

A Deep Study on Aluminum Composite Panel: Applications, Merits, and Demerits

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Abstract

In the contemporary world, all engineering and manufacturing industries mainly concentrate on quality metal and manufacturing materials. Some recent research works also focus on designing, manufacturing, simulating, modelling, quality checking, and performance evaluation of composite materials mixing with various metals. Several materials are mixed with multiple metals in a defined ratio to create composites. A large number of composite products are used in our daily life. One of the essential things of human life is houses and buildings. Modern architectural designers use Aluminum composite materials like Aluminum Composite Panels (ACP) in building construction. This paper presents the general information of ACP with various characteristics. Since the ACP is a new technology used in multiple real-time application usages, this paper provides the manufacturing overview of ACP. It presents aluminum composite material sheets, aluminum sheets, and aluminum composite panel manufacturing. The ACP is highly suitable for building construction, car manufacturing, and other necessary productions from the specification and market report.

Keywords: Aluminum Composite Panel, Synthesisation, Characterisation, Composite Materials, Natural Fiber Composites.






Introduction

Metal Matrix Components are highly used in science fields, and the development tends to be increasing over the last decade. This enormous development is because; the metal components have better physical and mechanical properties. Aluminum composite panels are a special type of panel on which two aluminum foil sheets are bonded with a non-aluminum core. The bonding of the aluminum with non-aluminum is for increasing the physical and flexibility of the panel. Aluminum-based metal composites are highly preferred since it possesses the following characteristics. They are: 1) high strength, 2) high thermal conductivity, 3) stiffness to withstand high pressure, and 4) corrosion resistance abilities. Aluminum composites make their entry in all fields such as aerospace, automobile, construction, food packaging, and even household appliances [1]. Many materials are used previously as reinforcements in aluminum composites. Alumina dioxide, silicon carbide, titanium carbide, tungsten carbide, titanium carbide, titanium diboride, and many ceramic composites are used for aluminum reinforcements such as Al₂O₃, SiC, BN, and B₄C. In some cases, waste materials from industries such as red mud, slag, fly ash, waste glass, and dust from arc furnaces are used to replace aluminum composites. An advanced class of enhanced additives has been introduced in science novelty called carbon nanotubes (CNT's), fullerene, and graphene [2].

These panels are mainly used in external cladding or facades of buildings, insulation, and signage. Rather than using aluminum foil with other chemical components, aluminum composites are reinforced with natural fibers. Natural fibers are neither synthetic nor human-made. Natural fibers are extracted from plants and animals [3]. Natural fibers are used in both renewable and non-renewable sources such as oil palm, sisal, flax, and jute. They are used to produce a better composite material, and the composite materials are more effective in reinforcements over the past decade [4]. Natural fibers are more robust than synthetic fibers. Natural reinforced fibers consist of better advantages than synthetic fibers. Natural fibers are more flexible, and they are biodegradable. Natural fibers incorporated with aluminum composites could increase the panel's overall stiffness and strength [5]. Though natural fibers are stronger and they are biodegradable, they do possess some disadvantages. Natural fibers are not chemical fibers, and polymeric structures are absent in natural fibers. A natural fiber contains cellulose, hemicelluloses, lignin, pectin, and other bio substances.

With the presence of such substances, a natural fiber allows moisture absorption from the surrounding. This moisture absorption weakens the bonding between the aluminum and the fiber. The various chemical structures from the aluminum and the natural fibers make the bonding process more challenging. This will cause ineffectual stress while coupling the fiber with the aluminum composites. Combining the natural fibers with the chemical composite requires more changes. Using reagents will bring the necessary modification, bringing the fibers to bond with the chemical substances. After using such reagents, the moisture absorption is abruptly lowered and provides more enhancements between the fiber and the polymer matrix [6]. It is observed that the fibers did lose the hydroxyl groups because of using different chemical components. By reducing the hydrophilic behavior, the fibers will attain their maximum enhancement in physical and mechanical strength. Aluminum composite panels are used in all modern machinery types because people prefer modern technologies and a modern lifestyle.

