Constantly updating vendor-supplied loading information allows engineers to stay just ahead of fabrication and construction.

A Timed-Release Design

BY CRAIG WEISENSEL, P.E., LEED AP

HOW FAST CAN YOU DELIVER a project from schematic to owner occupancy? If given the chance to design a building in a complete vacuum, could you deliver faster than 99.9% of all projects? Could you achieve this speed while also maintaining a least cost scope mentality and streamlining an efficient design? Oh, I may have forgotten to mention this facility isn't a typical \$150-sq.-ft office; this is a \$900-sq.-ft complex fill-finish facility. Project success will hinge on orchestrating an entire team to work in unison, from design through construction. Are you ready for the challenge?

This was the setting and challenge the design-build team for a biotherapeutic company's new fill-finish facility was presented with in December 2006. The goal was to attain full occupancy of the 290,000-sq.-ft facility within 24 months. To accomplish that required a full commitment to teamwork by every individual on the project site. Team members would only be able to move fast if they moved together, emphasizing that every individual on the project was accountable not just for his or her own specialty, but for the overall success of the project's delivery.

Located in the Pacific Northwest, the facility resides on 12.5 acres of a 75-acre site and is a super-block of five separate buildings—manufacturing, warehouse, distribution center, administration building, and a central utility plant. All are designed to U.S. Food and Drug Administration (FDA) standards, including its Current Good Manufacturing Practices (CGMP), for the final manufacture, packaging, and shipping of pharmaceutical products. Work began first on the distribution center and continued through each of the other four major components,

▲ The flexibility of structural steel allowed easy integration of unique design features, such as projecting conference rooms along the main street corridor.

➤ **Top:** A gravity-fed system works great from a process planning standpoint. However this system arrangement locates the heaviest equipment on the top floor, which makes seismic design quite interesting.

➤ **Middle:** The site during July 2007 had steel being erected and foundations being poured. While structural drawings were completed months before, the balance of the design team was just completing CD's.

➤ **Bottom:** Concrete pump nozzles were detailed at the bottom of each brace, and the braces were filled from the bottom up. The nozzles were removed and the braces were patched per the protection zone requirements.

