APPLICATION OF ALUMINUM IN "GREEN" ARCHITECTURE – TODAY AND TOMORROW

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Abstract
Architects are facing new challenges due to recent ecological and energy conservation recommendations that are being introduced for the latest buildings. This is a significant change in the approach to building design and construction, which will meet the new building requirements of 21st century. Modern architecture is often described as human-friendly taking full advantage of the properties of construction materials including their durability, esthetics, recyclability and lack of emissivity. There are few structural materials that show these engineering characteristics as well as allow for the responsible use of natural resources while maintaining respect for the natural environment. There are very specific expectations and requirements from the architecture and construction industry regarding this matter. A material of choice must have both high formability and strength, allowing for the production of parts with unique and complex shapes that can be easily and firmly joined together. The joining requirement is especially important due to the need for an assembly of large panels to be used as the building facades. The design of a facade is a very good example of how the physical properties of aluminium are justified in both the design and the final application. In the design and fabrication processes of the energy active glass facades it is very beneficial to use a wide range of extruded aluminum profiles with different geometries and mechanical properties.

Streszczenie
Obecny stan środowiska i zasobów energetycznych, potrzeba ich ochrony i oszczędności, staje się wyzwaniem dla architektów w projektowaniu nowych budynków. Rysuje się znaczna zmiana rzeczywistego podejścia do projektowania i konstruowania budynków, które charakteryzować będą środowisko zbudowane XXI wieku. Nowoczesne budownictwo określane jako przyjazne człowiekowi zmierza do wykorzystywania właściwości materiałów budowlanych charakteryzujących się takimi cechami jak: wytrzymałość, estetyka, bezemisyjność w procesie produkcji i eksploatacji a także materiałów, które nadają się do powtórnego wykorzystania. Istnieją materiały o strukturze i konstrukcji wykazujące powyższe cechy a zarazem zapewniają odpowiedzialne wykorzystanie bogactw naturalnych w poszanowaniu środowiska naturalnego. Architektura i przemysł budowlany formułuje bardzo konkretne oczekiwania i wymogi. Dostosowany do tych wymagań materiał o specyficznych własnościach fizykalnych musi posiadać nieograniczone możliwości formowania i łączenia elementów w dowolne kształty, co jest niewątpliwą zaletą w kształtowaniu konstrukcji i pokrycia fasad. Konstrukcja fasady jest polem, na którym właściwości aluminium znajdują uzasadnienie w zastosowaniu. Szeroki zakres aluminiowych profili systemowych odpowiada wymaganiom założeń ekologicznych w projektowaniu przeszklonych fasad – aktywnych energetycznie.

Keywords: **„Green" architecture; Sustainable architecture; Energy conservation; Energy efficiency; Environmental concerns; Aluminum application; Aluminum facades.**

1. INTRODUCTION

The extruded profiles manufactured from aluminum and its alloys present wide range of geometrical shapes with unique physical properties, which makes the aluminum structures superior to those made from commonly used steel. The architectural and building community have embraced the aluminum shapes due to their design and fabrication flexibility in terms of geometrical and metallurgical changes. Industry has also embraced their ability to provide easy assembly using well established techniques such as welding, mechanical or adhesive joining. Research groups are very familiar with the use of aluminum in architecture and construction as well as with the history of aluminum application in this field [1]. The first applications of aluminum took place before the Second World War in Western Europe as well as in Poland in the form of aluminum doors, windows and wall siding [2]. In the 1950s and early 1960s these aluminum elements combined together with glass and composite plates, which started playing additional roles as structured elements of the building facades. This development allowed for an introduction of new building technologies potentially providing novel architecture aesthetics combined with more energy efficient lightweight wall facades. These very characteristic facades are typical for American architecture of the 1950s.