Table-1. Aluminum Composite Panel and Real-Time Applications

Use of ACP	Proof of Image
<p>Enterprise Company Silver Metallic ACP (ER 102), Metallic Blue Metallic ACP (ER 122), Burma Teak Wooden ACP (ER 372)</p>	
<p>Textile Industry Cement Grey Solid ACP (ER 140)</p>	
<p>Chennai Metro Station Champagen Gold Metallic ACP (ER 104), Lake Blue Solid ACP (ER 106), High Gloss Orange High Gloss ACP (ER 918)</p>	
<p>Residency Bright Silver Metallic ACP (ER 101), Dark Grey Silver Metallic ACP (ER 126)</p>	
<p>GRAND CHETAK HOTEL Off White Solid ACP (ER 112), European Walnut Wooden ACP (ER 375), Rosewood Wooden Texture ACP (ER 710)</p>	

Reinforced aluminum panels are used for building construction purposes. Aluminum composite panels bring more sustainability. Aluminum panels are low in cost with more excellent durability, and it is recyclable. Usage of natural fibers gives less chance is pollution. Aluminum panels are fire-resistant with light-weighted characteristics. The Table-1 shows the applications of ACM and ACP in real time daily life. The paper's contribution is that it explains the manufacturing process of aluminum sheets, aluminum composite materials, and aluminum composite panels. It also describes the specification of the ACP, utilization in real-time human

life, and market details. For understanding the research problem in a better manner, a detailed literature survey was carried out and given below.

Literature Review

The basic key factors of composite material are high strength with low density. While combining the aluminum composites with natural fibers, the ratio of mixing the components and their proportions is important in making anisotropic materials. The main aim of bonding the aluminum composite to a natural fiber is to decrease the weight [7]. Aluminum and its respective alloys such as LM4, LM2, and LM6 are widely used components in many industries. Mainly LM4 is used in industrial applications because this LM4 produces no ferrous elements while compared to previous LM2 [8, 9]. LM4 has good corrosion resistance used primarily as a head in cylindrical type bodies. Using inorganic reinforcements such as oxides, carbides, and nitrides is extraordinarily costly, and they are hazardous. The cost is relatively low in natural mounts such as fly ash from the arc, slag, red mud, etc. Microstructure properties allow the natural fibers to get attached to industrial waste materials [10]. Catalysts are used in oil refineries for breaking the petroleum from crude oil. Catalysts are highly eliminated at the start because of their toxic components and non-biodegradability. Disposal of some triggers has its own environmental regulations from the government side.

Fly ash is a residual from coal combustion, and it is a by-product of flue gas. By using fly ash, low-density reinforcements are available in nuclear power plants' construction [11]. Electric furnace specks of dust are hazardous solid waste that is obtained as a by-product in steel manufacturing. Usage of these specks of dust will lower the cost and gives extra protection in the manufacturing process [12]. Slag is also a waste material from the steel manufacturing process. Slag could be reused throughout the year. Powdered metallurgy is used in manufacturing aluminum slag composites [13]. This gives a significant result in its strength in aluminum composites.

Previous researches are done on aluminum reinforced waste glass. It is noted that the strength and durability of the aluminum reinforced waste glass is relatively higher [14]. Authors [15] researched the usage of aluminum composites with the waste products from the mines. It also results in improved strength of the component. Graphene oxide is used as an anti-corrosive layer. It prevents corrosion, especially in aluminum composites. The corrosion resistance property is due to carboxyl groups with many advantages such as wettability and dispersibility [16]. The name graphene suggests the honeycomb structure, and it is wrapped into thin sheets or stacked as laminates [17]. Aluminum composites with graphene oxide provide more corrosion resistance, and it could help in improving the binding quality [18]. The mechanical and the chemical composition of the GO are to assist in the bonding process. Particular research is taken by using epoxy resin in construction industries. This method gives the reusability function in industrial wastes. The wastes from construction sides are reinforced with aluminum composites [19]. The elasticity of the product is increased while using natural fiber materials with aluminum composites. The reinforced metal components have improved flexibility, which is helpful in industrial areas [20]. Using a special aluminum alloy called LM6 is used for developing a composite material. By using this alloy with the natural, the thermal stability is increased concerning corrosion.

From the above review of the studies, it is obtained that aluminum composites are one of the highly demanding materials in recent days due to their power of use. Some of the contemporary researchers stated that aluminum with natural fiber composites could improve various electromagnetic and physical behavior. This paper motivated me to analyze the aluminum composite material, such as aluminum composite panels, since they are used in various higher-end real-time applications.