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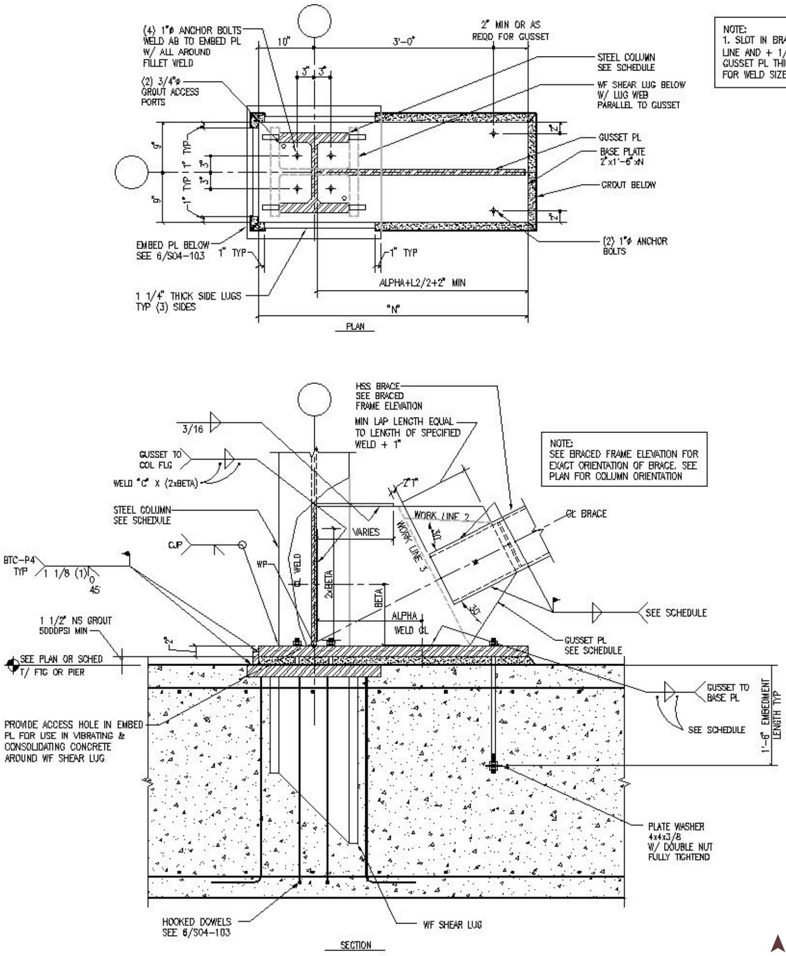
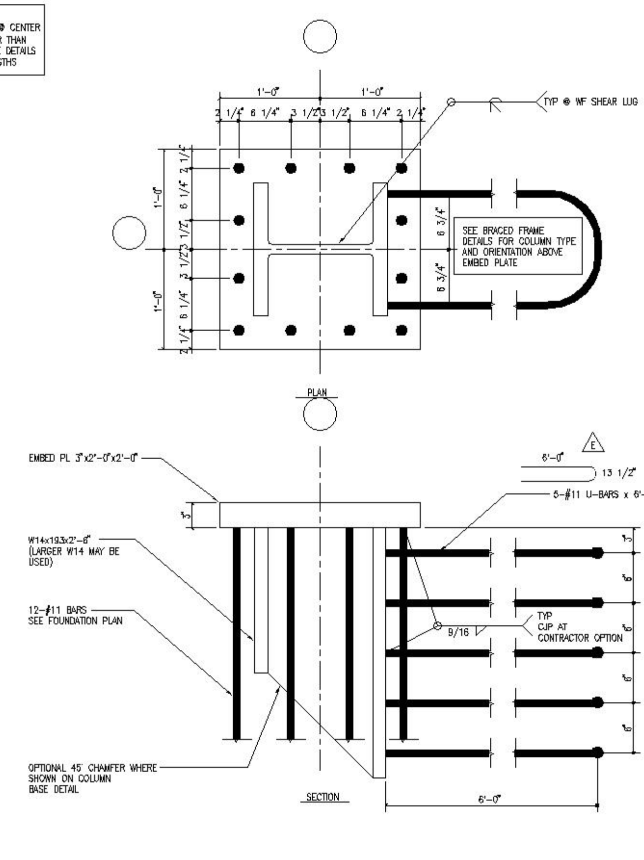


DETAIL AT WF COLUMN WEB CONDITION



DETAIL AT WF SHEAR LUG

▲ The SCBF frame connections at the foundation were designed in accordance with AISC 341-05. Do you still call it a shear lug if you use a W14x193?

◄ The SCBF connection and gusset plate was dramatically smaller than typical because of the benefits of concrete-filled tubular braces.

erecting the entire steel structure, totaling 5.4 million lb, in only six month's time. In the end, the team delivered the finished facility to the owner two months ahead of schedule, a combined effort totaling one million construction hours.

Structural Steel Team

Critical path elements included the concrete, steel structure, and skin of the building. Due to a combination of the aggressive project schedule and the time of year in which construction began, the critical path focused directly on structural steel. The fall rainy season would be approaching and the building needed to be enclosed as quickly as possible, causing the fabrication and erection of steel to become a main driver. For every day lost on the critical path, days also would be lost on the entire project's master schedule.

While the overall design effort was only beginning in late 2006, the general contractor realized that because of the shorter than usual schedule the steel fabricator, erector, and detailer would have to be brought onboard almost immediately to begin work with the design team. Although a nontraditional approach, this decision ultimately would aid in both team communication and speed of delivery.

