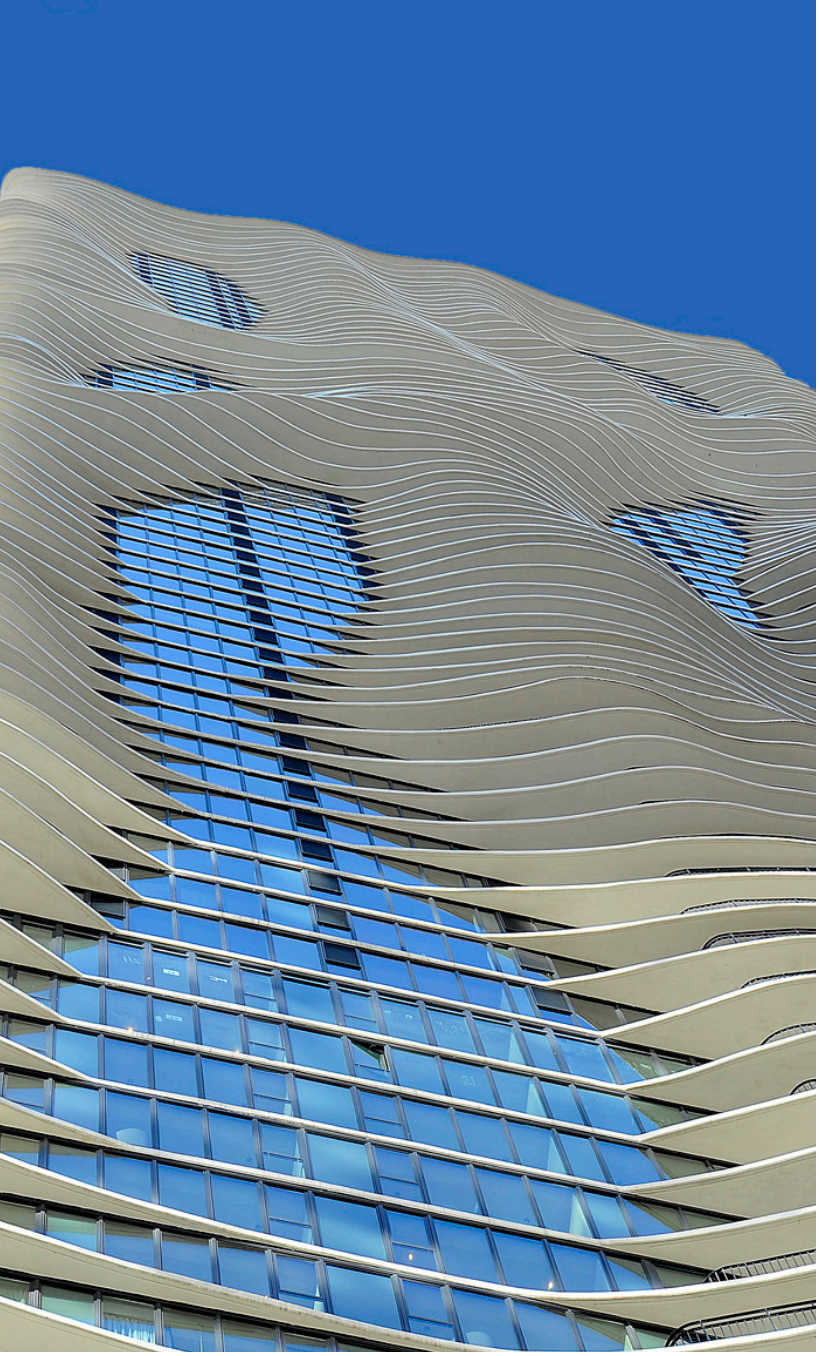
ALUMINUM

The total solution for sustainable, strong and efficient commercial building design



ALUMINUM MARKET SHARE

Aluminum is widely used in both commercial and residential construction in applications such as window and door frames, exterior cladding, storefront, curtain wall, shading devices and skylights. In 2009, according to the Aluminum Association, the building and construction market accounted for 2.13 billion pounds of net aluminum shipments, which represents nearly 12 percent of total shipments and is the third largest North American market for aluminum.

