A Tale of Two Projects

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Teams from two health-care projects offer some insight into choosing between field-welded and field-bolted moment connections.

WHETHER IT'S A 5,000-SQ.-FT ADDITION OR A $185 MILLION FREE-STANDING BUILDING, MOST OF THE HEALTH-CARE FACILITIES WE'VE DESIGNED DURING THE PAST DECADE SHARE THE SAME LATERAL FORCE RESISTING SYSTEM: A STEEL MOMENT FRAME.

This preference is the result of special design requirements for "essential facilities," as well as the unique combination of a need for long life and renovation flexibility in health-care construction.

Most hospital buildings are considered essential facilities, which the 2003 International Building Code defines as "buildings and other structures that are intended to remain operational in the event of extreme environmental loading from flood, wind, snow, or earthquakes."

At the same time, it's typical for health-care buildings to be kept in service longer than the typical 50-year life cycle. However, medical campuses frequently morph and change—constructing new facilities, demolishing outdated buildings, and renovating and adding on to existing buildings—all in an effort to keep up with the constantly evolving "state-of-the-art" for modern medicine and clinical practices.

Because of this "ever-changing" mentality, owners and architects prefer to use structural systems that provide as much future flexibility as possible.

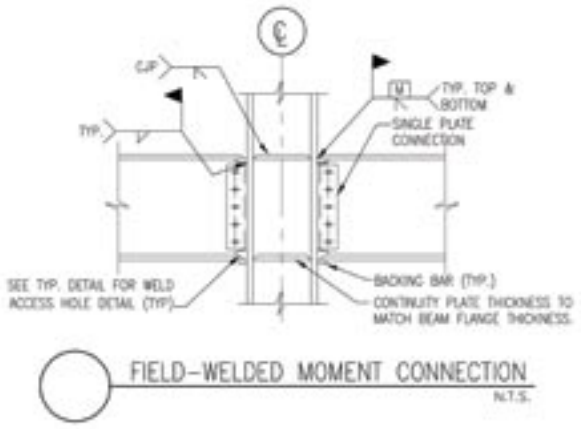

Figure 1. Typical field-welded moment connection detail.

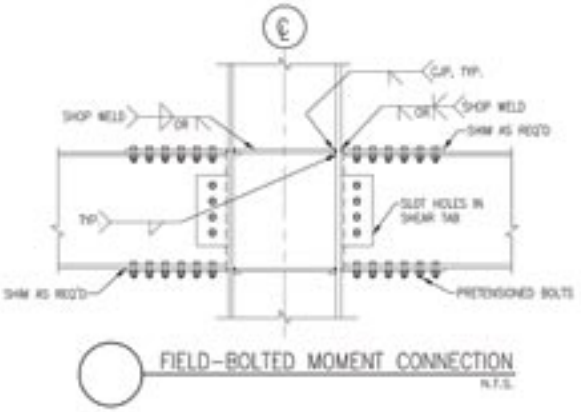

Figure 2. Typical field-bolted moment connection detail.

Two Hospitals, Two Moment Connection Details

For ordinary steel moment frame (OSMF) buildings located in the eastern half of the country, we typically provide two options for moment connections: field-welded (Figure 1) and field-bolted (Figure 2). The fabricator is then able to choose the moment connection most appropriate for the project.

By comparing two projects after completion (both in the eastern half of the U.S., with one using a field-bolted flange-plate moment connection and the other a field-welded moment connect), we can objectively look at lessons learned and challenges faced during the detailing and construction phases.

The Heart Hospital at SwedishAmerican Health System in Rockford, Ill. is a four-story, 130,000-sq.-ft facility that was designed to accommodate a future two-story vertical expansion. The fabricator on this project, Zalk Joseph Fabricators, went with flange-plate moment connections using all field-bolted connections.

The second project, the Women and Infants Building at the Maine Medical Center in Portland, is a five-story, 210,000-sq.-ft facility that was also designed to accommodate a future two-story vertical expansion. The fabricator, Novel Iron Works, chose field-welded moment connections for this project.

