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An Ecological Product: Wood Sandwich Panel

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Abstract – In this study, wood sandwich panels (WSP) are investigated and reviewed in term of its advantages, weaknesses and usage areas. WSP composite was manufactured to meet humanity's increasing need for wood in the last century. The rapid increase in human population has led to an increase in the amount of consumption. Increasing consumption habits have put pressure on the world ecology. Especially forests are insufficient to meet the increasing need for wood. In order to reduce the pressure on forests, industrial plantations have begun to be built with fast-growing tree species. But this method is insufficient. Wood preservation technologies have been developed to protect existing wood materials. Efforts are being made to extend the life of wood and reduce the pressure on forests through methods such as heat treatment, impregnation and acetylation. All these methods are inadequate in the face of humankind's increasing consumption approach. For this reason, researchers are working on new materials that can replace wood. WSPs have begun to be produced by using thin wood veneer in the surface layer and light, cheap and abundant polymers in the core layer. WSPs can be produced specifically for use as lightweight, fire-resistant or for insulation purposes. In this study, the usage areas of WSPs and the latest research are compiled. Studies on WSPs will directly help protect forests and indirectly preserve ecological balance. More research should be done on WSPs.

Keywords – Wood, Core Layer, Sandwich Panel, Light Board, Surface Layer

I. INTRODUCTION

The rapid increase in the human population has led to an increase in consumption [1]. The rapid increase in consumption has also increased the pressure on renewable natural resources such as forests [2]. The increase in consumption pressure on forests has caused to decrease the forest areas in the world rapidly. Today, the increase in forest products does not meet the population growth rate. Per capita wood consumption is decreasing every year. The need for forest products is increasing. This increasing need is at a level that cannot be met from existing forest resources. For this reason, fast growing forest trees and industrial plantations have been developed to meet the wood needs of the industry [3]. But this effort is not enough. Various wood preservation methods have been developed to extend the lifespan of wood [4]–[6]. In this way, the pressure on the forests was tried to be reduced. In the last century, composite boards such as artificial wood (chipboard) and medium density fiberboard began to be produced from wood residues using glue [7], [8]. Nowadays, these factories have difficulty finding wood raw material. In fact, they have to pause manufacturing for 1-2 months during the year because they cannot find wood raw materials [9].

For the reasons mentioned above, researchers are investigating new materials that can be used instead of wood raw materials in the middle layers of wooden boards. Thus, wooden sandwich panels with different properties have been produced.

Wood sandwich composite boards are increasingly used in the furniture industry due to their superior features such as price, lightness and strength [10]. WSP has a layered structure and consists of two surface layers covered with a thick middle layer (Fig. 1). Surface layers are dense materials with high resistance properties. Most of the mechanical properties of the panels are thanks to the surface layer.

WSPs have lower nail and screw withdrawal resistance than solid wood. For this reason, it is difficult to make connections to each other and to other materials. Due to the use of low density polymers in the core layer, its mechanical properties are lower than solid wood. The fact that WSPs can be specially designed according to their usage areas makes them superior to solid wood. For example, the polymer to be used in the middle layer can be designed to be unaffected by water or fire resistant. Considering this aspect, WSPs are superior to wood.

II. RESEARCH ON WSP

As mentioned above, WSPs can be designed specifically for the need. One of the most important of these designs is WSPs produced for insulation purposes. Addressing global warming necessitates the development of advanced materials with enhanced thermal insulation properties, characterized by lower thermal conductivity to ensure indoor temperatures remain unaffected by external temperature variations. Additionally, these materials should exhibit excellent warmth-retention capabilities, achieved through lower thermal diffusivity, offering protection against drastic temperature fluctuations. Achieving optimal performance in both steady and transient heat flow situations is essential for effective insulation, and it's imperative that these materials possess sufficient thickness to provide the necessary thermal resistance when in practical use [11].