According to the *AAMA/WDMA 2011/2012 Study of the U.S. Market for Windows, Doors and Skylights*, aluminum accounted for 89 percent of the commercial market share in 2011. (See chart below.)

Aluminum frames containing a thermal barrier continue to grow in popularity (47 percent) following the trend of increasing energy efficiency standards. In 2011, the share of aluminum frames without thermal barriers represented approximately 43 percent of the market. Although aluminum frames with thermal barriers were historically used most commonly in northern regions, more stringent energy codes have caused this technology to gain market share across the United States. Thermal barriers are often achieved via use of polyamide insulating strips or polyurethane poured and debridged methods.

Additionally, in 2011, aluminum accounted for nearly 40 percent of the nonresidential entry door market and 24 percent of the nonresidential interior door market. Aluminum framed skylights were the dominant (87 percent) configuration on the market in 2011.

Framing Materials Used in Nonresidential Construction (2011)

Framing Type	Curtain Wall	Storefront	Site Fabricated	Shop Fabricated	Overall
Aluminum	100%	98%	100%	55%	89%
Wood	-	1%	-	20%	5%
Other	-	1%	-	25%	6%

FREEDOM OF DESIGN

Aluminum answers the call. Innovative construction materials and products give architects the scope and ability to implement unconventional solutions in the design and detailing of buildings and other structures. Aluminum extrusions offer a number of benefits relative to alternative materials and processes for the architect during the design stage.

Here are some of the characteristics inherent when designing with aluminum extrusions :

- **Lightweight**: Aluminum is about one-third the weight of iron, steel, copper or brass, making aluminum extrusions easier to handle, less expensive to ship and an attractive material for use in applications where weight reduction is a priority.
- **Strong**: Aluminum extrusions can be made as strong as needed for most applications and, due to the nature of the extrusion process, the strength can be concentrated where it is really needed by including varying wall thicknesses and internal reinforcement in the profile design. Cold-weather applications are particularly well served by extrusions, as aluminum becomes stronger as temperatures fall, and in warm weather applications, aluminum will not warp. Also, aluminum will not rot, peel or flake.

Aluminum extrusions offer a number of benefits relative to alternative materials and processes for the architect during the design stage.

- **High strength-to-weight material**: Aluminum extrusions' unique combination of high strength and low weight makes them ideal for applications like curtain wall, storefront and commercial windows.
- **Resilient**: Aluminum combines strength with flexibility and can flex under loads or spring back from the shock of impact.
- **Corrosion resistant**: Aluminum extrusions offer excellent corrosion resistance. They do not rust, and the aluminum surface is protected by its own naturally occurring oxide film, a protection that can be enhanced by anodizing or other finishing processes.
- **Noncombustible and Nontoxic**: Aluminum does not burn, and even at extremely high temperatures, does not produce toxic fumes.
- **Reflective**: Surface treatments can produce high reflectance on aluminum components, making aluminum extrusion attractive for today's commercial applications.
- **Seamless**: Complex shapes can be realized in one-piece extruded aluminum sections without having to rely on mechanical joining. The resultant profile is typically stronger and less likely to loosen or leak over time

FREEDOM OF DESIGN

- **Easily tailored**: While there are a variety of standard extrusion profiles available, the ability to design a profile to meet specific functional, aesthetic and manufacturability objectives makes aluminum extrusions a preferred element in many product solutions.
- **Quick-to-market**: Tooling for aluminum extrusion is relatively inexpensive and generally has short lead times, which facilitates prototype development, testing and product launch.
- **Easy to fabricate and assemble**: Effective design of aluminum extrusions can greatly simplify subsequent fabrication and assembly, and there are a wide variety of fabrication processes that are routinely employed in the production of extrusion-based components and assemblies.
- **Sustainable**: Aluminum can be recycled infinitely with no degradation of mechanical properties. Aluminum extrusions are often produced with high recycled content— without compromise to aesthetics or functionality. Further, extrusions' inherent properties of light weight, strength and design flexibility leads to significant in-use benefit to the environment.