Production Process of ACP

Many manufacturing industries for ACP manufacturing follows several processes. Following the composite methods of core plastic panels folded by aluminum panels on both sides. They are categorized into two methods as cold and thermal composite methods. Again, it has been divided into continuous and intermittent composite methods. In the production method, ACP is, initially, the aluminum coil is cleaned.

Cleaning Process

During the aluminum coil production, the surface is coated with anti-oxidants and lubricants. Next, it attaches some dirt during the transportation, affecting its adhesion, and needs to be cleaned. It is called chemical treatment. After applying the chemical treatment, a dense chemical film is formed on the surface to do protection. This chemical film increases the oxidation resistance of the aluminum coil. It helps to increase the lifetime of the color film.

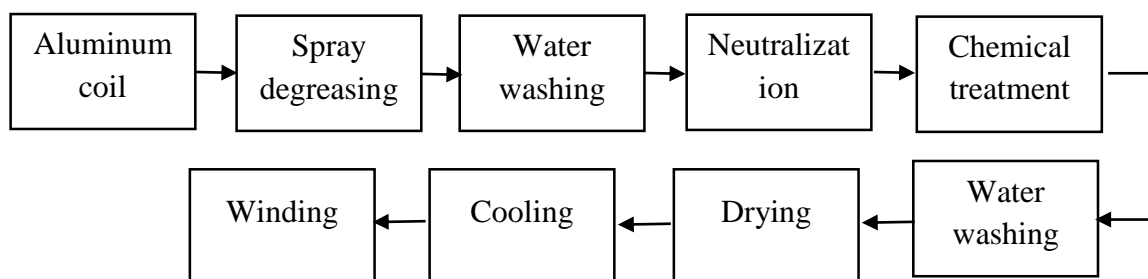


Figure-1. The General Process of Aluminum Coil

Coating Process

After cleaning the aluminum coil, the coating process is done using a coater. The coater is a high-power fluorocarbon resin coated on the outside surface of the aluminum coil. In the coating process, fluorocarbon coating is applied on the aluminum composite panels. The external surface of the ACP is coated with two layers using paint and primer. The final (topmost) coating is a weather-resistant coating called polyvinylidene fluoride (PVDF). The PVDF has an outstanding UV resistance, protects the surface from environmental pollution, and maintains the aluminum coil's beautiful look and feel.

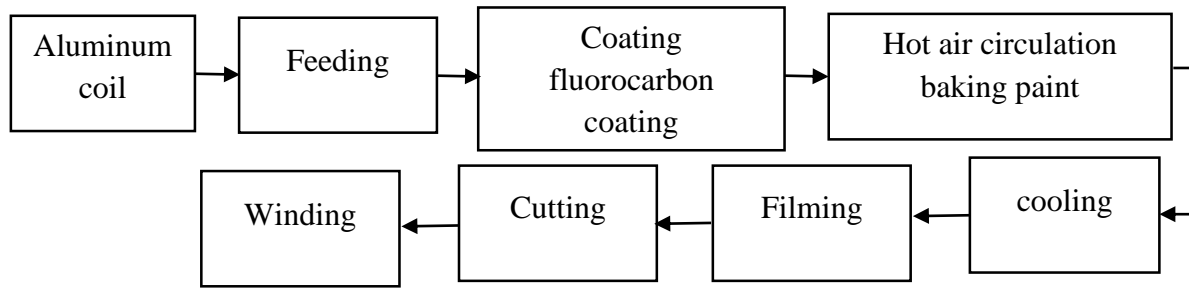


Figure-2. Coating Process of the Aluminum Coil

The surface of the ACP has the color of the metal along with wonderful marble patterns. The fluorocarbon coating is coated on the aluminum coil using a roll-coat method, and try them by backing at high temperature. The coating process is continuously carried out on the equipment production by priming, top-coating, and final coating with surface polish repeatedly. Thus, the thickness of all the layer paint becomes **30 μ m**. Every layer of the paint is baked at **200°C** for **60** seconds to dry. After baking, it is immediately cooled using an air cooler. The wall paint is made of polyester resin, epoxy resin, and acrylic resin. After the primer, top-coat, and surface polish coatings, a PE protection film is applied on the coating surface to avoid any scratches on the surface during continuous process, transportation, and installation. Since the film attached for protection is self-adhesive, it can be removed after installation.