Over the years there were different trends calling for the increase or decrease of aluminum usage in architecture often linked to the cost of aluminum as well as to the cost of its application during the fabrication process on the construction site. John Tobin presented a very important and informative paper at ET '96 [3] informing the engineering and aluminum extrusion community, why he as an architect and university professor, would like to see much more information on structured material such as aluminum alloys before they can be used. He also compared the very limited information available to the architects on aluminum to those widely available on steel and timber. However, it is necessary to mention that there have been more internal publications prepared to disseminate information regarding aluminum extrusions in architecture [4]. What is still a problem is lack of more open dialogue of aluminum producers with architecture and construction industries. The purpose of this paper is not to judge how much we have learned and applied since 1996 but to discuss new opportunities for aluminum as a structural and a decorative material in architecture. There is a new pulling force creating new opportunities for aluminum and aluminum profiles in architecture. With the significant changes taking place in architectural design there is an opportunity for new aluminum products to emerge. Close collaboration among the aluminum industry, especially aluminum extrusion and architects, can greatly benefit both groups. There is also a significant role for education in both the architectural and engineering/design communities regarding these new opportunities. We need to alert the aluminum community about the potential prospects in the architectural design known as green architecture or specifically in the US what is known as the LEED (Leadership in Energy and Environmental Design) Green Building Rating System® [5],[6].

2. ENERGY NEEDS, ENVIRONMENTAL CONCERNS AND ENERGY EFFICIENCY METHODS

The environmental concerns, mainly focused on possible global climate changes, have been attracting a great deal of attention and have posed new challenges worldwide in recent years. For example, the numbers representing energy consumption for buildings in the European Union (EU) are as high as 35-40%, which are responsible for 40-45% of the carbon dioxide emissions. According to global statistics the existing infrastructure consisting mainly of buildings and transportation systems consumes approximately 75% of the world's energy. About three billion tons, which represents around 40% of raw materials, are used in building construction annually. Even more alarming is the fact that 20-26% of landfill waste comes from building construction, renovation and demolition [8-11]. The data for year 2005 for the environmental impact of the commercial and residential buildings in the US is represented by the following set of numbers [11]:

- 65.2% of total electricity consumption
- 36% of total primary energy use
- 30% of total greenhouse gas emissions
- 136 million tons of construction and demolition waste (approximately 1.3 kg/person/day)
- 12% of potable water.

Various methods for evaluating energy efficiency within buildings were developed in the 1990's. The British evaluation method known as BREEAM was developed in 1990 and is the most commonly used method today. BREEAM or Building Research Establishment Environmental Assessment Method has been widely accepted for the evaluation of commercial buildings, mainly the office structures. In the UK alone this method is used for about 20% of new office buildings, mostly because of the requests from investors or from the companies renting these dwellings. In London the percentage of evaluated real estate is up to 50%. The BREEAM system has been used as a foundation for the similar system developed in Canada in 1992 known as BREEAM Canada as well as the BEEPAC developed in 1994. In the United States of America the US Green Building Council introduced an independent system in 1998 under the name of The Leadership in Energy and Environmental Design (LEED). Both the federal government and the private sector represented by construction companies support this program. Other evaluation methods, which have been developed using the Life Cycle Assessment for particular building design and construction, have been proposed. Among them are ECO QUANTUM (The Netherlands), ECO-PRO (Germany), ESCALE and EQUER (France), ECOEFFECT Sweden, ECO-PROFILE Norway and ATHENA (Canada). An equivalent body was formed in Poland in 1994 called the National Energy Conservation Agency (NECA), which operates under the directives of the Union's Guideline 2002/91/EC of the European Parliament and European Council. These regulations were introduced in December 2002 and are focused on the energy efficiency of buildings. A group of experts from Poland including the NECA president Aleksander Panek have been very involved in the activities focused on the application of sustainable building environment since 1997. A methodology of evaluation of the influence of a building on environment, known as the Green Building Challenge has been developing parallel to this task. The goal of the NECA is to prepare a set of the guidelines for building design guaranteeing their limited impact on the environment [7].