Aluminum extrusions' unique combination of high strength and low weight makes them ideal for applications like curtain wall, storefront and commercial windows.

FINISHES

Anodizing

Anodizing successfully combines science with nature to create one of the world's most durable metal finishes.

Anodizing is an electrochemical process that thickens and toughens the naturally occurring protective oxide on aluminum. The resulting finish is the second hardest substance known to man, second only to the diamond. This characteristic makes anodized aluminum an excellent choice for use in doors and railings, storefronts, commercial windows and curtain wall where hardness, abrasion resistance, corrosion resistance and UV resistance properties are vital.

Unlike other finishes, anodizing highlights aluminum's metallic appearance. Because it is an integral part of the substrate, the anodic coating results in a hard and durable substance providing excellent wear and abrasion resistance with minimal maintenance. Anodized aluminum can be stripped back to raw aluminum through a traditional etch process and then can be painted or re-anodized. Etching is an important step during the anodizing process. Etching is designed to dissolve a thin layer on the surface of the aluminum to develop a smooth uniform finish. A recent alternative to traditional caustic etching has been introduced , which is typically referred to as "acid etching." This acid etching process is a more eco-friendly etch process. This new etch process creates an aesthetically appealing, "frostier" matte finish that improves the ability to hide small defects, such as extrusion die lines and mild scratches, that may occur on the aluminum surface of architectural products. Although neither conventional caustic nor acid etch removes all irregularities in the aluminum, acid etch does a better job of concealing them. This gives the material a more architecturally desirable, aesthetic finish using either primary or secondary (recycled) billet.

The purpose of anodizing is to form a layer of aluminum oxide that will protect the aluminum beneath it. The aluminum oxide layer has a much higher corrosion and abrasion resistance than raw aluminum. A typical anodized finish used in the architectural industry is called "two-step electrolytic." The actual anodizing and coloring of the aluminum occur in separate steps of the process. The anodizing step takes place in a tank that contains a solution of sulfuric acid and water, while the coloring step takes place in another electrolytic tank.

The benefits of anodizing are many.

- **Value**: Anodizing has a low initial cost, plus low maintenance cost, offering superb life-cycle value.
- **Durability**: Anodizing offers exceptional resistance to abrasion because the anodic oxide is integral to the aluminum substrate; it simply cannot chip or peel.
- **Color Stability**: Anodic oxide is unaffected by ultraviolet light rays and is resistant to salts, making anodizing a colorfast finish that is repeatable and reliable.
- **Maintenance**: Anodized surfaces will not show fingerprints. It resists scratching during value-added processing such as fabrication, installation, cleaning or other handling. Soiled anodized aluminum may be cleaned with simple soap and water.
- **Aesthetics**: Anodizing yields a deep, rich metallic luster and is available in a wide range of gloss and color alternatives.
- **Environmental Safety**: Anodizing is a safe process that is not harmful to human health; it has little environmental impact and anodized aluminum is fully recyclable.

FINISHES

Liquid and Powder Coating

Liquid and powder coating have many chemistry options that allow an almost unlimited color and gloss range as well as cost and performance qualities.

Liquid and powder coating are multistep processes that coat and protect the aluminum. They not only protect the aluminum substrate but can enhance the appearance in many different ways. The process starts with a multistep pretreatment process by cleaning and etching the aluminum then using either a chrome conversion or chromate free pretreatment. This process not only will allow the coatings to adhere to the aluminum but also help to protect the aluminum from corrosion. The cleaning and coating of the aluminum can be used on extrusions that contain both primary and secondary (recycled) billet and will cover many small defects as a result of the extruding process.

Liquid and powder coatings can be applied with technologies to meet all three performance specifications: AAMA 2603, 2604 and 2605.

The process can be anything from a single coat liquid or powder to a four coat PVDF liquid using a primer, barrier coat, color coat and clear. Each of these options has advantages depending on the end use or application. Powder coating provides excellent hardness and mar resistance while liquid can utilize a protective primer and metallic topcoats to achieve many unique appearances. Fluoropolymer systems have been the first choice in the monumental construction curtain wall market for many years and continue to be considered the premier system for this application.