With the opportunity of early engagement in the project, the fabricator, erector, and detailer were able to work directly with the design team to find efficiencies in design and fabrication. These included opting for custom seismic bracing and designing to use readily available materials, resulting in quicker erection of the steel structure. Many coordination meetings took place with the design-build team and steel contractors to understand the scope, schedule and plan.

As design was still progressing, the fabricator worked with steel service centers to find the material's availability and used mill rolling schedules to establish overall lead times. It was determined that between the steel fabrication schedule and overall project timeline the procurement process needed to begin only weeks into the design effort.

At only six weeks into the design process the structural team had

- Close coordination was required with the structural steel fabricator/detailer for the layout of each brace connection. Shop drawings were shared electronically to expedite the review and allow instant approval.

calculated the tonnage of steel for the five buildings and produced material take-off lists for the fabricator. The take-off allowed the fabricator to order the billets to ensure the entire tonnage of steel would be available and delivered on time so fabrication could start on schedule. The team was locked into a project tonnage, including billets, at schematic level of drawings. Even though purchasing steel at schematic design level seems entirely too early, this decision was critical to maintaining the overall delivery schedule.

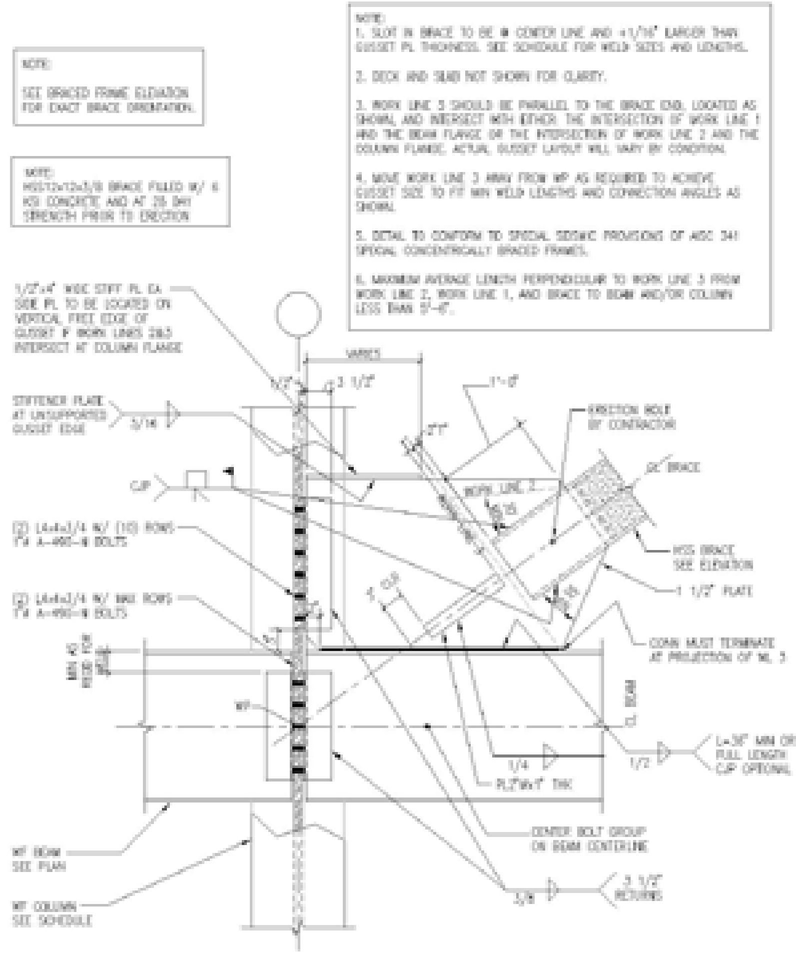
Custom Seismic Design for Performance

Another unique aspect of this project was the use of custom seismic design requirements, above code minimum, to meet the risk mitigation needs of the owner. Even though the seismic requirements in the Pacific Northwest are moderately high, the owner desired to increase the standards for this building above the code minimum requirements. The end result was a seismic design level comparable to a building located in the highest seismic zone.

