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İÇİNDEKİLER

Chapter 13

THE ARCHITECTURAL USE OF ALUMINUM IN 21ST CENTURY

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1. Introduction

New requirements have arisen for advanced structures. These requirements lead architects to make energy-efficient and ecological designs. This new change in the 21st century creates new developments in architecture and construction techniques. Modern architecture should be human friendly. If the development in building materials is well understood, it becomes easier to make designs with aesthetics, durability, longevity, recyclability, and low carbon emission in addition to modernism in architecture. However, there are not many building materials available that can meet these expectations of architects.

Few building materials are available that respect the natural environment and are suitable for responsible use of natural resources. There are important expectations from the lands and the construction sector in terms of sustainability. At the same time, building materials should be useful. For example, high strength building materials that are easily available, easy to assemble, and can be produced in complex shapes are more preferred (Biedrońska, J., Misiołek W. Z. 2009).

Extruded profiles, which have a wide variety of uses in architecture, have superior properties that cannot be found in other building materials. Among these features, there is also the production of aluminum in many geometric ways. Aluminum structures have more common design options than steel structures. This flexibility and diversity in manufacturing and design made aluminum even more preferred in the 21st century. Again, mounting options such as welding bonding and mechanical joining, which cannot be applied in every building material, are among the superior properties of aluminum. Recently, researchers are even more concerned with the history of aluminum, which started to take its place in the construction industry in the last century (Bojęś A 2006).

The use of aluminum in the door and window joinery; It started in Poland and western Europe before World War II. In the 1950s and early 1960s, aluminum began to be used together with glass and composite plates, especially on building facades. This development played an important role in the development of energy-efficient lightweight building facades. This new technology has provided the potential to bring aesthetics to the fore in architecture. These characteristic facades are common in 1950s American architecture. Over the years, there have been different trends for the use of aluminum in architecture to increase or decrease. The main reasons for these trends are generally the cost of aluminum as well as the application cost during the manufacturing process on the construction site (Tobin J. 1996).

Aluminum producers need to increase their dialogue with the architectural and construction industries. The purpose of this book chapter is not only to discuss how much we have learned and applied aluminum in the 21st century but also to discuss alternative opportunities for aluminum as a structural and decorative material in architecture. There is a new attraction in architecture that creates new opportunities for aluminum and aluminum profiles. Significant developments in architectural design create an opportunity for new aluminum products to emerge. Close cooperation between the aluminum industry, particularly aluminum manufacturers and architects, can significantly contribute to both groups. Regarding the scientific developments for the use of aluminum in architecture, we can say that education has an important role in both the architecture and engineering/ design communities. We need to warn the Aluminum community about potential possibilities in an architectural design known as green architecture, or particularly about the possibilities known as the LEED (Leadership in Energy and Environmental Design) Green Building Rating System® in the USA (URL-1; Biedrońska J. and Misiołek W. Z 2008).

The reason why aluminum has become widely used and popular in the last century is its strength and versatility. Aluminum can be described as a revolution not only in architecture but also in other leading industries in the last century. Aluminum alloys were not used for structural purposes before. It was generally used for decorative purposes. The reason for this may be that it can be easily shaped and polished.

For this reason, aluminum was used for decorative purposes in the Empire State Building, which was built in the early 20th century and became the tallest building in the world for many years. It is generally preferred to be used in window joinery, elevator doors, and decorative strips. Other uses of aluminum in the 20th century can be listed as gutters, roofing, panels, and other decorations.

The biggest reason why aluminum was not preferred in the building sector in the last century was its cost. However, there were some technological developments in the production of aluminum. Therefore, the production cost has decreased by approximately 80%. Aluminum, which has started to be preferred in structural applications due to the decrease in cost, has found new application areas.

In the 21st century, aluminum began to be widely used in architecture, door and window joinery, roof and facade cladding, canopies, balustrades, and divider walls.

Aluminum, which was not popular in the past, continued to push the boundaries until the 21st century. Modern aluminum alloys, for example, can easily support the weight of heavy glass openings. Thus, it can

maximize the amount of natural light to buildings. The combination of glass and aluminum frames in skyscrapers pushes the boundaries around the world due to their superior properties. In addition to achieving gravity-defying shapes, aluminum frames allow the design and build of buildings that are taller, more energy-efficient, and with significantly reduced CO2 emissions than ever before.

