because they are made by extrusion combining wood flours (sometimes from different species) with a polymeric matrix. Some types of laminates can likewise be included in this category. Clearly, the adhesive mixtures used in WBCs can also vary depending on the intended end use (e.g., structural, for humid environments, etc.).

The products described so far have, in fact, the common denominator of all being manufactured by means of a primary processing that reduces (by sawing, peeling, chipping, defibering, etc.) the wooden raw material in unitary elements of different size (respectively, sawn timber, veneers, particles, fibers, etc.) that are, after drying, then reaggregated by bonding and pressing [13].

In this regard, a stricter definition of WBCs considers only those obtained by bonding together two or more of the above components in a secondary production process. This is the case of the sandwich structures in which the external skins are made of a wood-based panel (e.g., plywood) glued to an inner core of materials that usually are different than wood. This provides high-performing static behavior: the skins distribute the loads in the product's plane and can have a decorative function, whereas the core increases the bending stiffness (depending on the distance of the skins, as is the case in I-beams). Cores are often made of lightweight materials, such as thermal-insulating foams (e.g., polystyrene), cork, or honeycombs whose cells can be made on aluminum, polypropylene, wood, cardboard, etc. Sometimes, combinations of the mentioned materials are also available, while another example of wooden core is that made of end-grain sawn wood.

Finally, panels manufactured by gluing sliced veneers (of natural, dyed, multilaminar wood [14]) or different materials with aesthetic value (plastic laminate, foils, etc.) to an inner support made of plywood, particleboard, or MDF, although manufactured through secondary processing, are usually named decorative panels. In this case, the final product can be realized in the same organization and plant that produced the support panel or by assembling the different semifinished materials purchased on the market. Similarly, several raw or prefinished products made of different combinations of wooden elements, WBCs, and other materials are present in the parquet/flooring sector.

Despite the large availability of WBCs, further combinations are still conceivable, leaving the way open for research and development. In this large and variegated context, the Forests Special Issue "Wood-Based Composites: Innovation towards a Sustainable Future" considers the WBCs in their wider interpretation but with particular attention to modern and new solutions.

2. WBCs in the Light of the New European Forest Strategy

The new European Forest Strategy (EUFS), released in July 2021 [10], recognizes "[. . .] the contribution of foresters and the entire forest-based value chain for achieving by 2050 a sustainable and climate-neutral economy while ensuring that all of ecosystems are restored, resilient, and adequately protected." Wood and its derived products are repeatedly mentioned by the EUFS, which is not surprising given their economic, social, and environmental relevance. The main indications of the EUFS for wood-based products can be grouped in four categories: sustainability, innovation, investments, and promotion (some representative sentences taken from the EUFS are reported in quotes below). Such indications are following put in relation with WBCs, in order to provide a brief overview on some of the most relevant challenges and opportunities they are facing currently.

Sustainability is considered as a key aspect by the EUFS: "Sustainably produced and long-lived wood-based products can help to achieve climate neutrality by storing carbon and substituting fossil-based materials; Respect for circular economy principles is also crucial; [. . .] ensure that the amount of wood we use [. . .] is optimally utilised in line with the cascading principle; [. . .] taking into account the overall availability of wood within sustainability boundaries in 2030 perspective."

Sustainability of WBCs is necessarily based on the legality of the wooden raw material. This is a topical issue, as shown by the fact that the European Commission is currently working on a new regulation on deforestation-free products [15]. Forest certification, with its ever-growing diffusion and relevant impacts on the market [16], is another key aspect related to the sustainability of WBCs. They also benefit from the lower environmental impact of wood, especially in terms of lower greenhouse emissions compared to those of their main competitor materials, e.g., steel, aluminum, and plastic. Starting from this vantage point, several strategies can be adopted to further minimize the environmental impacts associated with the manufacturing of wood and WBCs: changing the energy sources that power the processes, using (more) wood wastes as energy sources, improving the efficiency of machineries and drying systems, using environmentally friendly chemicals, developing integrated industrial sites, etc. [17].

