1AL21 **Aluminum Fenestration for Use in Building Envelopes**

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AZON USA INC. • ALUMINUM EXTRUDERS COUNCIL

Presented at: 2005 National Manufacturing Week Conference • Chicago, IL, March 7, 2004

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ABSTRACT

The manufacturers of fenestration products (windows and doors) for use in a building envelope have many materials to choose from to produce their products. This paper discusses the use of aluminum with a structural thermal barrier as the material of choice for fenestration worldwide. It will offer fundamental facts about aluminum for commercial and residential applications. The structural longevity and design flexibility of such products is discussed. Data will be provided which illustrates the ability to meet energy codes required for the architectural building industry. Comparison studies are also given on various types of systems that can be used for insulating aluminum windows and doors.

Industry Overview

Aluminum is one of two of the most abundant materials found in the earth's crust. Bauxite, the base raw material for the production of aluminum, has an almost inexhaustible state of supply. Bauxite, is easily removed, transported and processed in the process of manufacturing aluminum. Over 60 percent of the energy used to extract bauxite is generated from environmentally friendly sources, such as hydropower. Since its inception, aluminum has become one of the most widely used materials in the manufacturing segment of the world's economy. Regardless of how aluminum is used, or measured in quantity and value, its use exceeds that of any other metal except iron. It has been produced in commercial quantities for over a century, and is a key contributor in virtually all segments of the world economy. Aluminum is utilized in almost every industry in the world, transportation (airplanes, auto, marine, bridges), packaging (cans, foil), durables (appliances, HVAC, cooking utensils), electrical components, equipment, food, and all facets of building and construction. Extruded aluminum products discussed in this presentation are used primarily in the following market segments;

- Transportation – trains, planes, automobiles, bridges, railings
- Engineered products – appliances, HVAC, agriculture
- Building and construction – windows, doors, skylights, roofing, walls,

Extruded industry segments use close to 4 billion pounds of aluminum per year—and its widespread use is ever increasing. The amount of growth has been dependent on the industry that is focusing, or even discovering the use of aluminum at any particular time. For example, lighter, more fuel-efficient vehicles are required in today's energy conscious world. The use of aluminum in automobiles has grown over 200 percent in the last 10 years, and 300 percent in the sport utility and truck market during that same time period. It has been rediscovered in this market that aluminum achieves the end goal of strength in conjunction with lighter weight. The use of aluminum in engineered products has always been strong and grows continually. Aluminum usage in construction grows along with the building industry and within each sector. The construction market grows about 5 percent to 10 percent per year, while it continues to find new and innovative ways to use Aluminum in the building envelop more uses for the material grows.

As material science evolves, there are revolutions within industry sectors, these are historically cyclical in nature. New and innovative products are continually introduced to the market. Aluminum—especially extruded aluminum—might be perceived as an old industry. It is a relatively simple process that has been in existence for more than a century, without dramatic change—strong evidence that says a lot about the material. Aluminum is lightweight, yet strong, it is malleable, ductile, easily machined and cast, has excellent corrosion resistance, durability and highly recyclable. New materials attempt to replicate the market success of extruded aluminum, especially in the construction industry. These new materials, from chemical blends to composites, strive to be as strong, lightweight and other similar attributes as aluminum, yet they miss the mark.

Why a revolution now? For most, conservation, in all forms, is the theme in construction. A return to aluminum products is somewhat an historical revolution. Extruded aluminum is one of the highest consumers of energy during its manufacturing process, of all building materials currently utilized. However, its end use, in every market it serves, results in the most energy efficient, green products available. Consider, in automobiles alone, every pound of aluminum that replaces the weight of two pounds of steel, saves 20 pounds of C02 being released into the ozone layers. (To the consumer, it is 3 more miles per gallon in our autos). Having said that it is an energy consuming production process, the industry has cut its emissions in half since 1990, and continues to dramatically reduce the energy required in the production process. It must be kept in mind that this initial energy use is rapidly offset by savings in use and recycling of the product as will be realized further in this document.

Building and Construction

Building and construction consumes the highest poundage of extruded aluminum of the three mentioned industry segments. This industry, consisting mostly of windows, doors, store fronts, skylights and curtain walls, utilizes aluminum as the main component in use today for all building envelopes and facades. This paper will delve into the benefits for the use of aluminum in this industry and thus the prevalence in the specification of aluminum in the production of the entire building envelope.

Strength and Durability

Aluminum has been described as revolutionizing the airline industry, it can also be said that of the building envelope design industry. Aluminum has one of the highest strength to weight ratios of all materials used in industry. In its original state, aluminum is an inorganic, homogeneous material. Aluminum is more than 7 time more rigid than wood and more than 23 times more rigid than vinyl. These properties are extremely important in window, door and building envelope fabrication. Another way to express this is in deflection limits under loads. Aluminum far exceeds other materials in its ability to withstand wind loads under high-rise edifice applications or in regions prone to hurricanes and typhoons.