The coating of an aluminum coil with fluorocarbon provides a compound including plastic core materials. The plastic core material comprises three layers. Among the three layers, one is PE plastic in the center and adhesive on both side layers. Then all the three layers are extruded with one another, including the structure of adhesive is delivered. Combine the lower and upper aluminum sheets. On both sides, **0.15mm** thick aluminum sheets are attached. The thickness of the core layer is **3mm to 5mm**. The total thickness is **4mm to 6mm**. Finally, the specification of ACP is **1220mm x 2440mm**.

Aluminum Composite Sheets

Manufacturing aluminum sheet is not an easy job. The largest industries are manufacturing aluminum composite sheets using the most powerful machine. All the devices are arranged in flexible layout methods for the automatic manufacturing process. Aluminum sheets are initially mixed (dipped) into plastic sheets. On one side of manufacturing, plastic sheets are rolled out and joined with the aluminum sheets after melting the plastic by spraying the hottest air. While spraying the hottest air or water most desirable plastic sheet, it got melted and pasted on the aluminum sheet. Both the sheets are feed into punching rollers and compressed with a heavy load in cooling condition. Based on the load, both plastic mixed aluminum sheets are produced.

In some cases, instead of plastic, any other fiber contents or natural fibers are mixed. According to the thickness, the fiber materials are stuffed in the center, place between two aluminum sheets on both sides, compress with a heavy load. Most of the time, the composite materials are mixed with the metal under raised temperature and cooling. It makes the bonding heavy among the metals and materials. The aluminum composite sheet manufacturing with plastic mixing is shown in Figure-3.

Aluminum Composite Panels

Once the aluminum composite sheets are ready, then it is easy to make the aluminum composite panels. One kind of manufacturing process of ACP using natural fibers is illustrated in Figure-4. In this ACP manufacturing, two aluminum composite sheets covering a composite material-based structural material and compressed into a sheet. Finally, the quality of the panel sheet is examined by various machines, shown in Figure-4. The quality analysis verifies the strength, strangeness, flexibility, etc.