Traditionally used solid wood and boards such as chipboard and plywood are not used as insulation materials. However, these plates provide much better insulation than structural elements such as iron and aluminum [12]. WSPs can be designed as materials with the lowest thermal conductivity. This makes them preferred as insulation materials in buildings, despite their low mechanical properties. Many studies have been conducted on WSPs in recent years.

A. *Isolation WSPs*

Kawasaki and Kawai [11] studied about the thermal insulation properties of wood-based sandwich panel for use as structural insulated walls and floors and reported that the WSPs exhibit a well-balanced combination of thermal insulation and warmth-retention properties in both steady and non-steady states, making them ideal for maintaining stable indoor temperatures and mitigating the impact of fluctuating external temperatures in residential settings subjected to diurnal and seasonal variations.

Ramirez et al. [13] studied about the thermal conductivity of coconut fibre filled ferrocement sandwich panels and reported that the thermal conductivities for various construction materials, including red clay brick (0.93 W/m K), hollow concrete block (0.683 W/m K), and lightweight concrete brick panel walls (0.536 W/m K), demonstrate their respective heat transfer characteristics. Notably, the proposed configuration boasts a significantly lower thermal conductivity of 0.221 W/m K, indicating superior insulating properties when compared to commonly employed construction materials for residential buildings within this particular region.

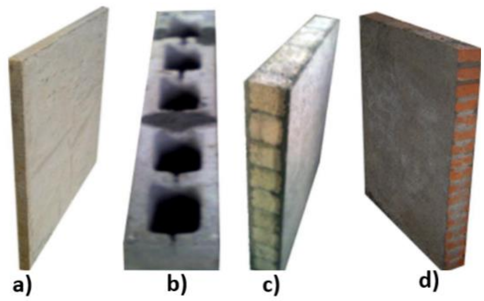

Fig. 1 Conductivity test materials: (a) panel wall of ferrocement, (b) panel wall of hollow concrete block, (c) panel wall of lightweight concrete brick, and (d) panel wall of red clay brick [13]

Neves de Alencar et al. [14] studied about the thermal insulation and acoustic isolation materials for construction an reported that the natural rubber as a polymeric matrix incorporated with eucalyptus filler foam exhibits significantly enhanced acoustic insulation capabilities, as evidenced by its maximum absorption coefficient of 0.83 at 3257 Hz, representing a threefold improvement compared to natural rubber foam; this enhancement can be attributed to its highly inhomogeneous cell structure, characterized by large interconnected pores, which significantly enhances its acoustic performance, with a sound absorption coefficient akin to that of PU foam, a well-established acoustic absorbent in the construction industry, boasting a thickness of 20 mm, a density of 47 kg/m^3, and an impressive 98 % open cell content.

B. *Fire Resistant WSP*

Hýsek, Š., Frydrych et al. [15] studied about the Fire-Resistant Sandwich-Structured Composite Material and reported the All of the sandwich composites manufactured with particles of winter rapeseed stalks, geopolymer and reinforcing basalt lattices resisted flame for more than 13 min and the fire resistance was positively affected by the density.

Zhou et al. [16] studied about the fire-retardant wood/polyethylene composites based on a continuous honeycomb-like nanoscale carbon black network (Fig. 2) and reported that the conductive carbon black (CCB) content of 3 wt %, honeycomb-distributed wood plastic composite (WPCH-CCB) exhibited superior electrical conductivity at 1.5×10^{-2} S·cm^{-1} and significantly higher EMI shielding effectiveness of 20.2 dB, while in contrast, honeycomb-distributed wood plastic composite by extruder (WPCU-CCB) displayed substantially lower conductivity at 8.3×10^{-14} S·cm^{-1} and a reduced EMI shielding effectiveness of 5.0 dB; furthermore, cone calorimetric analysis indicated that WPCH-CCB presented lower levels of smoke production and heat release when compared to WPCU-CCB.

