WHITE PAPER:
Should You Consider the use of Custom Aluminum Extrusions in Your Next Project?


Illustration 1: Custom designed extruded aluminum railing system, aluminum trellis and barbeque canopy, Hydro Architectural Products.

Most architects and design engineers are somewhat familiar with aluminum extrusions. Whether a component in an entry door, window, curtain wall, canopy, sun shade, light fixture, railing system or any of a host of other building elements, aluminum extrusions are valued for their light weight, strength, durability and corrosion resistance, low maintenance, finish options, and contribution to sustainability.

However, extrusions are often thought of as "a given," arriving on site as an element in a finished product, with their selection and design the purview of the building component supplier. If the designer, engineer or architect does inquire about something different – for example, a unique shape to meet a specific project objective – they are often put off by responses about one-time charges, additional cost and the impact on delivery schedules.

Yet custom extrusions can create a signature design solution, with differentiation, personalization, enhanced function, and greater value, and the aluminum extrusion process is ideal for custom solutions, with tooling costs and turnaround times among the lowest of material processes.

This article outlines the practicalities (i.e., costs, timelines, minimums) involved in designing and using custom aluminum extrusion, as well as the key design and specification considerations.

Illustration 2: Entrance, Edith Green – Wendell Wyatt Federal Building; *Nic Lehoux Architectural Photography*

Practicalities:

OK, you have an inspiration for a custom element – a canopy, a series of decorative lighting fixtures, or a sun-shade system, like the one created for the renovation of the Edith Green – Wendell Wyatt Federal Building in Portland, Oregon; something that will bring a distinctive individuality to your project. Is it feasible?

There are likely two areas you want to consider: the availability of extrusion presses to produce the size/shape you envision and the cost and budget implications. To investigate either you need to have an idea of the shape's weight-per-lineal-foot and its "circle size" (the smallest circle that fits around the shape).

TABLE 1: NORTH AMERICAN EXTRUSION PRESS AVAILABILITY

	Circumscribed Circle Size in inches					Corresponding Profile weight (lbs/ft)	
Cross Section Area in sq. inches	<1	1 to 7	8 to 10	11 to 14	>14	Min	Max
<.050	L	L	x	x	x	-	0.06
.050 to .100	G	G	L	x	x	0.06	0.12
.100 to 1.0	W	W	L	x	x	0.12	1.18
1.0 to 2.5	x	W	W	L	x	1.18	2.94
2.5 to 10	x	W	W	G	L	2.94	11.76
>10	x	x	W	G	L	11.76	-

X: Not Available L: Limited Availability G: Generally Available W: Widely Available

As indicated in Table 1, there is generally good availability of presses in North America to produce extruded shapes with circle size from under 1 inch to 14 inches. If you anticipate the need for larger shapes, options may include designing these profiles as a single part or as multiple extrusions that snap together, contingent on the profile's structural load requirement. You should discuss options and capabilities with your extruder.

Costs and lead times for the tooling to produce the desired extrusions must be considered as well, though both are generally far less than for competitive materials. Extrusion tooling (i.e. dies) for presses with 7- to 10-inch circle size often cost between $1,000 and $2,000 for solid shapes and $1,200 to $4,000 for hollows, with typical lead times of 2 to 3 weeks. In contrast, production tooling for rolled steel shapes can easily *exceed $30,000*, with lead times of 3 *months*.

Illustration 3: Extrusion tooling typically offers the lowest cost and fastest lead times.

The relatively low cost and quick availability for extrusion tooling not only preserves budgets, but permits full-scale prototyping with little “penalty” for subsequent revision. Note that tooling for larger shapes – 12 inches, 14 inches, etc. --will cost more due to the expense of tool steel.

Note also that if complex or highly precise fabrication – e.g. bending, CNC machining – of the extruded shape is required, costs for the attendant fabrication tooling and check fixtures can become significant. It is prudent to begin working with an extruder with appropriate experience early in the design and specification process to avoid unpleasant surprises later. Often your extruder will be able to make suggestions early, which can significantly reduce extrusion, subsequent tooling, fabrication and ultimately product costs.