Figure-3. Manufacturing Aluminum Sheets

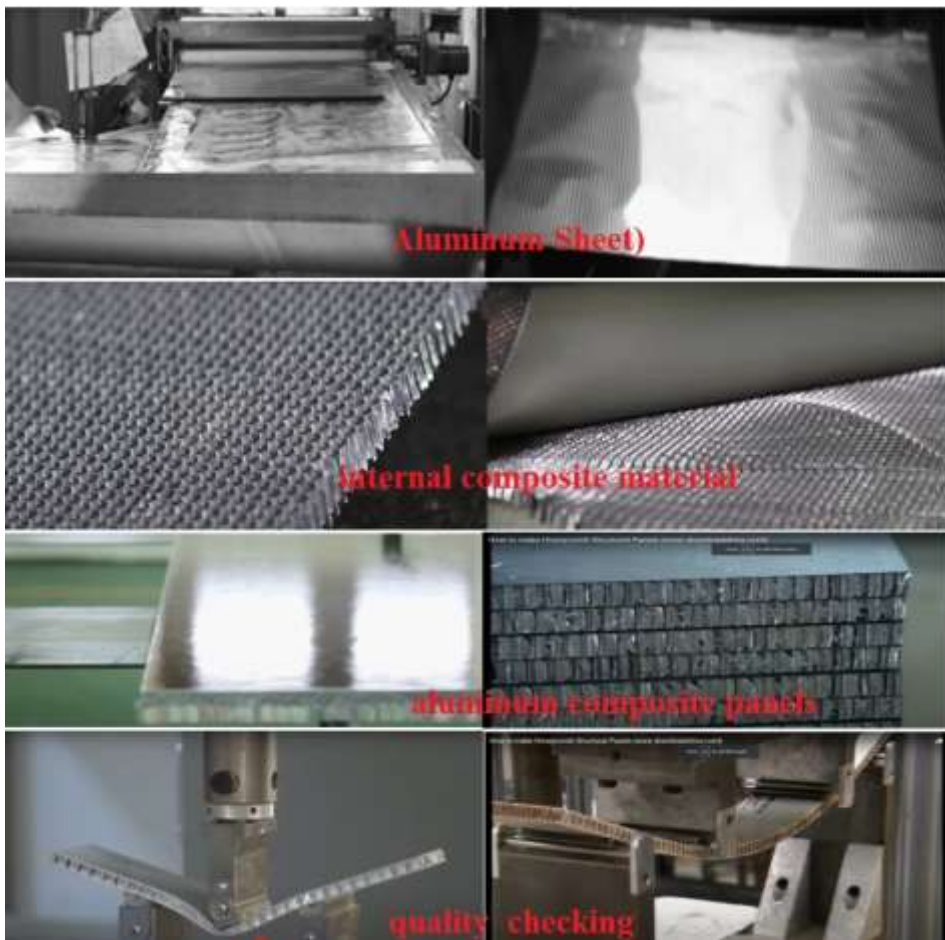


Figure-4. Manufacturing Aluminum Composite Panels

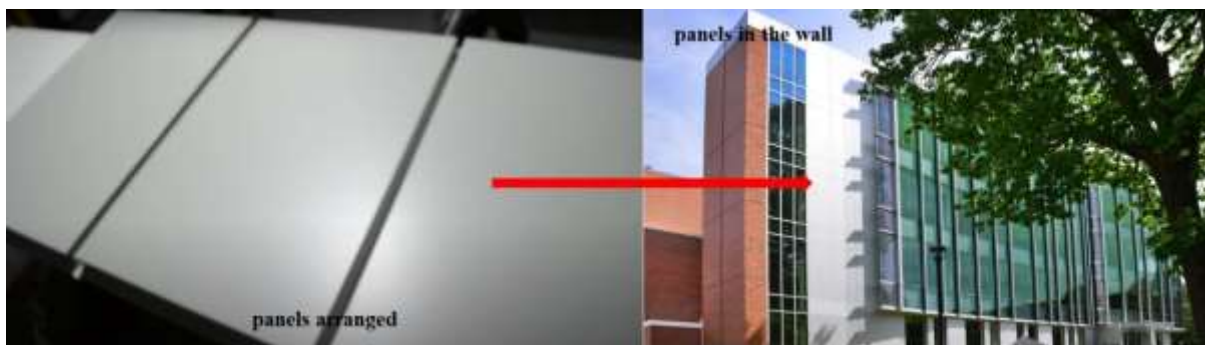


Figure-5. AC Panels arranged and Deployed on the Building Wall

In the earlier works, the ACP has various cores. According to the usage, the central core is decided. In certain types of ACP, the cores are FR, honeycomb, and PE. The PE model has >30% of polyethylene. Thus, it is not efficient in terms of fireproof. Also, not applicable for specific places like hotels, kitchens, and high-rise buildings. Whereas in the FR model, the portion of polyethylene is 10% only. Thus, it can be used for fire resistance. Fire-retardant materials are mainly suitable for exterior use. FR models are also used in various applications where really need fire safety. But the honeycomb models do not have polyethylene, but an aluminum-based honeycomb core is used. Aluminum is also an FR core. Thus, it improves the high quality and is in high demand. ACP panels are used in building facades to enhance the beauty and price of the building. The PVDF coating in the ACP provides more comfortable by avoiding dust. The ACP thickness is set up from 2mm to 10mm and is considered one of the best building materials. ACP melts at above 700°C only, where this temperature reached after 15 to 20 minutes in the fired location. Even in critical situations, people come out of the building before reaching the highest temperature.

It is already discussed that in ACP manufacturing, plastic and metals are used to make this product durable. The shape of the ACP cannot change because it is highly resistant unless the climate very worst. ACP doesn't lose its quality in terms of paint. Various real-time industries have already proved it. The lifetime of the ACP is 40 years in a harsh situation. The ACP's overall specification is used in building as decorative material; the panel size is created from 2mm-10mm is given in the following table.

After manufacturing the ACP as a product, the specification is given below. ACP has comprised of several layers of composite materials. The upper and lower layer of the panel is a pure aluminum alloy sheet. The central layer includes a non-toxic, protective layer based lesser density PE core board in any required shape from 2mm to 16mm. One of the models, KYNAR500 PVDF, adopted for the surface coating for outdoor and PE coated indoors. The standard and basic information about the ACP is given in Table-2. The specification of the ACP product details is provided in Table-3.

