

## CONVENIENT CONNECTIONS

Cast connections provide an efficient and attractive connection alternative for exposed hollow sections.

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**IF YOU'VE BEEN TO EUROPE LATELY** — or within the last few decades — chances are you've seen structural steel castings in action. Since their landmark applications in structures like the cable-net roof for the Olympic Stadium in Munich and the truss nodes in the Centre Georges Pompidou in Paris, steel castings are seeing increased use in structural applications not only in Europe, but all over the world as well.

Steel castings are especially common in European bridge applications, where cast steel nodes significantly improve the fatigue life of otherwise highly complex welded joints. Conversely, castings in building applications have been predominantly used for statically loaded exposed structural steel connections, particularly in structures using hollow structural sections (HSS). Generally speaking, custom-designed steel castings are particularly well suited for any application requiring intricate geometry and a little extra finesse.

With steel castings gaining in popularity, recent research at the University of Toronto focused on exploiting the most significant advantage that casting manufacturing provides over standard fabrication: mass production. The result was the development of innovative cast steel connectors for two common yet complex steel fabrication issues for HSS: seismic bracing connections and true-pin connections suitable for architectural exposure.

### Special Concentrically Braced Frames

Concentrically braced frames are among the most popular lateral force resisting systems for medium- to low-rise steel structures. In the event of an earthquake, the diagonal brace members of braced frames dissipate seismic energy through yielding



Cast ConneX high-strength connectors for seismically loaded HSS bracing connections (left). A connected brace in frame (right).

in tension and inelastic buckling in compression. This cyclic yielding and buckling imparts significant loading on the brace's connections. Consequently, North American design codes require seismic bracing connections to be detailed such that they are significantly stronger than the nominal cross-sectional capacity of the brace member.

The degree to which the connection strength must surpass the nominal cross-sectional yield capacity of the brace is dependent on the expected overstrength of the brace. Detailing connections to provide this level of strength can be rather difficult, particularly when dealing with HSS, which are the preferred bracing elements due to their efficiency in carrying compressive loads, their improved aesthetic appearance, and the wide range of sections sizes that are readily available in North America.

End connections for hollow section brace members are typically achieved through a gusset connection between the brace end and the beam-column intersection. However, conventional slotted HSS-to-gusset connections have been shown, both in the laboratory and in the field as witnessed during post-earthquake recon-

naissance, to be prone to failure when subjected to cyclic inelastic loading. Thus, current seismic design provisions recommend the use of net-section reinforcement whenever slotted HSS-to-gusset connections are specified in seismic-resistant frames.

However, designing, detailing, and fabricating reinforced slotted connections to HSS can be both challenging and costly. Recognizing the need for a simple solution to the seismic brace connection dilemma, a research team at the University of Toronto, headed by Professors Jeffrey Packer and Constantin Christopoulos, developed standardized cast steel seismic-resistant HSS connectors shaped to eliminate the need for connection reinforcement. The geometric freedom that casting manufacturing provides allowed for the design of a connector that accommodates bolted connection to a gusset plate on one end and complete joint penetration (CJP) welded connection to a round HSS brace member on the other.

Thus, in practice, the cast connectors can be welded to round HSS braces in the shop using a turning roll, with the brace-connector assembly being bolted to the

Editor's Note: Cast ConneX's Universal Pin Connectors for HSS were launched at the North American Steel Construction Conference in April in Nashville. More information on structural steel castings can be found at the Steel Founders' Society of America website, [www.sfsa.org](http://www.sfsa.org). For more information on Cast ConneX, visit [www.castconnex.com](http://www.castconnex.com).



A brace assembly being tested.

gussets in the field. Further, each connector is standardized to accommodate all round HSS of a given outer diameter, regardless of wall thickness or grade of steel. The specification of a pre-qualified CJP shop weld between the connector and the round HSS eliminates the need for field welding of the demand-critical welds between the gusset plate and the brace member.

### Standardized HSS Connectors for Architectural Use

An emerging trend in steel construction is the use of exposed structural steel and connections. Because of its aesthetic appeal, HSS are commonly used in exposed applications, and true-pin connections to round HSS are commonplace in airports, stadiums, and atriums. However, it's no secret that the fabrication complexity of true-pin HSS connections increases significantly as the required aesthetic increases.

When extraordinary aesthetics aren't required, a pin connection detail can be accommodated with a single gusset plate inserted into a slot created in a round HSS member. As discussed above, this slotted HSS-to-gusset detail is a typical end connection for wind loaded HSS braces and does not present any significant fabrication challenge. The complexity of the pin connection arises in the clevis-type connection at the base of the pin that receives the single plate fixed to the HSS member. Here, two plates are necessary, since pin connections must maintain a concentric load path. Due to the relatively small gap between the two plates, both can-

not be fillet welded to the base plate; one of the two plates must be fastened to the base with a groove weld. Further, the parallel alignment and match up of the pin holes in the two plates is critical, as the 2005 AISC *Specification for Structural Steel Buildings* requires that the pin hole be only  $\frac{1}{32}$ -in. larger in diameter than the pin itself. With almost no tolerance allowed in the pin hole, any out-of-straightness or misalignment of the plates may lead to significant field erection challenges. The fabrication difficulties increase with other more aesthetically pleasing pin-type end connections for round HSS.

### Mass Quantities

It is well known that castings become economically viable with repetition or as the fabricated alternative increases in complexity. Given the complexity of aesthetic fabricated pin connections, as well as the opportunity for mass production, it is clear that a series of standardized cast steel pin connectors for HSS could be practical. In addition, casting manufacturing allows for a streamlined and curving connection geometry that is otherwise unattainable using standard fabrication practices.

Cast ConneX has now developed a line of standardized pin connectors that are meant for use as architecturally exposed structural connections. The company's "Universal Pin Connectors" provide attractive, smooth, compact, and robust connections that can be easily integrated into a structure and can save steel fabricators and designers hours of complex engineering, detailing, and fabricating. And with the "off-the-shelf" approach, schedules can easily be accommodated in a fast-track job.

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Cast ConneX Universal Pin Connectors.

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