Order minimums are a final practical consideration. Most extruders have a minimum order size that they will consider; often 1,000 to 2,000 pounds per shape. In some cases a minimum charge will be an alternative. Stated minimums can become an impediment especially when prototyping, or when small quantities of one or two shapes are needed as accessory items to higher volume extrusions. Again, early discussion with your extruder can result in a solution that meets both parties’ needs. Often an extruder with a smaller diameter press can handle smaller order sizes, assuming that the press can handle the circle size (smaller billet diameters utilize smaller, and thus less expensive tooling and less pounds of aluminum per extruded push).

Design & Specification Considerations:

While it is impossible to comprehensively cover extrusion design in limited space, the following should help guide interested designers.

Design Process: If, like many architects and design engineers, you are familiar with designing steel assemblies, you may need to shift your thinking to create optimal extrusion designs.

In designing with steel, one typically chooses from a limited, and well known, list of choices; the finite selection of shapes results from the rolling and manufacturing processes that produce steel members. Steel structures are widely understood, and designers know how to design, evaluate and specify steel structures based on familiar, limited shape choices, and commonly available design software. They know how to fabricate and join these limited choices into structures that meet their needs.

With extrusion, however, the designer is *not choosing*, but *creating* the shape to meet their desired aesthetic and function. The extrusion process provides the unique ability to *create a shape* with metal placed EXACTLY where required for aesthetic, structural or functional purposes. Solid or hollow, shapes can be customized to best achieve their intended purpose.

Alloy Selection: Extrusions are available in a variety of alloys and tempers. While other alloys may provide greater strength, electrical conductivity or other functionality, for most building and construction applications, 6000-series alloys are ideal.

ILLUSTRATION 4: ALLOY CHARACTERISTICS

Alloy	Major Alloying Elements and Alloy Characteristics
1000 Series	Minimum 99% Aluminum High corrosion resistance. Excellent finishability. Easily joined by all methods. Low strength, poor machinability. Excellent workability. High electrical conductivity.
2000 Series	Copper High strength. Relatively low corrosion resistance. Excellent machinability. Heat treatable.
3000 Series	Manganese Low to medium strength. Good corrosion resistance. Poor machinability. Good workability.
4000 Series	Silicon Not available as extruded products
5000 Series	Magnesium Low to moderate strength. Excellent marine corrosion resistance. Very good weldability.
6000 Series	Magnesium & Silicon Most popular extrusion alloy class. Good strength. Good corrosion resistance. Good machinability. Good weldability. Good formability. Heat treatable.
7000 Series	Zinc Very high strength. Poor corrosion resistance. Good machinability. Heat treatable.

Typically used in building applications

Alloys to consider include 6060, 6063, 6061 and 6005A, with 6060 and 6063 generally preferable for less structural/more aesthetic applications and the latter two alloys more appropriate for structure. Designers should work with extrusion suppliers and other experts when choosing alloys, but here is a quick overview:

6063, 6060 (and variants):

- Lowest strength and slightly lower costs, but with better “extrudability” and surface finish

- Appropriate for uses such as light fixtures, furniture and entrance doors where properties such as yield and ultimate strength are not the controlling factor, but where elastic buckling or deflection is paramount (6060 and 6063 alloys have lower yield and ultimate strengths, but perform similarly to 6061 and 6005A in buckling and deflection). Most aluminum has substantially equal modulus of elasticity, so a higher strength alloy may provide no deflection benefits.
- Applications requiring a painted or anodized finish for aesthetic reasons may best use 6063/60.

6061 (and variants):

- High strength and higher cost, due to lower extrudability
- Poorer surface finish.
- Often specified due to familiarity, but generally 6005A is better suited to many applications.