Aluminum window frames and facade covering are extremely resistant to any corrosion that the weather can create, including acid rain, and will not be damaged by cleaning products. Besides, unlike wooden or PVC-U frames, aluminum window frames do not swell, crack, split or bend over the years due to moisture and heat, regardless of the weather. Aluminum is a cheaper alternative to wood. Time and money can be saved in maintenance. With the right glass options, aluminum windows have good thermal performance.

The reason for the worldwide popularity and strength of aluminum's building and construction materials is that it is low in cost compared to its quality, it is environmentally sensitive, and allows the most important architectural designs in the world to be realized. These superior properties of the material play a key role. Due to the flexibility that aluminum provides in the design, customers may demand light streaks, bright colors, or wavy surfaces. New aluminum production technologies have the potential to best meet the requirements of the building industry. As we mentioned before, it is also possible to achieve these unique designs in an environmentally friendly and affordable way.

The most vital in any commercial building or residence is fire protection. Only fireproof architectural products can be used in buildings over 20 meters in height, according to international standards. However, regardless of the height of the building, these fire resistance requirements apply in all cases, especially in public buildings (such as hospitals, kindergartens, schools, hotels, train stations, and airports). A1 is the largest non-flammability class. Some aluminum building materials are not only fire-resistant but also have the highest A1 rating according to the worldwide non-combastibility standards (DIN EN 13501; DIN 4102-20; 96/603/EC).

2. Suitable characteristics of aluminum for architecture

Aluminum alloys are highly valued for their lightweight, easy shape, and environmental friendliness. One of the primary reasons why aluminum is invaluable for architectural purposes is its extremely high weight/ strength ratio. For this reason, wide glass openings, a common feature of skyscrapers, are made possible by aluminum. It is also fire resistant and has some other physical properties that make this material safer than other building materials.

Aluminum is different from other building materials with its stylish appearance. With developing technology, it is possible to have a variety of products in which different metallic colors and brightness are obtained. Aluminum, which can also be used structurally, manages to attract the attention of designers with its excellent formability. One of the reasons why aluminum has started to be preferred in the modern architecture of the 21st century is its durability. Due to the natural anodizing property of aluminum, it is much higher against corrosion than other metals. Compared to other building materials, it is resistant to all weather conditions and is not affected by harsh climatic conditions. Since it is long-lasting and its maintenance cost is low.

Aluminum's wide application variety in buildings and its excellent performance even in the most challenging conditions have pushed the limits of what is possible by enabling architects to take great steps in design in the last century.

3. How aluminum changed architecture?

Since its widespread emergence in the early 20th century, aluminum has been a revolutionary driving force in modern architecture. It is strong, lightweight, durable, endlessly recyclable, corrosion-resistant, and can be transformed into almost any other traditional structure such as aluminum, brick or wood realizes what its materials cannot do in architecture.

4. The manufacturing process and technical properties of aluminum

The basic components of bauxite (Al2O32H2O) are used in the production of aluminum in architecture and industry. Bauxite contains hydrated aluminum oxides and some silica and iron. There are also aluminum ores other than bauxite. Some of these are corundum, kaolin or china clay, and chrysolite. The ore is first purified by Bayer's process and then reduced to aluminum in two stages by Hall Hiroult's process. In the first stage, roasting, grinding, heating (with sodium hydrate), and filtering are used to convert bauxite to alumina. It is then shaken for several hours at 1000 °C to precipitate the hydrate which has been separated, washed, and calcined. In the next step, aluminum is extracted by electrolysis of alumina in a molten crystallite bath (a fluoride consisting of alumina and sodium). Aluminum is shiny metal and has a silver-white color. Aluminum is malleable, less ductile than copper, but superior to zinc, tin, and lead. Aluminum is a very light, soft, strong, and durable metal. It has low thermal conductivity but is a good conductor of electricity. Aluminum can be riveted and welded, unfortunately not soldering. Aluminum is a harder material than tin. The tempering degree is 350 °C. Tensile strength is 117.2 N/mm^2 in the form of casting, but 241.3 N/mm^2 when pulled on wires. Its

melting point is 657 °C. Aluminum is known to be resistant to nitric acid, dissolving slowly in concentrated sulfuric acid and soluble in hydrochloric acid. It is not affected by carbonic acid, carbonic oxide, sulfur, vinegar, seawater, and the like at normal temperature. However, it is rapidly eroded by caustic alkalis (Duggal, S. K. 2008).