A proprietary system such as buckling-restrained braced frames (BRBF) would have been ideal for this application. However, through previous experience with BRBF, the design team realized that the constraints of the schedule would not allow enough time to design and coordinate this type of system.

The team needed a lateral system that would not only perform as needed for the custom seismic design requirements, but also be readily available to fabricate and erect. The ultimate solution to this challenge was to use hollow structural section HSS12×12×⅜ concrete-filled tubular braces. This system met the special seismic requirements while also providing a solution to keep the critical path fabrication and erection on schedule.

The tubular braces that would eventually contain the concrete were shipped hollow to the job site. Each brace was first lifted into place, then filled with concrete. A nozzle attached in the shop to each brace simplified the work of filling the braces in the field. Flowable concrete was pumped into the brace from the bottom end ensuring consolidation and preventing voids within the concrete. The nozzle was then



removed and the area repaired per the protected zone requirements.

The concrete-filled tubes offer superior characteristics beyond typical braces including:

- Increased number of cycles before brace failure.
- Changes in local buckling mode, reducing the severity and delaying the occurrence of cracking.
- Reduced local buckling.
- Composite design allows for smaller HSS brace sizes.

The efficiency of this brace also reduced the overall area of steel required in each brace, which in turn greatly reduced the brace connections required to meet AISC 341-05, 13.3. The concrete-filled tubular brace system was a perfect compliment to the overall special concentrically braced frame (SCBF).

The sequencing of brace construction was planned specifically around the critical path. The concrete filling was a field activity, instead of a fabrication process, therefore removing a step from the critical path for brace fabrication. As a result, the contractor gained float time to manage these secondary activities being done simultaneously with the critical path.

Overall Team Coordination

As the overall building design effort was finishing the design development stage, the steel design was already nearing completion, the fabrication process was under way, and foundations were being poured. Steel began arriving on site even before the finishing touches were put on the design. The schedule of this project simply did not allow the team the luxury of taking one step at a time. Instead, the different pieces of the building complex were constructed and finished as they were ready. Design information was constantly being updated for the complex formulation and production process and the structural team was taking any new or expanded information and validating the overall structural design.

A specific example of the coordination necessary between the design and steel team members was planning for and installing the lyopholizer—a two-story piece of equipment weighing more than 90,000 lb. Supported on the facility's second level, it has a pendulum piece that hangs below through the floor. Other pieces of equipment with special structural needs included isolators with 400 psf footprints and formulation equipment with independent platforms.

Accommodations had to be made for the proper support and installation of these specialty pieces. In this effort, the structural engineer and architect helped define datum point

Project Snapshot

- $400 million total project cost
- 2,700 tons of steel
- 3 months from start to first IFC steel package issued
- 5 months from start of design to ground breaking
- 7 months from start of design to erecting steel
- 24 months from concept design to mechanically complete
- 17 weekly standing meetings
- 1 million construction hours worked
- 520 trade workers on site at height of construction
- Very safe site—94% better than industry standards

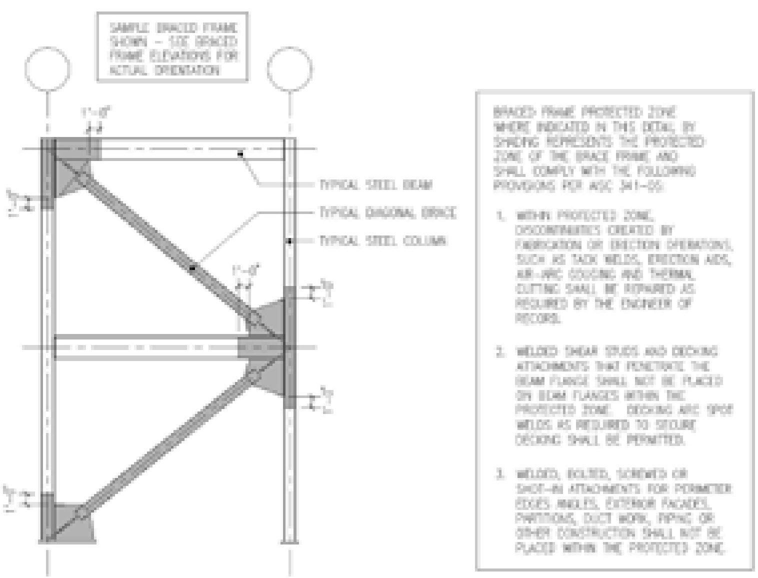
locations for locating the equipment in the building and developed support infrastructure (platforms) for all process equipment, working closely with the process engineer on the maintenance requirements.

