product expert series

CAST AWAY!

BY CARLOS DE OLIVEIRA, P.ENG., AND MICHAEL GRAY, PH.D.

Common questions on steel castings for structural applications.

WILL YOU be using cast connections in your next project?

Assuming the answer is "Yes!" or at least "I'm considering it," there are several questions that may arise.

As designers and implementers of both standardized and customized steel castings in steel structures, Cast Connex is commonly asked how to design and specify cast steel structural components. We've attempted to answer some common questions about steel castings below.

When does the cost of casting a connection make economic sense? We often think of the cost of fabricated steel on a per-ton basis—where the cost of the connections is amortized over the tonnage of the entire building frame. If you compare the cost per-ton of cast steel to that of fabricated steel in this way, of course cast steel appears to be far more expensive. But were you to take the cost of fabricating a connection over the weight of the steel in the connection region alone, you'd probably be astounded at the cost of connections on a per-pound basis and at how much that cost can vary from simple to complex connections. That's not to say that castings always make economic sense, but one can imagine that there is a breakeven when labor and material costs in the fabrication of complex connections can surpass those associated with producing a cast steel alternative. And when the costs associated with the design, detailing, tooling and qualification of a new cast geometry can be amortized over many identical cast connections, you can appreciate that there are many scenarios where cast steel connections can be far more economical than manually fabricated connections. This is the reason for the success of our company's standardized cast steel connections.

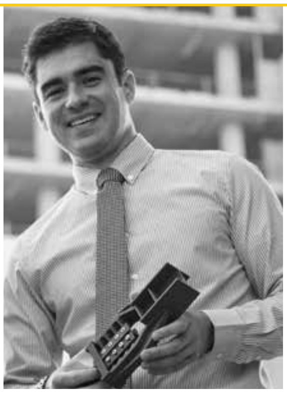
For custom cast components where engineering, tooling and first article (e.g., sample component) qualification costs cannot be amortized over many connections, a total cost comparison must be carried out if one's goal is to justify the use of cast components on economics alone. For example, consider that a cleverly designed cast connection may eliminate field welding and therefore reduce the cost of both erection and of special inspection—the latter being a cost that is born by the owner rather than the contractor. This "fringe" savings can be very significant but may not be apparent to the steel fabricator nor general contractor. As such, simply asking your steel fabricator if a cast connection is more economical will often yield an incomplete picture; castings can save an owner's money more often than most appreciate.

Consider also that there may be other performance benefits to the use of cast connections—such as aesthetics, improved connection strength and stiffness and improved fatigue life (both high- and low-cycle fatigue)—which may be more difficult to quantify but that are likely very important to your client.

For those looking for more tangible guidelines, we often suggest that castings may be appropriate in any of the following circumstances, with the suitability of castings being increased in scenarios where more than one of these conditions applies:

- Complex connections (i.e., with incoming members at different angles)
- Connections subject to very high loading, where large welds are required but would be difficult to apply and inspect, or where connections require significant stiffening
- Architecturally exposed joints, particularly for HSS connections
- Fatigue-critical connections
- Repetitive details

How does one go about designing and analyzing an arbitrarily shaped steel component like a casting? First, we have to admit that we're exaggerating a bit when we often boast that steel casting manufacturing offers complete geometric freedom. To produce economical and structurally sound steel castings, one must shape cast connections simultaneously for their end use and for the casting manufacturing process. In general, castings should be shaped in consideration of the molding process and with feeding and solidification in mind. The aim is to promote directional solidification, which limits the necessity



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Jeff Mullins


Cast Connex and Sadken, Inc.

A nearly 16-ton cast steel node for the Queen Richmond Centre West in Toronto. The node has just been removed from the heat treatment oven and is being forced-air cooled pursuant to Cast Connex's specifications.

A cast steel node and wishbone pedestal in Terminal 5 of Heathrow Airport.

A cast steel node, featuring recessed reveals, in the tree-like roof supports of Stuttgart Airport.


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for the addition of risers to feed liquid metal into the part as it solidifies and cools. We've said it before: The design of steel castings is as much of an art as is the design and detailing of fabricated structural steel connections.

The design of castings requires the use of 3D solid modelling software, and the structural analysis of castings often requires numerical techniques. When it comes to finite element analysis (FEA) of steel castings, we are most commonly asked what level of stress is reasonable for a structural casting. Our answer: It's complicated.

First, the acceptable level of stress within a region of a cast steel element should be correlated to the allowable size and location of internal discontinuities within the part, as established through the non-destructive examination requirements stipulated in the casting specification. This is difficult for those without experience in the destructive structural testing of steel castings, as there has not been much work published on the structural performance of cast steel meeting, say, "Level III" ultrasonic testing. But that's not the whole story. Consider that for compact steel sections subjected to flexure, the code allows stresses and strains to exceed elastic limits (we compute the flexural strength of a compact steel section based on its plastic moment of inertia, Z, rather than its elastic section modulus, S). However, for elements loaded in tension, a safe margin must be left between the average stress and the yield strength of the steel material. This means that in proportioning economical steel castings, one must consider the distribution of stresses in the casting under a variety of load combinations (not just the peak stress) as well as specify non-destructive acceptance requirements commensurate with the level of stress in each region of the casting. Furthermore, this approach also often requires the use of non-linear finite element analysis to understand how the cast steel component will behave, which in turn requires that casting designers consider the inelastic demand placed upon, and the available ductility of, the cast material. It's also important to note that although steel castings are generally isotropic, heavy-walled castings exhibit through-thickness variation in yield strength.

What considerations must be made with respect to lead time when specifying customized cast connections? This is a tough question because the answer really depends on the complexity and size of the part and how busy the selected foundry and pattern shop are. For an order of magnitude, those considering castings can assume anywhere from six to 10 weeks for the production of tooling, eight to 12 weeks for casting and qualifying a first article and another eight to 12 weeks to begin to receive production castings. Also, consider that your structural steel drawings are not casting shop drawings. Just like standard steel connections, cast connections must be detailed before casting manufacturing can begin, so time must be allotted for detailing and coordination. The extended lead time involved in the use of custom castings often requires special consideration by the design team and owner, which is why we are often involved in projects requiring custom castings well before they go to tender.

What should be covered in a casting specification? At a minimum a casting specification should cover foundry qualifications, quality control and assurance, material grade, non-destructive examination requirements for both the first article and production components, surface quality requirements, dimensional tolerances and machining requirements (if any). Also, be sure to include a line or two in your structural steel specification on the handling and integration of the cast steel elements into the structural steel framing. If incoming structural sections are to be welded to the steel casting, also note that welding procedure specifications must be qualified, because although many cast steel grades are weldable, there are currently no cast steel grades listed as prequalified base metals in AWS D1.1. MSC