A Seismic Note

Both projects are located in regions of low or moderate seismic activity and were designed as OSMFs. The contract documents specify that the detailing of the moment frames conforms to AISC *Seismic Provisions*

for Structural Steel Buildings, which requires the moment connection to develop the full plastic moment capacity of the moment girder.

During the construction phase of the Heart Hospital, the detailer asked if they could design the moment connections using a seismic response factor R = 3, consistent with a steel system not specifically detailed for seismic resistance. This is common practice in the low-seismic region of the Midwest. However, since the building was designed for a future vertical addition, and because it is uncertain how future code revisions may restrict the use of the R = 3 design and detailing practice, the OSMF system was retained.

Choosing the Proper Connection Type

During interviews with the construction managers (CMs), fabricators, and erectors for these two projects, five key criteria were factored into the selection of either welded or bolted moment connections:

Historical regional common practice. Past experience with steel moment frame projects and the prevailing common practice in the local geographic regions played large roles in both projects, in terms of the decision to use moment connections. According to Novel, approximately 90% of typical moment connections in New England are field-welded and 10% are field-bolted. In comparison, Zalk Joseph estimates that over the past decade approximately 50% of the steel moment frame structures they've fabricated used field-welded connections and 50% used field-bolted.

Labor cost: shop labor vs. field labor. Field-bolted moment connections typically require more shop fabrication time to shop-weld large flange plates to the columns with complete joint penetration (CJP) welds. However, the amount of field labor should be considerably less, because installing bolts is faster than field-welding.

In the Rockford area where the Heart Hospital is located, the local ironworkers union requires a two-person team (one welder and one helper) to work on all field-welded moment connections, which effectively doubles the amount of manpower—with certified welders at a premium—and increases the amount of welding equipment needed. Zalk Joseph chose to shop-attach the flange plates, anticipating that the reduction in field labor would compensate for the increases in required shop hours, resulting in a net savings.

The flange plates were fabricated with an extra ¼-in. gap—to accommodate beam depth tolerances—which was filled with full-coverage shim plates with matching bolt holes after erecting the girder. Because the flange plates were designed to develop the full plastic moment capacity of the moment beams per the AISC *Seismic Provisions*, the fabricator considered the physical size of the flange plates to be burdensome. The flange plate thickness (up to 2 in.) and length (up to 3 ft 6 in.) made coordination troublesome with the architectural precast façade connections bearing on the exterior moment frame girders near the moment connections. The thickness of the plates also required additional flange extension plates to support the metal deck near the ends of the beams.

Weather concerns. Weather is another critical factor to consider as it can impact the erection schedule. CMs for both projects mentioned that the anticipated time of year for construction—and the related weather patterns—plays a role in selecting a moment connection detail. If steel erection was to be scheduled for the winter, they recommend bolted flange plate connections, since bolts can be installed in most weather conditions. However, if the weather was to be favorable during the erection phase, both CMs preferred using field-welded connections since the erection tolerances are not as strict. (Field-welding is significantly more weather-dependent than field-bolting, especially in sub-freezing winter climates and during rainy weather.)

Preheating top flange of moment girder before welding in cold weather conditions at Maine Medical Center.

Erecting Heart Hosptial's column "trees" with shop-attached flange plates for bolted moment girder connections.

A completed bolted moment girder connection with top and bottom flange plates at Heart Hospital.

SwedishAmerican Health System's Heart Hospital in Rockford, Ill. is a four-story bolted steel moment frame with capacity for two additional stories.

Since much of the Women and Infants Building's steel erection occurred during winter months, the welding schedule was significantly impacted by severe cold, wet, and windy weather. William A. Berry & Son, the CM, said they would seriously consider using a bolted moment connection for future projects where steel erection was scheduled for winter months.

Conversely, because the construction for the Heart Hospital occurred mostly during warmer months, the CM on that project said that if they had to do it all over again they would likely go with field-welded connections to avoid much of the coordination problems between the bolted connections, precast supports, and metal deck. Zalk Joseph said that in hindsight, the savings they received on the field labor during steel erection was not adequate to offset the increase in shop time spent making flange plate connections.