3. GREEN BUILDING DESIGNS

The energy crisis in the mid 1970s forced improvements in building standards and practices in terms of reduction of energy consumption, improved thermal insulation to better control heat losses and gains, as well as displayed data of equipment efficiency. It is very common to use an integrated system of heating, ventilation and air conditioning (HVAC) for year-round indoor control of temperature, humidity, and air quality in both commercial and residential structures in the US. Because of the associated costs of the relatively high-energy consumption of the HVAC system, and its application in general, building design is constantly being re-evaluated. Very often the generic term "bioclimatic" is also used in description of the "sustainable or ecological architecture" which mainly refers to passive and/or hybrid, lower-energy design principles. [11-16]

The terms green building and green architecture are very often replaced by other terms such as sustainable buildings or sustainable architecture. The green buildings are described as constructions which are sensitive to the environment, resources and energy consumption, and which provide comfortable and safe indoor space for occupants. The impact on people regarding the quality and healthiness of work environment are also an integral part of this new approach. It is important to keep the financing part of this equation therefore the architects must be aware of cost-effectiveness measured by cost-return point of view. Additionally, this new policy is seen as a part of broader global issues such as climate change and ground water recharge.

Everything starts with the future owners having the necessary knowledge and the vision of green building followed by the ability to work with an integrated design team, which can make the dream a green reality. However, it is also necessary to find a construction team educated in green architecture, which is capable of understanding the design and constructing the building. In the Integrated Design the goal, according to B. Wilson [12], is to achieve higher performance at lower cost by creating an environment in which construction disciplines such as general architecture, HVAC, lighting and electrical, interior design and landscape design are integrated within the design and construction throughout the entire process. As a result the synergistic benefits can only be achieved through such collaboration.

The main assumptions of the European guidelines regarding the building energy efficiency in the year 2020 presented in Green Paper on Energy Efficiency are as follows [17]:

- Accomplish 22% energy savings in buildings on heating, air conditioning, hot water and lightning
- Double contribution of the renewable sources of energy from 6 to 12% in general energy use in Europe
- Increase an input from ecological sources of electrical energy from 14 to 22% in total use of electricity

These assumptions are used to develop common methodology for all the parameters influencing energy use for all types of buildings including residential and office buildings, as well as facilities for education. This approach would be consistent with the role of the LEED methodology present in the US. What is common for the above-mentioned approaches is the fact that they do impose the requirements for further improvement of the building energy efficiency for all players in the construction and real estate industries.

These findings need to be understood not only by architects but also by engineering staff in aluminum companies so that all are well educated about the potential gains and are ready to join the Green Architecture discussion and design new aluminum intensive buildings.

4. THE ROLE OF ALUMINUM IN GREEN ARCHITECTURE

As mentioned before the "Green Architecture" is another term commonly used as an equivalent to the sustainable architecture. The fact that the alloys perfectly match the material requirement in Green Architecture described as *the use o safe materials with a "closed life cycle" that allows reuse or recycling, must be encouraged* [8] is the most important fact for aluminum producers. Additionally aluminum alloys perfectly meet all of the requirements for non-toxic and recyclable building materials. More education regarding the cost of producing aluminum is necessary due to the fact that this material while recycled is very attractive from an energy conversion point of view. However, when the initial cost of producing aluminum form bauxite is concerned it appears to be very cost prohibitive. It is critical to stress aluminum's potential for reuse and recycling, as well as the importance of reducing energy costs.

The use of aluminum alloys has been continuously growing throughout last 20 to 30 years. The "Aluminum Now" journal of the Aluminum Association has published a number of papers presenting the use of aluminum alloys and composites by leading architects. The physical and chemical characteristics as well as the environmental advantages of aluminum make it a prime candidate for new designs and engineering solutions for Green Architecture [8]. Among material characteristics the most important for architects are:

- Inherently safe material due to its non-toxicity, non-magnetic and incombustible nature
- Very low maintenance due to long service life
- Ability to improve aluminum strength and durability through alloying
- High strength-to-weight ratio makes it very attractive structural material
- Good thermal conductivity makes it attractive material for easing the problems related to "heat island effects" from building materials
- High reflectivity and low emissivity are important for solar radiation control
- High workability of aluminum in many forms (rolled, cast, extruded) and ability to weld it makes it a very attractive material to be processed on the construction site
- Ability to anodize or paint aluminum provides various decorative and aesthetic possibilities.

Equally important are the environmental advantages of aluminum, which are of significant importance in today's Green Architecture.

- Aluminum can be recycled many, many times using only 5% of energy required for its primary production with electrolysis. Today, about 40% of aluminum is recycled
- Due to the low weight of aluminum, the energy, transportation and application costs are minimized
- Because of recycling aluminum reduces amount of building material waste and landfill use.