Table-2. Basic Information

Information	Explanation
Model number	2mm to 16mm
Maximum width	1590mm to 1630mm
Coating	>25um PVDF coating
Common size	1220mm x 2440mm
Maximum length	5900mm, can be loaded easily to 20ft
Application usage	Outdoor
Specification	Common size
Panel thickness	4mm
Aluminum thickness	0.5mm

ACP Sign Board

Another essential use of ACP is signboard manufacturing. Like the ACP in the outdoor or exterior decoration of building walls, ACP in signboard also has upper and lower ACP with various thicknesses. The thickness of the anti-rust aluminum sheet is not lesser than 0.2mm. The total thickness of the board is not lesser than 4mm. In the signboard panel, fluorocarbon or polyethylene coating is used. Some of the construction technologies used in the ACP signboard are line of discharge, connectors of the fixed frame, fixed frame, installation of the ACP. The specification of the ACP signboard is given in Table-4. A sample aluminum composite panel signboard is shown in Figure-6. The ACP signboard illustrates the size, shape, installation, color, and another look and feel.



Figure-6. ACP Sign Board

Table-3. Product Specification

Properties	Value
Width	1000mm, 1220mm, 1250mm, 1500mm, 1550mm, 1570mm/ As per the need
Length	2440mm, 3200mm, 4000mm, 5000mm, 5800mm / As per the need
Total thickness	2mm, 3mm, 4mm, 5mm, 6mm, 8mm, 10mm, 12mm
Aluminum thickness	0.21mm, 0.25mm, 0.3mm, 0.35mm, 0.4mm, 0.45mm, 0.5mm / as per the need
Inner core	Non-toxic PE core, half unbreakable, unbreakable, virgin LDPE, FR core
Color and Finishing	More colors are suitable and attractive. Some of them are solid, metallic, brush, mirror, marble wooden and glossy.
Brand	Aluminum
Coatings	PE, PVDF, NANO, Anti-Scratch
OEM / ODM	Yes, acceptable.

Table-4. Specifications of ACP Sign Board

Properties	Values
Aluminum skin thickness	0.04mm-0.21mm
Total panel thickness	3mm (for signage) Width: 1000mm, 1200mm, 1220mm (regular), 1250mm, 1500mm, 1550mm, 1575mm, 2000mm (maximum)
Length	Up to 11500mm
Standard size	1220mm (Width) ×2440mm (Length)

Final ACP Products Available in the Market

In the latest market, compound aluminum composite panels are available readily. It has a thermoplastic major of low-density polyethylene, binding with two aluminum sheets. The aluminum sheets are attached with the chemical pasting method under high temperatures. The sheet is coated with high-performance polyester coating, wax-free, and protected with a removable masking layer. The ACP specification (which is referred to from "wieland.com") from the final product in the market is given in Table-5 and Table-6.

Table-5. Specification of the Final ACP Product

Alloy	Aluminum Thickness	Skin	Composite thickness	Standard width	Customized width	Length
3003	0.005, 0.008, 0.012, and 0.020"		3mm, 6mm, and 4mm upon request	48" 60"	It can be customized based on the application	96" 120" and 144"

Table-6. Final ACP Products Available in the Market

Product Type	Thickness	Metal
Value Panel	0.005" thickness	Aluminum sheet
Sign Panel	0.008" thickness	Aluminum skinned sheet
X-12 Premium Sign Panel	0.12" thickness	Aluminum skinned sheet

Conclusion

The main objective of this paper is to analyze the necessary information about aluminum composite panels with specifications. It provides a detailed literature review where most of the studies insisted that ACP is one of the major elements used in major real-time applications as building construction. According to the features and usage in various applications, the ACP panels are ordered frequently and chosen with the required features. In addition to that, AC panels are fire-resistant and therefore used in popular architectural facades. Most popular Government buildings, higher offices, IT companies, and shopping malls are using ACM panels worldwide. Thus, the ACM panel becomes one of the most popular and essential components in building construction. Thus, it is concluded and advised that ACP is highly suitable for buildings.

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