The benefits of painting are many.

- **Durability**: Paint is available in nearly any durability required from extreme corrosion protection of some chemistries to color and gloss stability in others lasting for decades.
- **Color Stability**: Many paint systems have durability that far exceeds the weathering specifications of AAMA 2605 with minimal color change after 10 years.
- **Maintenance**: Minimal maintenance is required with only mild detergent and a clean water rinse to maintain appearance.
- **Aesthetics**: Options are nearly unlimited from white to black, soft muted colors to extremely intense reds, bright silvers to iridescent pearl coats all can be achieved with paint.
- **Environmental Safety**: Painting and powder coating is a safe and environmentally sound process with options ranging from a zero VOC powder to a low VOC liquid. High-performance coating lines use the latest technology to capture and destroy the VOCs, making it a more environmentally friendly process.

THERMAL BARRIERS IN ALUMINUM FENESTRATION SYSTEMS

Although aluminum has a multitude of positive attributes, it also has a relatively high thermal conductivity requiring the incorporation of thermal barrier technology in fenestration systems in many climate zones.

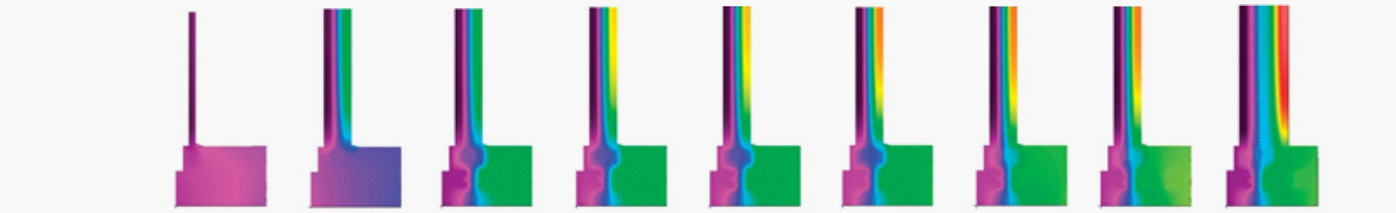
What is a thermal barrier?

Thermal barriers are made from resins that are incorporated into the aluminum profiles, separating the interior and exterior surfaces. These materials have thermal conductivities that are 500-1300 times lower than aluminum thus creating a "thermal barrier" in the profile systems in which they are used. This break in the thermal path is necessary to inhibit cold or hot exterior temperatures from transferring through the aluminum to the inside of the building while maintaining the structural integrity of the aluminum profiles. While originally used in colder northern climates, thermal barriers are equally important in hot climates to reduce heat transfer in air-conditioned buildings.

Thermal Barrier Attributes

1. Thermal barriers reduce heat loss or heat gain through aluminum.
2. Thermal barriers dramatically improve the U-value characteristics. (See chart below.)
3. Thermal barriers dramatically improve condensation resistance.
4. Thermal barriers are essential for energy conservation.

Energy-Efficient Fenestration Timeline for Thermally Improved Extrusions



	single glazed	insulating glass (IG)	+ thermal barrier frame	low-E hard coat	low-E soft coat	+ argon filled IG	+ spacer, warm-edge	+ dual or wide cavity thermal barrier	+ tri glaze IG, low-E on #2 and #5 surface
	1950	1960	1970	1980	1990	2000	2005	2010	2012
U-factor	1.00	0.66	0.50	0.44	0.41	0.39	0.37	0.32	0.22
Condensation Resistance*	16	28	52	54	55	56	61	65	68
U-cog (Btu/h ft²F)	1.03	0.49	0.49	0.36	0.29	0.24	0.24	0.24	0.12

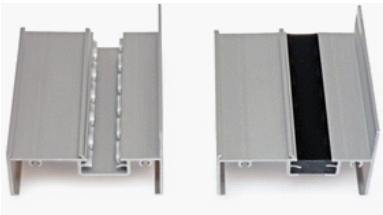
Thermal graphics created with THERM 5 and Windows 5 * NFRC 500 Condensation Resistance

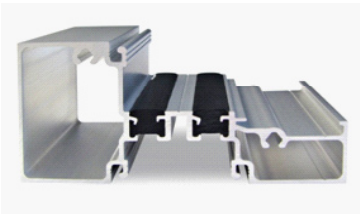
AAMA 1503-09, *Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors and Glazed Wall Sections* is commonly used and widely accepted in the commercial industry for determining a product's condensation resistance factor (CRF). A CRF tool is also available on the AAMA website.