5. ALUMINUM FACADES

The discussion regarding the role of aluminum in Green Architecture can be summarized through the production of new products leading to new requirements for materials and manufacturing processes creating new business opportunities. An example of such new opportunities for aluminum composite panels as well as aluminum extrusions is the new generation of facades in buildings. This new development was stimulated, or in some cases forced, in Europe by the European Union regulations referring to the energy performance of buildings [14, 15, 18]. The main goal is to achieve 50% of the energy savings compared with today's building envelope. This will be achieved by: reduction of heating and cooling energy, use of natural ventilation and daylight, improved occupant comfort and ergonomics through life cycle analysis and smoke control, and sustainability of the architectural construction. The use of opaque components made from recycled aluminum as well as the use of solar energy (passive via glass and active via photovoltaic) will significantly reduce energy consumption. A more controversial decision is to eliminate air conditioning systems being that it could be very impractical in certain climates. This illustrates how the proposed idea must be customized for any particular country to operate efficiently and effectively.

Generally aluminum has a large role to play in allowing these new designs to reduce energy use during building construction and to provide improved comfort and better control of temperature and natural lightning while functioning more ecologically. Because of the provided flexibility in terms of the design and fabrication, cost efficiency, simplicity and safety the aluminum alloys are perfect candidates of extrusions and rolled panels for these applications. Some technical solutions are using aluminum alloys or aluminum matrix composites panels' cladded on the both sides of the up to 4 mm polymer core to provide improved insulation. It is necessary to promote functional designs that guarantee significant reduction of the energy demand involving functional glass as well as blinds and shades incorporated together with panels into facades. The concept of double skin facade presented in Figure 1-2 is especially promising.

Figure 1-2. Examples of double skin facedes

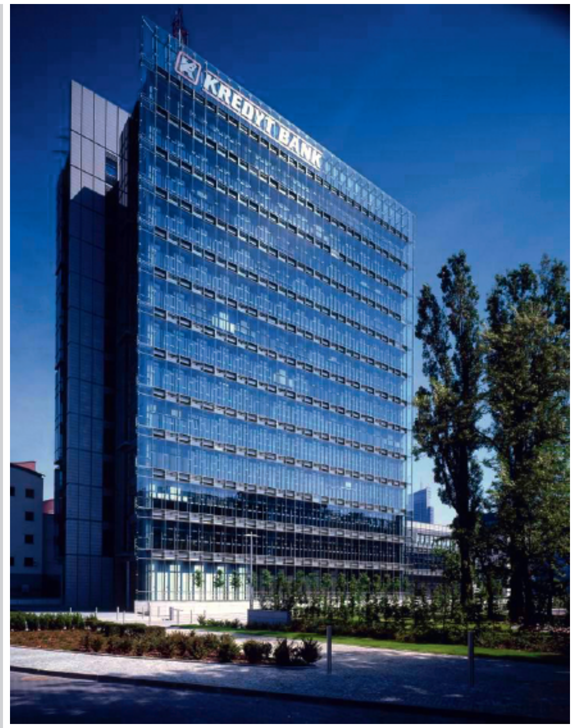

Figure 2.
An example of double-skin facade, office of Kredyt Bank in Warsaw, Poland (the author's (JB) photograph)

Figure 1.
An example of double-skin facade, office building, Berlin, Germany (the author's (JB) photograph)

The double skin facade can provide significantly improved sound insulation, as well as heat exchange control through the possibility of ventilating the building naturally. It also provides additional protection for more sophisticated and more efficient shading systems. There are different engineering solutions such as double skin facade or double skin window, which can also be beneficial. It is sufficient to say that significant improvements in temperature distribution can be achieved using various techniques including the computer-controlled ventilation systems [18, 19]. The authors would like to make a point that Green Architecture is a fact of life in Europe today and will become more and more popular worldwide. Therefore, it is in the best interest of the aluminum extrusion industry to take an aggressive approach and collaborate with architects, glass engineers, and the construction industry to educate society about the benefits of this new trend and to become prepared for this new challenge that lies ahead.

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