Engineering the Building of Buildings

BY ANDREW TWAREK, SE, PE

Construction engineering is a diverse, challenging, and crucial branch of structural engineering that ranges from shoring supports to designing for temporary loads on existing structures.

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WHEN I TELL PEOPLE I'm a structural engineer, they assume I design buildings or bridges—which is fair.

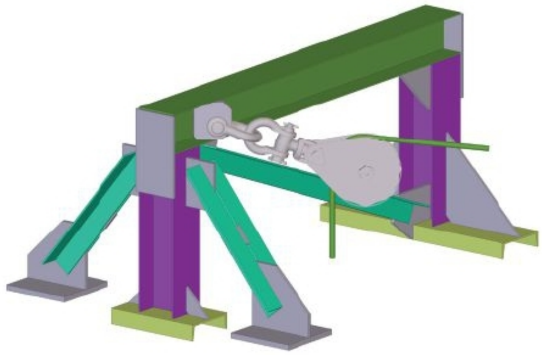
While many structural engineers do that, there are other specializations within the field that aren't geared toward new project design but that still use the background of structural engineering. It's this wide variety of project and client types that I enjoy—especially construction engineering.

Construction engineering, as a branch of structural engineering, is distinct from the engineering needed to design the structure itself and often includes assistance with the contractor's "means and methods" and the details that are needed to get a project from a plan to the real world. For purposes of this article, it can be defined as specialty work performed by a structural engineer (usually with a PE or SE license) to provide solutions to problems encountered during the construction or modification of a structure.

However you define it, construction engineering is rarely if ever mentioned in college curriculums, and I've never seen a textbook for it. Instead, it relies on basic structural engineering principles (statics, and sometimes even dynamics!), material-based codes and specifications—such as AISC's *Specification for Structural Steel Buildings* (ANSI/AISC 360, aisc.org/specifications)—and a variety of specialty or proprietary resources (like shoring tower manufacturer brochures, concrete anchor calculations, rigging components, construction equipment documentation, and more).

What does a construction engineering project look like? Project types are diverse, but typical examples include:

- Temporary shoring or supports
- Demolition design and stability analysis
- Reviewing construction equipment loading on elevated structures—e.g., a worker lift on a second-floor slab
- Designing for temporary loads on existing structures—e.g., crane pressures on a basement wall



A 3D model of a steel support frame used to install an electrical transformer on a tight site where a crane wasn't feasible.

- Loads for construction safety equipment or systems (personal fall-arrest tie-off points, temporary platforms, etc.)
- Field modifications or repairs to construction defects

A Tight Fit

Let's get into the details of some real-life construction engineering projects that Ruby + Associates has been involved with.

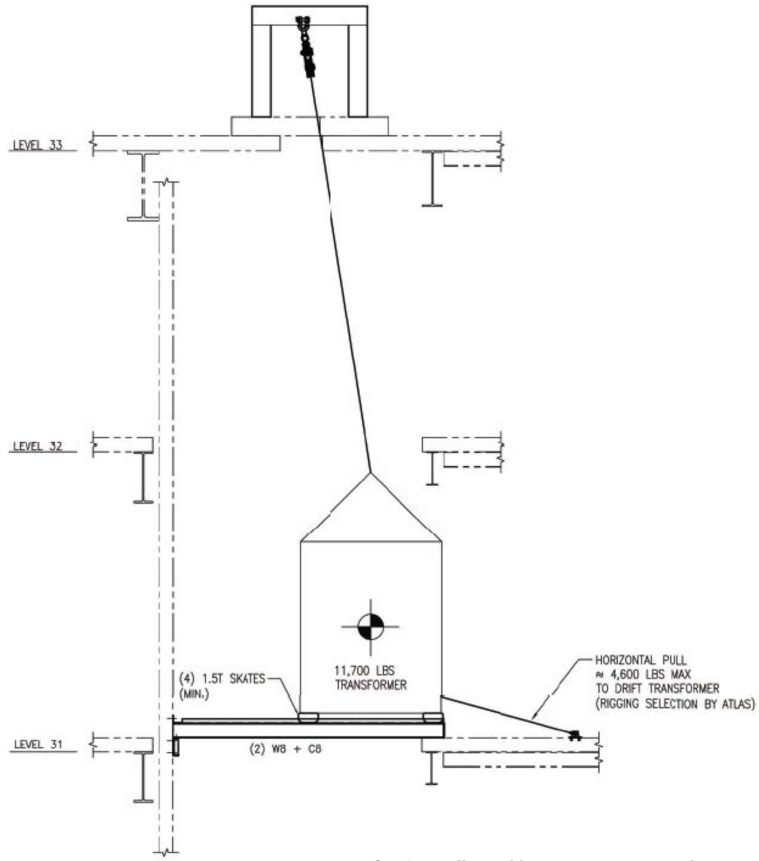
In the first one, a longtime client called us to assist with the installation of an electrical transformer for a building. My initial thought was that it sounded like something I'd done several times before. I pictured a crane placed next to a concrete pad, a semi trailer pulling up alongside, and the crane picking up a box and setting it down. Easy peasy.