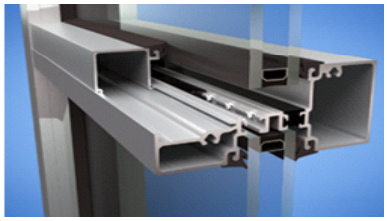
THERMAL BARRIER OPTIONS

In North America, architects, engineers, developers and building owners have two primary options when it comes to thermal barrier technology: polyurethane and polyamide. Although these two systems perform similar functions, they are different in the way they perform and the way they are incorporated into fenestration products.

Polyurethane poured and debridged systems





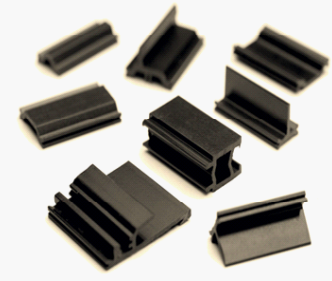


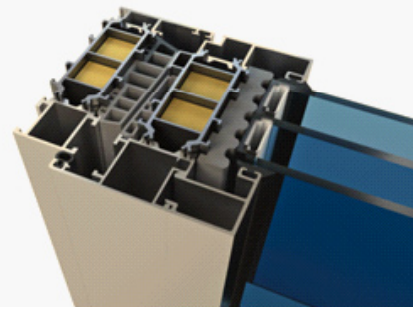
- This process starts with a single extruded aluminum profile.
- A mechanical lock may be added to the extrusions to improve structural strength.
- Structural thermal barrier polymer is placed into the thermal cavities of the aluminum profile.
- Once cured, the bottom of the profile is removed in a process called debridging.
- The result is an aluminum profile containing a structurally strong thermal barrier separating the interior and exterior surfaces of the aluminum.

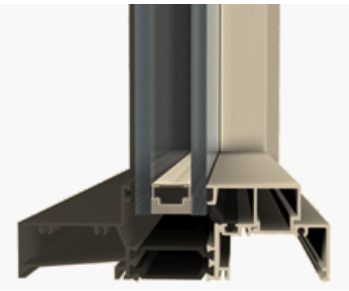
Primary benefits of polyurethane systems

1. Polyurethane has low thermal conductivity, maximizing thermal efficiency in the smallest possible separation.
2. Polyurethane systems are very strong, allowing for wider spans.
3. Polyurethane systems are cost effective to produce.

Polyamide thermal barrier systems







- This process begins with two separate extrusions; one interior and one exterior.
- The aluminum framing members are knurled and polyamide strips are inserted into the aluminum profiles.
- The composite extrusions are then crimped to secure the polyamide strips, thus producing a structural composite.

Primary benefits of polyamide

1. Two-color finish options are simple and cost effective due to the fact that two separate profiles are used in the process.
2. Flexible designs allow for incorporation of window components into the thermal barrier such as foam, gaskets or glass stops.
3. Wide separation of the aluminum allows for lower U-Factors.

Thermal barrier windows, storefronts, curtain wall systems and skylights

Since their inception in the 1970s, the incorporation of thermal barriers in commercial fenestration systems has been instrumental in saving millions of barrels of oil and other natural resources. As energy-efficient building design continues to play a key role in the shaping of our cities, thermal barriers will play an important role in these design considerations.