6005A:

- A newer alloy with high strength, moderate cost and good extrudability and surface finish.
- Because it is much less "quench sensitive" than 6061, extrusion process parameters are more reliably achieved without distortion from water quenching.
- Typically recommended for structural applications.

Profile Design: This is an area where those not well experienced in designing extruded solutions can gain tremendous benefits from working with extrusion suppliers; often, seemingly subtle differences in a profile's design can translate into significant differences in cost.

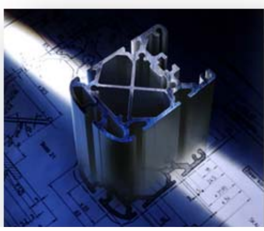


Illustration 5: Talk to your extrusion supplier. Seemingly subtle differences in profile design can translate to significant differences in cost.

Designers should keep a few guidelines in mind as they put metal where it is needed:

Think outside of the box. Don't be constrained by thinking in terms of only rectangles, tubes, L's, C's, I-beams, etc. USE the capabilities of the extrusion process to place metal where needed or desired for structural or aesthetic purposes.

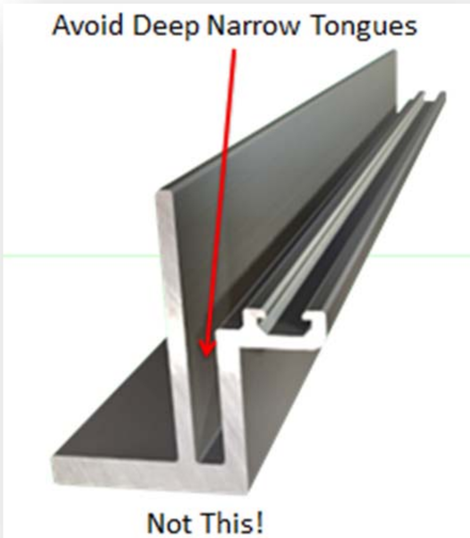
Where possible, to achieve lower cost solutions, it *may* be preferable, but not required to:

- Avoid dramatic differences in wall thicknesses.

ILLUSTRATION 6: PROFILE DESIGN HINT – TRY FOR UNIFORM WALL THICKNESSES

- Use smaller “tongue ratios” (e.g.: <3) (the area of the “void” that the die must create / the length of the base dimension of the “tongue” that creates this void[2]).

ILLUSTRATION 7: PROFILE DESIGN HINT



- Avoid sharp corners and radii.

ILLUSTRATION 8: PROFILE DESIGN HINT: MAINTAIN SMOOTH TRANSITIONS

- Design more symmetry into shapes (work with your extruder)
- Simplify shapes while incorporating necessary features.

Tolerances & Surface Specifications: Industry standard tolerances for the range of extrusion attributes can be found in *Aluminum Standards and Data*, published by the Aluminum Association (aluminum.org). Note, however, that many extruders routinely hold tolerances significantly tighter than industry standard. Thus, it is useful to discuss specific tolerance requirements with your extruder. Similarly, it is important to indicate which surfaces on the resulting extruded components will be visible to assure that the finish on visible surfaces is optimal.

Structural Considerations: Designing structures, like canopies or pedestrian bridges, with extrusions utilizes the same analytic process and software as with steel, with one critical difference. While steel shapes are *limited* to a finite variety handled by tables in the software, the variety of *extruded* shapes – because of the extrusion process – is virtually infinite. This is a boon and a bane to the designer, as design software to automatically choose the optimal extruded shape is not yet commercially available.
(Note: such software is being developed and will hopefully be available within the next year.)