Aluminum is an extremely stable construction material. It is immune to any climatic effects that it is subjected to. Organic materials, such as wood, require impregnation and coating to resist degradation. Wood and wood composites can be twisted or warped and change dimensions under stress and inclement climatic conditions. Vinyl, (PVC, Poly Vinyl Chloride), is a blend of chemicals that require plasticizers, coloring agents and lubricants. This can make it prone to change, (expansion and contraction with the elements), and deterioration over time. PVC expands and contracts 2.6 times more than aluminum. In contrast to these materials, aluminum is inorganic and one of the most stable construction materials available. It does not absorb moisture or support mold growth, it does not swell, shrink, split crack or rust. Climate and temperature extremes have no effect on aluminum. Other materials are prone to rot, become brittle or soft, and will change in shape and design with weather and time. Aluminum maintains its extruded form and rigidity so as not to allow for frame deformation due to climate and building movement or weathering over time. Windows and doors remain operable and reliable throughout the life of the building.

Design, Production, Protection

Architects and specifiers are more often being asked to duplicate or replicate historical designs, or designs that are unique and somewhat a departure from the everyday door and window design. Aluminum offers unlimited possibilities in design. It can be extruded in any shape specified and is limited only by the imagination of the designer. Aluminum, being extremely strong and malleable can be extruded into any shape and form. A simple die alteration is all that is needed to allow the designer freedom in putting the architects' vision into reality. Window shapes can be extruded to duplicate any previous design and new idea, including narrow sight lines, large openings; that do not require any special reinforcements or unsightly structural supports. Aluminum is able to support large lites that allow the architect to bring the outdoors in, and offer dramatic views from both interior and exterior motifs. Large glazed openings allow the architect to utilize natural lighting for occupancy comfort and energy savings.

The structural characteristics of aluminum make it the only material feasible to meet and exceed new building codes requiring safety and security. Today's building codes now require that windows and doors be able to offer blast, hurricane and intrusion protection for the occupants. Aluminum by its very nature has the impact and deflection capabilities to withstand these rigorous tests and still offer beauty and comfort for the occupants. Security features of a material like aluminum are inherent. Along with the ability of the product to withstand natural forces, it also has the ability to offer the occupant security from forced entry, that other materials have difficulty offering. Even over time, it simply does not deteriorate or change shape to allow easy access of intrusion. Aluminum is one of the few construction materials able to withstand heat and fire for longer periods of time. It does not sustain fire or emit deadly gases during combustion.

Fit, Finish, Maintenance

Color can add many attractive accents to buildings and homes that make it unique and appealing. Because of its "locked" together molecules and its homogeneous state, aluminum cannot absorb moisture or promote growth of any kind on its surface. Thus it provides an ideal finish base for an unlimited variety of finish applications. Any finish applied becomes permanent in comparison to other construction materials finishes. This is most difficult to state with wood, and although slightly more permanent for PVC or other composite materials, climatic conditions and ultraviolet rays can phase alter surfaces impregnated with colors. With aluminum as the application base, almost any finish can be securely and permanently applied, with UV protection inherent in the finish. The variability of paints and anodic finishes to aluminum allow the specifier to depict any color or color combination that the imagination can dream.

The array of finishes also allows the building to be finished in a product exactly suited for the environment it must withstand. The many varied paint application techniques and anodic type of finishes offer 20 plus year warranties on fading or chalking of the finish regardless of the environment. Thus, maintenance is eliminated. The fit and finish of the fenestration product remains as new over the life of the building.

Energy Efficiency

In the beginning of this paper, we mentioned that the initial production of aluminum consumes a high amount of energy. However, there are many aspects of energy efficiency that one must look at when deciding a construction material of choice. Today, more than ever, energy conservation, green house gas emission, green building techniques and cradle to cradle construction, are important considerations for the architectural community when specifying materials.

One of the most important aspects of energy efficient products is recycling. It is the most important component of cradle-to-cradle construction and energy conservation. Aluminum is one of the most recycled materials in use today. When aluminum is recycled and reproduced, it returns to its original state with all properties as originally produced, in tact. About 65 percent of America's aluminum is being recycled today, and this number grows daily. Producing aluminum from recycled components requires less than five percent of the energy originally used to produce the product from bauxite ore. This fact alone reduces the energy impact on the overall production and use of aluminum to be one of the most energy efficient products that can be utilized in construction. With utilizing only a fraction of its original energy requirements for re-production, aluminum far exceeds all other products in energy efficiency. The National Fenestration Rating Council (NFRC) provides tools—either through uniform guidelines for independent testing or computer simulations—enabling manufacturers to quickly judge the efficiency of their materials within their products lines.