5. The use of aluminum

Since pure aluminum is very soft, it is not suitable for structural purposes. Copper, manganese, zinc, silicon, nickel must be alloyed with aluminum to obtain structurally satisfactory properties. Aluminum is the most suitable material for making roof and facade systems, door and window frames, balustrades, and corrugated sheets. Since aluminum sheets are resistant to corrosion, they can be used on doors to prevent rotting in bathrooms and stamp them in various ways. It consists of aluminum alloys, angle brackets, channels, I-sections, round and rectangular pipes, rivets, and bolts. Besides, aluminum powder is used in paint production. Aluminum is used in internal combustion engines and aircraft. Also, kitchen utensils and medicine, chocolate, etc. It is also widely used in the production of packaging (Duggal, S. K. 2008).

There are some obstacles to the use of aluminum in architecture. We can explain these obstacles as follows. Considering that aluminum with lower hardness is three times lighter than steel, part of the price difference can be compensated. However, it is known that the price of aluminum is about three times the price of steel. They are resistant to architects working with new methods of production and construction of plans that require industrial buildings rather than manufacturing. For this reason, it is increasingly difficult for aluminum to stay out of building material. As it is the most delicate material on architectural objects, producers must have sufficient knowledge of artistic form, technical and technological physical properties. Working with aluminum requires precision and punctuality of details and an understanding of construction physics. In other words, the application of aluminum on architectural objects is not based on any improvised repair or additional repair and intervention that is nothing that is considered “normal” in manufacturing or traditional construction. Another reason is the traditional resistance of some architects to all sorts of new things and materials and in this case aluminum. So what is the state of aluminum and its application in architecture? It seems that the three reasons mentioned above are slowly being overcome. When architects know aluminum at least as much as they know about concrete or steel, we can say that the possibilities for shaping aluminum will increase further and its intensive application in architecture is possible (Dunovski. V. and Balkoski, D. 2016).

The basic and usual material for a window for a long time was wood and natural stones. In time, human beings have started to use metal constructions, and today light metal constructions and polyvinyl chloride (PVC). It has many advantages, especially if profiled aluminum constructions are used for large windows. The most outstanding properties of aluminum are durability and resistance to deformation caused by external factors (Dunovski. V. and Balkoski, D. 2016).

Due to the superior properties, we have mentioned, aluminum is widely used in many sectors. The main sectors are transportation, electricity, packaging and food industries, and architecture. Aluminum is a metal building material that offers both environmental and economic advantages due to its recyclable feature. Recyclability and environmental awareness are among the most important parameters in terms of sustainability. For this reason, it is a valuable building material in terms of sustainability. As it is known, the commercial use of aluminum started at the end of the 19th century. It was used in some applications in the construction industry in the 20th century, and today it continues to grow rapidly with the development of aluminum alloys. As a result, aluminum can be considered culturally a symbol of modernity in architectural design. Technological breakthroughs and economic growth have taken place in the 21st century. This development in technology has allowed aluminum to be used in new applications by going beyond its traditional use. New options such as the use of nanorods, 3D printing, composite materials, aerospace, and biomedical devices are among the current applications of aluminum.

The use of aluminum is expected to increase significantly in the 21st century. This is due to aluminum's excellent structural and aesthetic characteristics, significant scrap value, and accelerated global production, as well as a growing recycling market. The use of aluminum will continue to be a part of our daily life for centuries. Therefore, with the increase in aluminum production and consumption, it is necessary to minimize the negative environmental side effects related to the technological developments in aluminum production. At the same time, it can be said that additional research and development studies will be needed to create more technological innovations in the coming years (Ashkenazi, D. (2019).

The discovery of new materials and the development of new technologies has not only irreversibly changed humanity's cultures since ancient times but also affected our environment. The term "material of past cultures" is often used in archaeological studies, focusing on ancient objects as evidence of past civilizations (Hurcombe, 2014).

Material Culture, the materials used, consumption habits and purchasing, the use of altered items, work tools, the trade of artifacts, the trade of household goods, and the relationships between civilizations and

their physical objects (objects), including the interpretation of objects, rituals and individuals using the objects, and surrounding buildings represent the relationships between. These physical objects on our planet reflect the society in which we live, the social status of man, and therefore material culture prevails in our world. Innovation, which is based on technological breakthroughs, shows itself as a dynamic process that produces economic growth and social benefits, although it changes over time (Hekkert et al., 2007; Li et al., 2018).

