Aluminum – It's Not Just for Lightweights

The Aluminum Design Manual 2005

By J. Randolph Kissell, P.E.

Most of us were led to believe in college that real-world structures are built of steel or concrete. If aluminum were mentioned, it was as a light but rarely used metal for exotic structures like aircraft.

Not anymore. Already over 3 billion pounds of aluminum are used in building and construction applications every year in the US, and that figure is increasing, in spite of misconceptions about the material.

Did You Know?

Aluminum is more cost competitive now than ever before. When the Washington Monument was capped with aluminum in 1884, aluminum cost so much its weight was reported in ounces (100) instead of pounds. Yet over 37 miles of aluminum scaffolding tubes were used in the monument's 1997 renovation. This change was driven by dramatic cost reductions. Due to production improvements and international competition, real aluminum prices are near historic lows, giving steel, with its skyrocketing costs and supply shortages, a real horse race. Because aluminum weighs one third what steel does and doesn't need a corrosion allowance or coatings, many aluminum building products actually cost less than steel. Stainless steel, at triple the weight and costing more per pound, isn't even close to aluminum.

Aluminum is corrosion resistant. Even in marine and wastewater treatment environments aluminum needs no protective coatings, since aluminum oxide forms rapidly, is extremely durable, and bars further oxidation.

Aluminum is strong. 6061-T6 aluminum, a very common alloy and temper, has a yield strength of 35 ksi, compared to 36 ksi for A36 steel. Higher strength aluminum alloys are available; 7005-T53, for example, has a tensile strength of 50 ksi.

Aluminum is green. Aluminum is 100% recyclable; recycled aluminum requires only 5% of the energy to produce aluminum from ore. Today, the aluminum flat rolled products typically used in the building and construction market contain 80 to 85% recycled material. Furthermore, aluminum's light weight reduces energy consumption during use of portable (e.g., scaffolding) and movable structures (movable bridges), and its high reflectivity and low emissivity reduce heat gain in buildings in hot climates.

Aluminum scaffolding used during the 1997 repair of the Washington Monument

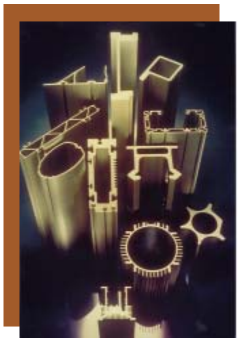
Aluminum is weldable. With advances in arc welding equipment and publication of the American Welding Society's structural welding code for aluminum (AWS D1.2), reliable aluminum welds are as readily achieved as steel welds.

Replica of the aluminum capstone on the Washington Monument

Aluminum is workable. Perhaps aluminum's most significant attribute is that of all building materials, aluminum is the most easily and inexpensively extruded, a process of squeezing metal through an opening to produce shapes. The cross section can be unsymmetric about either or both axes, may be hollow, and typically must fit within an 18 inch diameter circle. Standard shapes, such as I beams, angles, channels, tees, zees, pipe, and round, square, and rectangular tubes, are readily available. Custom shapes can be had for the small additional cost of an inexpensive die. Extrusions let you put the metal where you need it and customize shapes to provide gasket attachment grooves, provide built-in welding backer bars, snap-fit parts together, locate holes, identify parts, and many other purposes.

But How Do I Design Aluminum Structures?

To some, though, designing aluminum structures can be daunting. While every structural engineer has heard of the AISC Steel Manual and ACI 318, few are familiar with the comparable design specification for aluminum. Furthermore, since aluminum members are produced by either cold-forming sheet or extruding, there's a great variety of aluminum shapes. While this offers tremendous flexibility, it also complicates design, since designers can't assume shapes are compact and so must check local buckling.