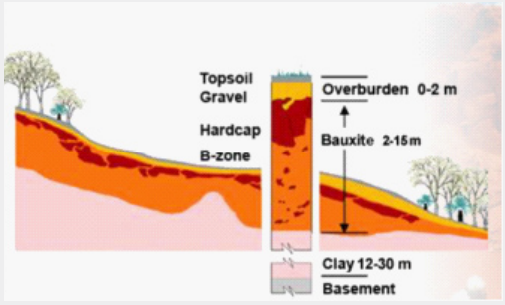
SUSTAINABILITY & RECYLABILITY

Aluminum is sustainable. Aluminum is a non-combustible and natural material.

It is the third most abundant element in the Earth's crust (in the form of bauxite), next to oxygen and silicon.

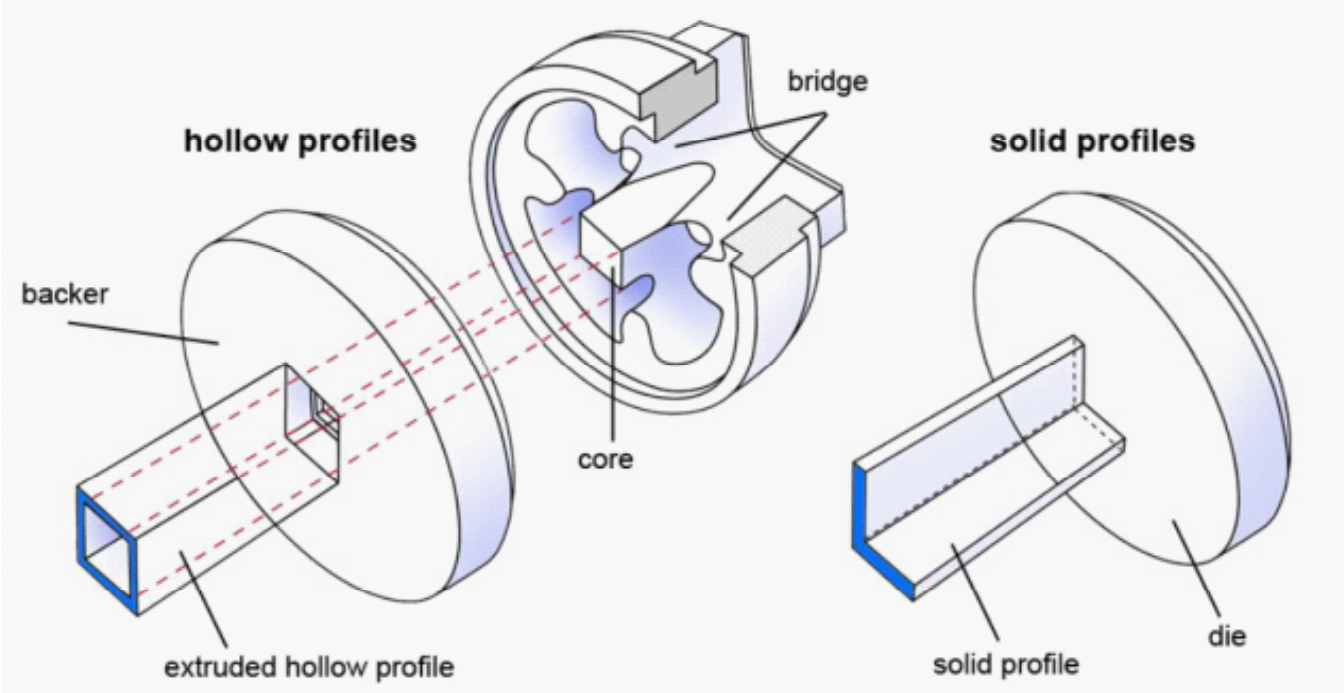
Aluminum is environmentally friendly and non-toxic,even when subjected to high temperatures. It is 100 percent recyclable regardless of any applied finish and can be recycled repeatedly while still retaining the same material physical properties. According to Aluminum Association data, 75 percent of all the aluminum ever produced is still in service today. A 2004 study by Delft University of Technology found that "95 percent of the aluminum used in B&C market is recycled at the structure's end-of-life." Because of this, and the desirability of the high scrap price, it reduces its environmental impact by not being deposited into landfills. Recycling aluminum takes only five percent of the energy required to make primary aluminum, seriously reducing GHG emission.