In order to achieve technological sustainability in the 21st century, social changes such as new regulations and industrial networks are inevitable (Hekkert et al., 2007).

6. Aluminum pergola/canopy application examples

6.1. Example I

The example I is a sliding glass system with a thin aluminum frame, double glazed panel. The system is made of minimally designed thin-framed aluminum profiles and is particularly suitable for large-area applications. It is completed with aesthetic and ergonomic accessories that perfectly fit into modern architectural living spaces.

The system has a silent and easy sliding movement and the sliding panels in a single row can be moved horizontally in one direction or parallel to both directions. Pergola applications are shown in Fig. 1. a, b, c.

Figure 1. a, b, c. Pergola and lighting application (URL-2)

6.2. Example II

Example II is an aluminum bioclimatic system that expands the usage options of outdoor living spaces with its high performance and allows you to provide climate control in all weather conditions thanks to its adjustable angled lamellae. An innovative concept, a practical and modern touch added to outdoor living spaces in example II. Pergola and lighting application examples are displayed in Fig. 2. a, b.

Figure 2. a, b. Pergola and lighting application example (URL-2)

6.3. Example III

Example III special architectural model is designed to provide stylish solutions for every project. Architectural models provide a suitable solution for every request with different mounting and carrier shapes. Canopy example is displayed in Fig. 3. a. b.

Figure 3. a. b. Canopy example (URL-2)

Due to the architectural requirements, the need for entrance cover in various forms and sizes arises. These types of eaves, canopies, etc. designs created by using materials of very different qualities are worked on specific to the project.

6.4. Custom built to fit your application.

Perfection Canopy Systems provide long-lasting protection from the elements while harmonizing with nearly any architectural and site design. The extruded aluminum systems resonate quality and value from any angle (URL-3).

6.5. Canopy design made easy

To design an aluminum canopy; the substructure configuration, width, and height must be measured first, then column and beam dimensions must be selected. Then the required spacing between the sub-structure has to be selected, then the foundation style has to be decided, a deck profile has to be chosen and finally, a finish has to be chosen. A canopy example is displayed in Fig. 4.

Figure 4. A canopy example (URL-3)

7. Aluminum joinery systems

Aluminum joinery hinged window and door frames are quite common as systems used in living spaces. The expected features of these systems can be listed as the ability to feel the external environment sound at a minimum level in the space, to take the needed daylight into the environment, and to offer a comfortable use, especially the thermal insulation and air-water sealing performance. Hinged systems are very rich in terms of usage options and they have many aesthetically oriented additional solutions such as hidden sash windows and flush doors, as well as standard uses such as inward and outward opening door-window, double-axis, transom, pivot.

7.1. Aluminum automatic sliding doors

Nowadays, doors should be functional, fast, aesthetically easy to open and close without any problems while providing entry and exit to spaces and offer aesthetics, comfort, and prestige together. The most important reason why automatic sliding doors are preferred is the air conditioning feature; In this way, automatic doors provide heat savings in winter and protect the indoor air in summer.

7.2. Why can aluminum window frames be used outdoors?

Aluminum window frames and facade covering are extremely resistant to any corrosion that the weather can create, including acid rain, and will not be damaged by cleaning products. Besides, unlike wooden or PVC-U frames, aluminum window frames do not swell, crack, split or bend over the years due to moisture and heat, regardless of the weather. Aluminum is a cheaper alternative to wood. Time and money can be saved in maintenance. With the right glass options, aluminum windows have good thermal performance.

7.3. Heat insulated aluminum door and window joinery system

The aluminum window and door system, which adds visual appeal to your building with its unique line and reduces your energy consumption by 60% with its high thermal insulation, can fulfill most architectural expectations with its wide range of application options. The windows and doors are enriched with new options and the joinery system brings along application and assembly facilities. The heat-insulated aluminum joinery system is shown in Fig. 5.

Figure 5. Heat insulated aluminum door and window joinery system (URL-4)

8. Aluminum divider walls

Today, interior partitions of modern offices are formed by various types of interior partition systems with aluminum carriers. Offices, which are formed in a blank way, provide a more transparent working environment and gain importance in terms of architecture.