Construction schedule. Both CMs indicated that the construction sequence, schedule, and logistics are always driving factors in selecting a moment connection design. Erecting a complete steel-framed building involves several different subcontractors working in concert with each other, with the CM serving as the conductor, directing the overall performance to ensure that each piece is constructed in the proper sequence.

On the erection side, the common industry assumption that field-bolted moment frame erection is faster than field-welded may not hold true in all cases. Novel said that the steel erection schedule typically drives the decision to use field-welded connections, noting that crane time is a primary component of the erection cost and that many erectors would rather take time after the pieces are erected to finish welding the connections rather than sacrifice crane time for troublesome erection.

Field-welded moment girders can be erected in the same manner as typical gravity framing, with a few bolts in the webs on each end of the girder to hold it in place. Once the shear connection is started, the steel erection crew can move on with the next piece of steel while the bolt-stuffing crew follows behind.

During erection of the bolted flange plate connections at the Heart Hospital, the steel erector, J.P. Cullen, commented that they had to line up not only the bolt holes in the beam web, but also several of the bolts in the top and bottom flange plates so that all of the bolt holes were aligned, before the crane could be "cut loose" to erect the next piece of steel.

Although erection of the bolted flange plate moment frame takes longer than the welded moment frame, once the steel is erected and in place, the bolted moment connections can typically be completed much faster than the field-welded moment connections. The bolted connections simply need the remainder of the bolts to be installed and tightened, and if tension-controlled (TC) bolts are used, the visual bolt inspections can be done quickly and easily.

In comparison, the welded moment frames need the remaining bolts in the web connection to be installed and tightened (often, slip-critical bolts), and then welding of the flanges can begin. Typically, several certified welding crews are required simultaneously on each project to ensure that the CJP welds can be completed in a timely manner. After the welding is completed, CJP welds must be ultrasonically tested by a certified weld inspector. Since the field-welding and inspection process is time-consuming, poor weather conditions can cause significant delays to the overall construction schedule.

Coordination with subsequent trades. Only after the moment connections are completely installed and inspected can the other trades follow. The metal decking crew will lay out the metal deck and fasten it to the steel framing, and then the rebar and concrete crews will place the reinforcing steel and the concrete slabs.

The metal decking crew must coordinate closely with the welding crew so as not to cover up incomplete steel connections, or the decking must be cut open to allow the welding crew to finish the incomplete connections. William A. Berry & Son stressed that the erection flow should properly schedule erection, welding, inspections, decking, and slab pours. The number one issue from the CM's standpoint is keeping all trades moving in unison. This involves making sure that connections are accessible for welders while the decking crew is installing deck and that the welds and inspections are completed prior to moving on with the construction sequence.

In Retrospect

OSMFs continue to be a preferable lateral force resisting system for health-care facilities in low and moderate seismic zones because they provide expansion capability and floor plan flexibility. Field-welded and field-bolted moment connections each have their own respective places in the construction industry. The dominant factor in deciding which connection to use turned out to be the anticipated weather conditions during the bulk of the steel erection phase. If erection is scheduled for spring, summer, or fall, welded connections would likely be the prevailing choice. And if steel erection will occur during winter months, serious consideration should be given to a field-bolted moment frame. Whenever possible, this decision is best left in the hands of the construction team. MSC

Maine Medical Center's Women and Infants Building in Portland, Maine (scheduled for completion in 2008) is a five-story welded steel moment frame with capacity for two more stories.

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Heart Hospital at SwedishAmerican Health System

Owner
SwedishAmerican Health System, Rockford, Ill.

Structural Engineer
Simpson Gumpertz & Heger, Inc., Waltham, Mass.

Architect
Perkins + Will, Inc., Boston

Construction Manager
Turner Construction Co., Chicago

Fabricator
Zalk Joseph Fabricators, LLC, Stoughton, Wis. (AISC Member)

Women and Infants Building at Maine Medical Center

Owner
Maine Medical Center, Portland, Maine

Structural Engineer
Simpson Gumpertz & Heger, Inc.

Architect
TRO-Jung|Brannen, Inc., Boston

Construction Manager
William A. Berry & Son, Danvers, Mass.

Fabricator
Novel Iron Works, Inc., Greenland, N.H. (AISC Member)