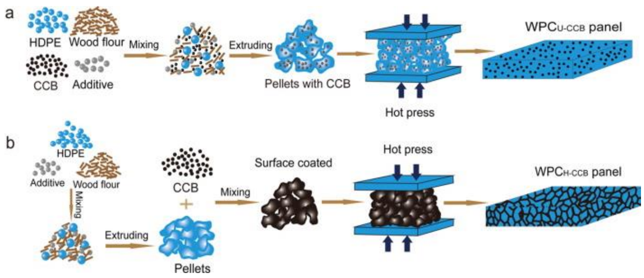

Fig. 2 Fabrication process of the $WPC_{U\text{-}CCB}$ (a) and $WPC_{H\text{-}CCB}$ (b) [16]

Yue et al. [17] studied about the fire resistance of light wood frame walls sheathed with innovative gypsum-particle composite and reported that the gypsum-particle composite (IGP)-sheathed light wood frame (LWF) wall had an obviously improvement in post-fire residual capacity compared to GB and conventional fire-side panel joints led to inferior fire performance of LWF wall. The test setup in which the fire resistance test is performed is given in Fig. 3.

Fig. 3 Vertical fire test furnace [17]

Some fire-retardant polymers were given in Table 1

Table 1. Some fire-retardant polymers [18]

Product	**Flammability**	**limit oxgen concentration (vol%)**
Fluoropolymer	UL-94 V-0	>95
Fluoropolymer films	UL-94 V-0	>95
Fluoro coatings	UL-94 V-0	30~5-
Polymer additives	UL-94 V-0	>75
Fluor elastomer	UL-94 V-0	>75
Coating resins*	UL-94 HB	-

*Measurement value of coating film blended with curing agent

C. *Light board WSP*

Shalbafan et al. [19] studied about the mechanical properties of lightweight foam core sandwich panels and reported that there is a significant correlation between the foam structure (Fig. 4) and the mechanical properties of the panels. The bending strength of the panels prepared at 130 °C was nearly 10 % higher compared to the panels prepared at 160 °C. A significant lower internal bond (IB) was observed for samples produced at the higher pressing temperature.

Fig. 4 lightweight foam core panels [19]

Four strategies for reducing the density of wood-based panels include using low-density wood and plant materials, employing foamed adhesives to create low-density spaces between particles, replacing heavy core materials with hollow structures, and adopting foam core sandwich panels. These approaches offer potential for substituting conventional, denser wood-based panels, particularly in applications where high strength is not a primary requirement. However, the large-scale industrial production of lightweight panels remains a non-routine practice.

Sandwich panel manufacturing traditionally involves batch or continuous processes with limitations, such as the inability to produce all layers simultaneously. However, a novel approach by Luedtke et al. [20] enables the continuous, one-stage production of foam core sandwich panels within existing particleboard production lines, overcoming some of these limitations.

Labans et al. [21] studied about the sandwich panels (Fig. 5) mainly designed for application in lightweight mobile housing and reported that the sandwich alternatives exhibit noteworthy mechanical attributes, boasting a potential increase of up to 42 % in specific stiffness when juxtaposed with solid plywood boards, all while retaining satisfactory strength properties.

Fig. 5 Sandwich panel with plywood face sheets and GF/PP

III. CONCLUSION

In this study, the advantages, disadvantages, usage areas and technological advantages of wooden sandwich panels are mentioned. Especially in the last hundred years, the population growth rate has increased considerably. This increase has had a negative impact on the world ecology.

The increasing amount of consumption due to the increasing human population has also increased the pressure on forests. The need for wood raw material is increasing every year. In order to meet this need, human beings carry out studies such as growing fast-growing tree species, protecting wood products and reusing wood waste. Today, these studies are also insufficient.

In this case, researchers have begun to develop substitute polymers that can be used instead of wood. In these studies, wood was used in the surface layer and low-density, cheap and customizable materials were used in the core layer. This resulting product is called wood sandwich panel (WSP). It is predicted that WSPs will be used more instead of solid wood in the coming century. Studies on WSP will help both protect forests and maintain ecological balance. Studies on this subject should be increased.

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