9. Aluminum mesh cladding systems

Aluminum mesh cladding systems are generally applied for visual purposes in fire stairways or sunshades on the covered facade. Depending on the project, it can be different colors, patterns, and sizes of pore gaps. Expanded metal products are resistant to the external environment and are an excellent facade cladding material.

It also represents an important decorative value in facade claddings. Architects can create their unique styles with our unlimited facade designs, with different colors and designs in our products, and thus differentiate them.

Aesthetic touches that shape metal are important in the construction and building industry. In this way, artistic structures emerge. However, another important issue is the materials used in construction and buildings. As the variety of materials increases, much more modern and comfortable structures emerge. While mesh is among the important elements used in the construction industry, it is also an important material for the industry.

9.1. What are its highlights?

It is known as mesh expanded, which is used as a building material in the construction industry. This product is obtained by cutting and expanding. It has an important use in the construction industry. In terms of having a decorative structure, it is a product that is used in many architectural and industrial areas.

9.2. Other important features of the mesh standard product

- The size of the product can be extended as far as the selected eye range and the grid allow.

- Mesh Standard can be produced from materials such as Aluminum, Stainless Steel, and Copper.

- Various eye range options are available. These range options can start from 6 × 10 mm dimensions up to 50 × 115 mm.

- In metal mesh production, the width is maximum 3 meters. (URL-5)

REFERENCES

Ashkenazi, D. (2019). How aluminum changed the world: A metallurgical revolution through technological and cultural perspectives. Technological Forecasting & Social Change 143 101–113

Biedrońska, J., Misiołek W. Z. (2009) Application of aluminum in "green" architecture – today and tomorrow. Architecture Civil Engineering Environment. The Silesian University of Technology No. 1

Bojęś A. (2006). Aluminium in architecture as material, technique and aesthetics. Świat Aluminium, 5/2006

Hurcombe, L. (2014). Archaeological Artefacts as Material Culture. Routledge, NY.

Biedrońska J. , Misiołek W. Z. (2008). The Role and Use of Aluminum in "Green" Architecture. Proceedings of the Ninth International Aluminum Extrusion Technology Seminar ET '08, Orlando, FL, USA, 13-16 May 2008, Vol.I, p.649-656

DIN EN 13501 (2018). Fire classification of construction products and building elements - Part 1: Classification using data from reaction to fire tests; English version EN 13501-1

DIN 4102-20 (2017). Fire behaviour of building materials and buildıng components - part 20: complementary verification for the assessment of the fire behaviour of external wall claddings

Duggal, S. K. (2008). Building Materials, New Age international Publishers. New Delhi

96/603/EC (1996). Commission Decision of 4 October 1996 establishing the list of products belonging to Classes A 'No contribution to fire' provided for in Decision 94/611/EC implementing Article 20 of Council Directive 89/106/EEC on construction products

Dunovski. V. and Balkoski, D. (2016.) Development of Aluminum in Architecture Int.

Hekkert, M.P., Suurs, R.A., Negro, S.O., Kuhlmann, S., Smits, R.E., (2007). Functions of innovation systems: a new approach for analysing technological change. Technol.

Hurcombe, L. (2014). Archaeological Artefacts as Material Culture. Routledge, NY.Journal of Engineering Research and Applications.

Li, M., Porter, A.L., Suominen, A., (2018). Insights into relationships between disruptive technology/innovation and emerging technology: a bibliometric perspective. Technol. Forecast. Soc. Chang. 129, 285–296.

Tobin J. (1996) An Architect's Perspective on Aluminum. Proceedings of the ET '96 Seminar, Chicago, IL, USA, vol.2, 263-265

URL-1 Green Building Rating System®. www.usgbc.org. Accessed date 10.12.2020

URL-2 Suntech Unique Outdoor life. http://www.albayrak.com/urunler/index.html Accessed date 10.12.2020

URL-3. Perfection Architectural Systems. LLC an AVAdeck Company http://www.perfectionarch.com/products/flat-canopy.php. Accessed date 10.12.2020

URL-4: http://www.elipsyapi.com.tr/sistemler.php Accessed date 10.12.2020

URL-5: http://www.sisikaluminyum.com.tr/tr_tr/aluminyum-mesh-kaplama-sistemleri/ Accessed date 10.12.2020