Benefits of Aluminum Recycling (Annually)



- Equivalency of about 70 million barrels of crude oil is saved —enough oil to feed U.S consumption for three days or nearly one day of the world's oil supply.
- Approximately 2.4 million meters^2 of land is saved.
- More than 45 million tons of fresh and sea water use is avoided—enough water to provide for the needs of New York City's 8 million people for 10 days.
- Approximately 7.5 million tons of solid waste is avoided.
- About 27 million tons of CO_2 greenhouse gas emissions is avoided—equivalent to eliminating five large (1,000 MW) coal-fired power plants.

COST ADVANTAGES & TOOLING COSTS



Aluminum extruded profiles can range from simple shapes to very complex, intricate shapes. Most architectural profiles range from simple to sophisticated as well. More than 80 percent of the aluminum extrusions used in window, door storefront and curtain wall applications fit within a 10-inch circumscribing circle. The extrusion tooling required to produce these shapes is very budget friendly, ranging from $500 for simple, solid shaped profiles, up to $5,000 for a complex, multi-void hollow shape. Typical lead-times for this tooling run from two to three weeks. Aluminum extrusion tooling can also be revised, in many cases, when minor changes in the profile design require modification, which is a real advantage in managing costs.

Other types of tooling used to manufacture fenestration shapes can be very costly, could have longer lead times and may be difficult to modify.

Tooling Types	Cost	Lead Times
Vinyl Extrusion Tooling	$1,500 and up	6-16 weeks
Injection Mold Tooling	$25,000 and up	20 weeks or longer
Roll Form Tooling	$25,000 and up	16-24 weeks
Die Cast Tooling	$30,000 and up	20 weeks or more
Stamping Tooling	$10,000 and up	8-20 weeks

Source: *AEC Extrusion Manual 4th edition page 24*

STRENGTH TO WEIGHT RATIO

Aluminum is a lightweight metal (low density), weighing about one-third as much as steel. This high strength-to-weight ratio means that less of a building's structure is spent supporting its own weight. Buildings in seismic zones benefit even more from this reduced weight, since seismic forces are proportional to the weight of the structure. The mechanical properties remain unchanged under 250° F, and even improve in temperatures less than 0° F, in terms of elastic modulus/stiffness. Certain alloy/temper combinations produce strengths as high as 80,000 psi to 90,000 psi or more. Mild steel strength is 44,000 psi.

Aluminum is resistant to time and temperature, impervious to humidity, warping or becoming brittle. Also, it doesn't absorb moisture, swell, shrink, split, crack, rot or rust, resulting in a longer service life.

CONCLUSION

Aluminum is an excellent construction material for use in windows, storefronts and curtain wall as well as window-wall, door and skylight systems because it is lightweight, strong and easy to process. Aluminum fenestration systems are available in an endless assortment of colors, shapes and sizes to fit any design specifications. The fact that aluminum can be recycled an infinite number of times without loss of structural properties, and for a fraction of the cost of producing virgin aluminum, it's easy to see why aluminum has been the material of choice in commercial construction for so many years.

References

AAMA/WDMA 2011/2012 Study of the U.S. Market for Windows, Doors and Skylights

AAMA 1503-09, *Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors and Glazed Wall Sections*

AAMA 2603, *Voluntary Specification, Performance Requirements and Test Procedures for Pigmented Organic Coatings on Aluminum Extrusions and Panels*

AAMA 2604, *Voluntary Specification, Performance Requirements and Test Procedures for High Performance Organic Coatings on Aluminum Extrusions and Panels*

AAMA 2605, *Voluntary Specification, Performance Requirements and Test Procedures for Superior Performing Organic Coatings on Aluminum Extrusions and Panels*

Additional Resources

The Aluminum Association

Aluminum Extruders Council

Aluminum Material Council Web Page

AAMA Aluminum Technical Documents

AAMA ALUMINUM Material Council

AMC-1-13