Aluminum is a highly conductive material meaning it will rapidly transfer exterior climatic temperatures through itself unless something is done to prevent energy loss. This is the single and only drawback of aluminum and we will demonstrate, it is simply a misconception. Code bodies such as the US Department of Energy's ENERGY STAR program, the Model Energy Code (MEC) and the International Energy Code Council (IECC) are driving u-factor ratings for windows and doors to levels that are a challenge for all framing materials to meet, but certainly not impossible.

The aluminum construction industry began addressing the issue of its thermal transmittance with the energy crisis in the early 1970s. The development of thermal barriers for aluminum frames began this process in earnest. With today's thermal barriers, an aluminum window product has the capability to meet the thermal

requirements that the end use consumers demand, and that the code officials are requiring.

Preventing Energy Loss

Windows lose heat through several avenues including glazing, conduction through frames and especially with air infiltration through componetry and around the frame as shown in figure 1. Beginning with the frame, today's thermal barrier products allow for the separation of the frame to which a non-conductive material is installed that stops the transfer of temperatures into and out of the building. This insulating thermal barrier material allows the aluminum frame to be as energy efficient as competing framing material without compromising the structural benefits of the frame. Thermal barriers are not all identical; the use of a thermal barrier requires the aluminum to become a composite. It is important that the proper thermal barrier product is utilized. The composite aluminum profile should retain over 95 percent of its original structural capabilities to maintain its superior structural performance. The proper thermal barrier will allow it to far exceed other materials and maintain its ability to withstand blast and hurricane conditions. From there, today's effective materials for glass, glazing, weather stripping all allow the aluminum window and door to meet all of the thermal and energy efficiency challenges in the market.

It is important to note the thermal performance of all framing materials is quite similar at the time of installation. A requirement of energy consumption with windows and doors is longevity. A thermally efficient product must maintain constant efficiency throughout its lifespan and aluminum does just that. The fit and ability to maintain structural properties in all climatic conditions gives aluminum long term energy performance over most other materials that will lose much of their efficiency as time progresses.

Strength, durability, thermal performance, long-term durability and conservation of raw material resources, make aluminum the most specified, beneficial and widely used materials on earth. Compared to PVC, a synthetic made from petroleum or wood, a natural resource that is sometimes difficult to keep consistent due its vulnerability to the elements, aluminum has no equal.