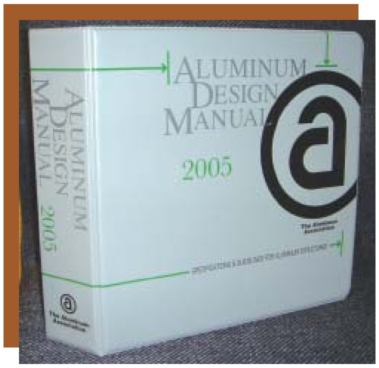


Custom aluminum extruded shapes

The US aluminum producers tackled this problem after World War II by publishing their own structural design handbooks. ASCE also formed committees populated by producers and published suggested aluminum design specifications. In 1967, The Aluminum Association, the US trade association for aluminum producers, published the *Specifications for Aluminum Structures*, the culmination of these earlier efforts. It provided rules for determining the strength and safety factors for aluminum structural members and connections.

The *Specifications* were subsequently adopted by all three model building code organizations and most building codes in the US. In 1994, The Aluminum Association consolidated the *Specifications for Aluminum Structures* and several other publications on aluminum structures into the *Aluminum Design Manual (ADM)*. Since its inception in 2000, the *International Building Code* (successor to the three model building codes used prior to that date) has required (in Chapter 20) that aluminum structural design comply with the ADM.

The ADM is now on a five year edition cycle, having been revised in 2000 and 2005. The 2005 edition, just published, incorporates significant changes and includes the following Parts:



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- Part I, **Specification for Aluminum Structures:** Along the way, the *Specifications* became the *Specification* (singular) and since 1994 has been available in two flavors: Allowable Stress Design (for buildings and bridges), and Load and Resistance Factor Design (for buildings only). ASD and LRFD yield about the same member sizes.

- Part II, **Commentary to the Specification for Aluminum Structures** (given for both ASD and LRFD methods), provides references and discussion documenting the reasons for the Specification provisions.

Scienceland Egg, a 164 ft wide aluminum-framed structure in Shanghai, China; photo courtesy of Temcor

- Part III, **Design Guide**, discusses the provisions of the specification, offers additional guidance for designing aluminum extrusions, and addresses corrosion issues.
- Part IV, **Materials**, explains the aluminum alloy and temper designation systems.
- Part V, **Material Properties**, lists minimum and typical mechanical properties (including strengths and moduli of elasticity) for various alloys and tempers at various temperatures.
- Part VI, **Section Properties**, lists commonly available shapes including channels, I beams, angles, tees, zees, and round and rectangular tube, and pipe. Be aware that not all shapes listed are readily available; to avoid wasted design effort, use The Aluminum Association standard channels and I beams (shown in the *Specifications'* Tables 4 and 8, respectively). These standard shapes have flat flanges (making connections simpler), compact flanges and webs, and load span tables are provided.
- Part VII, **Design Aids**, includes buckling constants for all alloy tempers given in the *Specification*, allowable stress tables for the common alloy-tempers, and load span tables for tread plate, AA standard channels and I beams, and roofing and siding.
- Part VIII, **Illustrative Examples of Design,** includes 31 examples of applying the Specification.
- Part IX, **Guidelines for Aluminum Sheet Metal Work in Building Construction**, provides details for non structural applications of sheet metal such as roofing and flashing.

The Bottom Line

It's worth considering aluminum, especially:

- Where steel has been used in the past: aluminum can be less expensive;
- In long span structures: the efficiency of such structures is especially sensitive to dead load;
- In structures in seismically active zones: smaller mass means smaller lateral forces;
- When members with complex cross sections are required: extrusions cost much less than fabricating complicated shapes by bending, welding, or machining;
- For retrofitting existing structures: existing structures often have limited capacity for additional loads or require a reduction in dead load to regain their original live load rating; and
- For signature architectural structures: aluminum is available in many painted and anodized finishes and structural components including sheet, plate, extrusions, forgings, and castings and can readily be formed to provide unique structures.▪

*Randy Kissell is a partner with the TGB Partnership of Hillsborough, NC, a consulting firm specializing in aluminum structural design. Randy is the secretary of the Aluminum Association's Engineering and Design Task Force which maintains the **Aluminum Design Manual**, and secretary of the American Welding Society's D1.2 subcommittee.*

The Aluminum Association, based in Washington DC, is the trade association for producers of primary aluminum, recyclers and semi-fabricated aluminum products, as well as suppliers to the industry. (www.aluminum.org)