As a rule, an increase in the overall fraction of wood in a WBC goes with lower environmental impact, higher carbon storage and wider opportunities for cascading use. Of note, the EUFS states that "[. . .] the most important role of wood products is to help turn the construction sector from a source of greenhouse gas emissions into a carbon sink." This represents a great opportunity for WBCs, as they are widely used in construction, for instance as thermoinsulating partitions, structural components, furniture elements, etc. In this sense, the use of low-grade wood and wood wastes for the core layers of sandwich structures has great potential for increasing the amount of carbon embodied in WBCs.

Modern WBCs should also be designed and manufactured for the purpose of enhancing, to the greatest degree possible, their suitability for cascading use, in line with the principles of circular economy. This should be seen not only from the product side but also from the perspective of developing and supporting integrated circuits that favor the efficient cascading use of WBCs.

Evidently, the characteristics of other non-wooden materials and of the bonding systems are also fundamental to determining the sustainability of WBCs. However, the number of possible variables and combinations is too vast to be considered here.

Innovation is seen by the EUFS as particularly linked to the increase in sustainability: "The processing innovations in this field can also provide bio-based materials and products with lower environmental footprint than the fossil-based ones; [. . .] research and innovation on architecture, green design and construction materials should be amplified, including on industrial improvements to use more low-grade wood, especially from hardwood species and on how to enhance cascading use and increase circularity [. . .]."

The development of bonding systems based on more environmentally friendly adhesive mixtures and bioadhesives [18] is currently a crucial aspect in which performance and sustainability of WBCs are strictly connected. Other relevant fields of research are the use of new materials, the combined use and mix of wooden and non-wooden materials, and the development of performing tridimensional structures (such as honeycombs) for the core layers of sandwich WBCs. In general terms, WBCs highly match the EUFS indications on using more low-grade wood: as already stated, one of the main reasons for which they are produced is precisely to effectively use small-diameter assortments, low-grade timber, and forest residues. Finally, innovation should take into regard not only the composition and performance of WBCs but also methods to enable their more efficient and longer lasting use in service, in addition to strategies to enhance their cascading use and post-consumer recycling.

The need for investments is also addressed by the EUFS: "[. . .] investments are needed throughout the wood processing chain; wood processing industries should be supported to better adapt to the changing and diversifying resources of forests; investments should also focus on the production of long-lived wood products from lower quality logs."

Investments are relevant for the WBCs sector, since the composition of such products often requires complex manufacturing processes, typically at industrial scale and by means of advanced technologies. Initiatives are also needed to trigger innovation, aimed at developing new WBCs with higher performance and sustainability and to advance the legislative and normative framework [19]. To support this sector, the European Union and its member countries should propose initiatives characterized by reduced times, as industries typically need to limit the span between the development of a product and its release on the market.

Finally, the EUFS also highlights the need for promotion of wood-based products: "Promoting the use of wood products in the EU also requires demand-side actions [. . .]; construction engineers and architects should be incentivized to design buildings with wood."

The above-mentioned increase in performance and sustainability of WBCs should, therefore, be accompanied by specific communication from industries, associations, etc., particularly to strengthen the image of WBCs as green(er) products. Moreover, communication efforts should be addressed towards different stakeholders, among which includes engineers and architects, namely for the purpose of demonstrating the potential of WBCs in construction and to overcome barriers such as, for instance, technical misconceptions, lack of experience, and legislation/standardization [20].

3. Conclusions

The sector of wood-based composites has worldwide relevance at the economic, social, and environmental levels. WBCs can benefit from the growing interest in the use of wood as a high-performance and sustainable material, especially in the construction and furniture sectors. The lightness of many WBCs and the possibility of combining different materials for improving some properties of wood (such as fire resistance, durability, or acoustical behavior) represent a further positive aspect regarding several applications, such as in the transport sector and where safety is a fundamental requirement.

Several scientific studies are already addressed at moving WBCs towards improved performance and higher sustainability. The Forests Special Issue entitled "Wood-Based Composites: Innovation towards a Sustainable Future" aims at presenting cutting-edge research on these relevant topics.

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