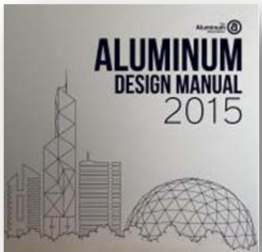


Illustration 9: The *Aluminum Design Manual* is available at www.aluminum.org

Currently, creating optimal structural solutions is often an iterative process, starting with the FUNCTION required and then working through various FORMS (geometries, joining means, etc.). A key resource is the Aluminum Association's *Aluminum Design Manual* (*ADM*). Issued every five years, the 2015 edition is the most recent publication. Part I of the ADM incorporates the Specification for Aluminum Structures, the basis for aluminum construction per the International Building Code and most U.S. state and municipal codes. The *ADM* is formatted similarly to the AISC steel manual, so those familiar with that reference will find the *ADM* easily approachable. The *ADM* addresses allowable strength design and load and resistance factor design, and provides key data for the design of extruded members in tension, compression, flexure, shear, etc.

Utilizing the *ADM*, one can pursue a design process similar to the following:

- Determine environmental conditions (wind and snow loads, for example)
- Understand the FUNCTION required of the structural system and aesthetics desired
- Involve knowledgeable extruders throughout the process; take advantage of their expertise
- Develop alternate geometric approaches to evaluate
- Utilize design software (e.g. Bentley Software's *Ram Elements*) and "idealized" members (simple tubular members, not yet focusing on connections, etc.)
- Vary the designs, geometry, etc. and use the software to estimate the weights and number of extruded and other components
- Choose the most likely alternatives
- Utilize more detailed design analyses, included in the *ADM* , the AISC *Steel Construction Manual*, Finite Element Analysis (FEA) and design software such as *Autodesk Inventor* to develop actual part designs and extruded shapes necessary for each alternative
- Iteratively fine tune these alternatives to achieve the optimal solution for each, taking material, fastener and assembly costs into account
- Select one or two designs worthy of complete/final design and produce appropriate extrusion, subassembly and assembly drawings
- Develop rapid prototyped part and assembly examples where desired or required
- Obtain quotations and make a final decision.

Again, do not hesitate to ask for help from extruders.

Finishing: Upon extrusion, aluminum instantly forms a tenacious oxide film providing protection against corrosion. This is a significant advantage for aluminum versus steel solutions, as the iron oxide (rust) in steel is NOT tenacious and spalls off exposing the underlying metal to additional corrosion. For aluminum solutions, additional finishing is generally not needed except for aesthetic or severe service conditions (e.g. salt spray, heavy pollution).

When additional finishing is desired, anodizing or paint (either liquid or powder) is typically specified, though in some cases mechanical finishing, such as brushing or sand-blasting, is employed. Most extruders either have in-house paint and/or anodizing capabilities, or have established finishing service relationships that allow them to provide a finished and fabricated component.

American Architectural Manufacturers Association (AAMA) Specifications 2603, 2604 or 2605 are generally used to define paint finish performance and parameters, while AAMA 611 Class l or Class ll specifications are used to define anodizing.

Recycled Content: A final consideration is recycled content. Aluminum has the marvelous ability to be recycled infinitely, with no degradation in physical properties, and studies show that roughly 95% of the aluminum used in buildings is recycled at the end of life. The use of extrusion feedstock (billet) based on recycled metal – as opposed to primary aluminum – significantly reduces the carbon footprint of the resulting extruded parts, as recycled aluminum requires only 8 percent of the energy to produce compared to primary metal production.

A recent Life Cycle Analysis completed by the Aluminum Extruders Council shows that North American extruders used nearly 55 percent recycled content in the study year of 2015. It is likely that recycled content has increased since that time, as extruders have worked to provide "greener" products. Even at the 55 percent level, North American extruders used over 3.75 billion pounds of aluminum scrap last year. Many extruders – and particularly those focused on the building and construction market – consistently offer product with substantially greater recycled content. Again, this is a topic to be discussed with your extruder.

The Aluminum Extruders Council (AEC) is committed to bringing comprehensive information about extrusion's characteristics, applications, environmental benefits, design and technology to users, product designers, engineers and the academic community. For more information and resources about the advantages of and practical considerations for designing with aluminum extrusions, visit our website at www.aec.org.