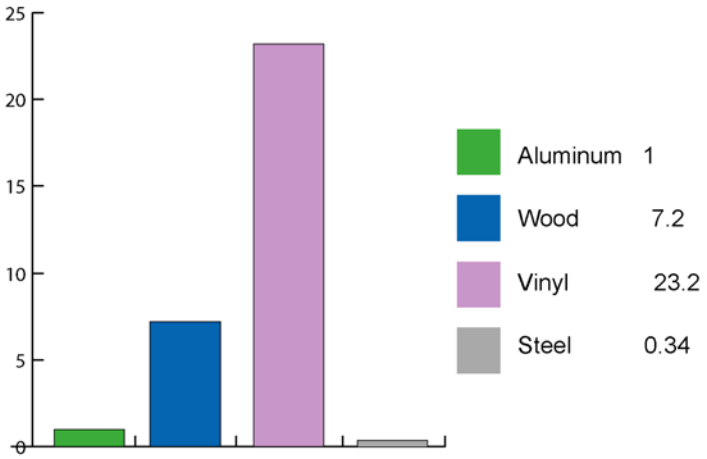


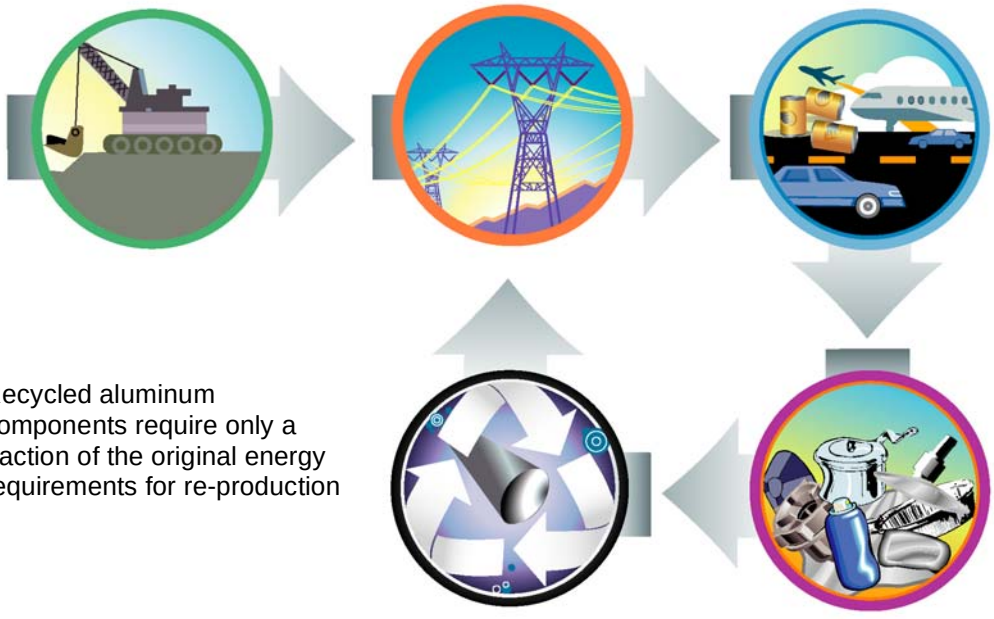
Figure 1:
Deflection Under Load

When subjected to the same load, vinyl will deflect 23.2 times *more* than aluminum

Wood will deflect 7.2 *more* than aluminum

Steel deflect *less* than all material by 2/3

Figure 2:
Life Cycle of Aluminum



Recycled aluminum components require only a fraction of the original energy requirements for re-production

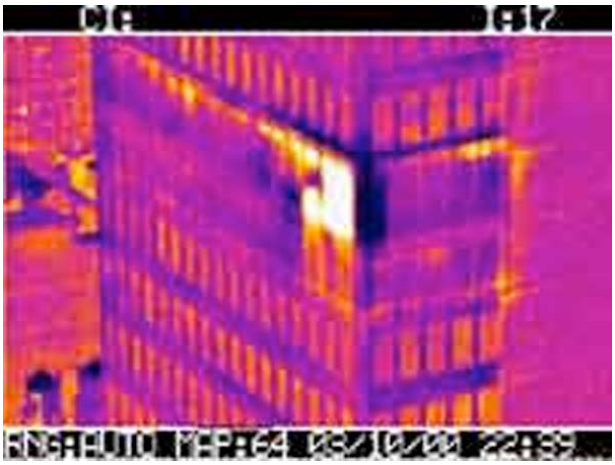


Figure 3:
Thermography

Thermography depicting energy leaking from a defective opening in the building envelope.

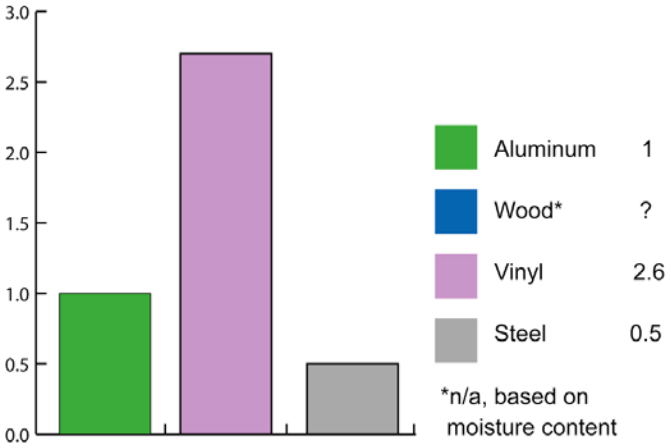


Figure 4:
Thermal Expansion

Expansion and contraction of vinyl is 2.6 times more than aluminum.

Steel expands and contract .5 times *less* than aluminum.

60-inch material at 10 degree Fahrenheit change.

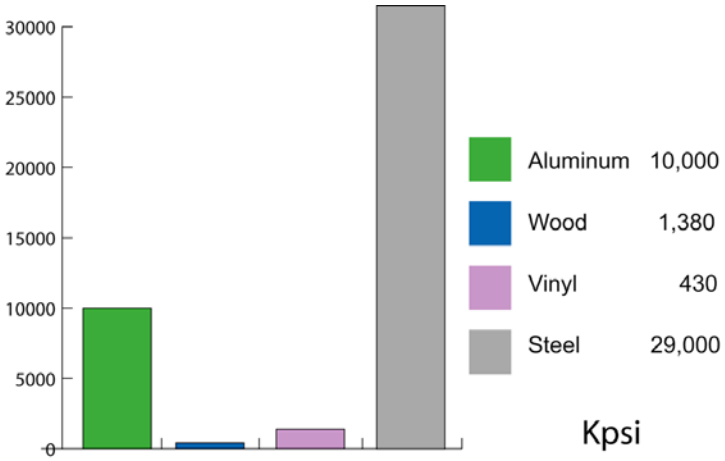


Figure 5:
Modulus of Elasticity

The higher the E-Value, the greater the resistance to deformation or bending.

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Links and resources

Extruders Technology for Aluminum Profiles Foundation

http://www.etfoundation.org

Aluminum Association Inc.

http://www.aluminum.org/

U.S Department of Energy. Energy Efficiency and Renewable Energy

http://www.eere.energy.gov/industry/