All equipment was validated and real-time updates were passed on to the steel team through constant communication. The structural engineer was also on site daily for the majority of steel erection to expedite problem solving and coordination.

Unique Site Safety Considerations

The steel team began work on the facility with the structure of the Distribution Center and continued across the complex to build each of the other facets. As soon as each major section of the structure was erected, work began to outfit the interior. At the height of the project, workers were setting steel and tying rebar on one side of the site while on the other side, floors were being laid and plumbing and electrical components were being installed.

Due to the large number of different trades working on the site at any given time, along with the fact that many of them rarely interact on a typical job site, the general contractor took heightened measures to communicate the existing and potential hazards to all personnel. A full-time quality manager documented daily pre-task plans, weekly safety meetings, and strict on-site safety rules were some of the tactics used to ensure everyone was aware of their surroundings and committed to keeping the giant site a safe place to work. As a result, accidents were kept to a minimum, resulting in a site that was 94% better than the industry standard.



New codes always bring a new surprise to the construction industry. Protected zones, as required by AISC 341-05 required coordination with all trades to ensure compliance.

BIM Coordination: Design = Model = As-Built

Another notable aspect of this job was the use of BIM to coordinate design and construction. The speed at which the project progressed demanded that all trades were fully coordinated, and that there were no conflicts in the field. Weekly BIM clash coordination meetings were held to ensure the design remained conflict free and could be constructed without issue. The construction schedule was dependent on the design team resolving issues before they became field construction problems.

The BIM coordination effort moved on a path that matched the overall construction sequence of the building. Conflicts were resolved using an efficient methodology and hierarchy from critical and essential elements down to backup and secondary elements. The BIM team was able to coordinate all MEPP (Mechanical/Electrical/Plumbing/Process) trades to ensure that all conflicts were avoided and that each discipline efficiently used available space to create a full building design that was efficient and conflict free.

The behind-the-scenes activity of BIM coordination was instrumental to the overall success of the project.

Making It Happen

Overall, the aggressive schedule required a total team approach and close collaboration. Various experts from disciplines including planning, architecture, process design, and engineering, collaborated with the owner to optimize innovation, minimize cost, and provide a holistic design approach. Approximately $12.5 million in savings was recognized through this approach. Additional savings were recognized by having the contractor assume responsibility for the on-site field coordination of the process design and installation.

Construction of the foundation and fabrication of the steel began only months into the overall design effort, experiencing no major issues through the end of construction. By coordinating at every stage of the process to confirm the validity of assumptions, the design team was able to maintain the necessary pace of design and construction. A key element was the ability of the team, as a whole, to come together in the design of this facility. As expressed by the general contractor, "we would either succeed as a group or fail as a group—there could be no individuals on this project. We had to work to understand each other and get there together."

In the end, the engineering of the buildings was completed in 7.9 months. According to industry standard information from Independent Project Analysis Inc., this is faster than 99.99% of projects delivered. Considering the complexities of a $400 million, 290,000-sq.-ft, high-tech pharmaceutical manufacturing facility, the speed and success of the design-build team was a remarkable feat. MSC

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