Unfortunately, the transformer was to be installed in a downtown area with limited room for cranes and material lay-down. Additionally, the building was over 500 ft tall—beyond the reach of the largest hydraulic crane in the region.

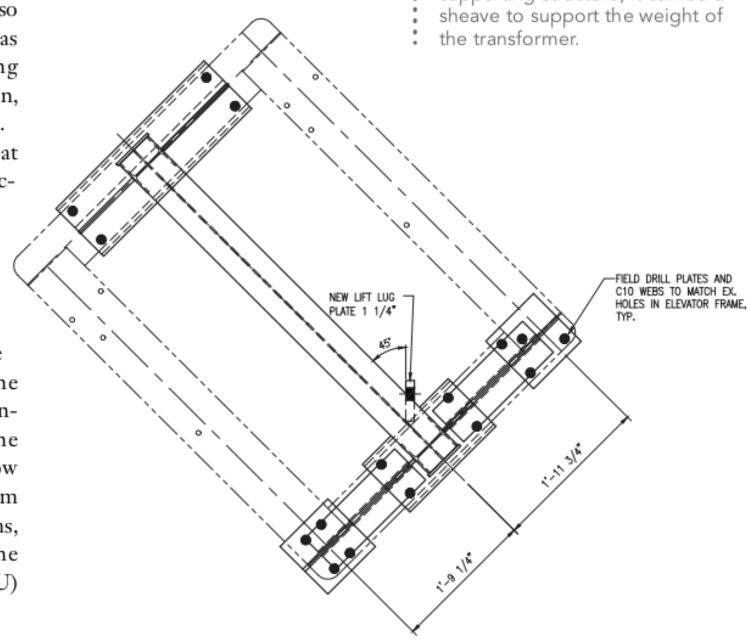
However, the transformer was just small enough to fit in the freight elevator shaft and could be raised that way, so that's what the contractor decided to do. The only catch was getting it into the shaft and raising it 30-plus stories. Using the elevator motor and cables wasn't going to be an option, so the contractor needed a structural engineer to help out.

We started by designing a small steel hoist structure that could be installed on the elevator support beams. Structural steel was the only solution that provided enough strength and could also be brought up in small enough pieces to be put into place. Once connected together and bolted to the supporting structure, it would carry a sheave to support the weight of the transformer.

An air tugger (or winch) was placed on the other side of the elevator equipment room wall, and we analyzed the existing steel floor framing and designed some small connector beams to anchor the tugger to the floor. Once the transformer was raised to the proper level one floor below the temporary hoist structure, it had to be removed from the elevator shaft. The Ruby team designed track beams, which were supported on the concrete slab outside the shaft and anchored into the concrete masonry unit (CMU) shaft wall at the other end, to "skate" the transformer.



A small steel hoist structure used to lift the transformer was installed on the support beams of an elevator shaft. Once connected together and bolted to the supporting structure, it carried a sheave to support the weight of the transformer.



With tight tolerances, many limitations, and a short schedule, this project presented plenty of challenges that required outside-the-shaft—er, box—thinking.

Shored Up (Down)

Our second example is tied to a common source of construction engineering projects: modification of existing structures. Building renovations requiring changes to a structure—like adding elevators, for example—can trigger the need to meet updated code requirements.

Hydraulic elevators are efficient for low-rise structures, and their equipment requires a pit below the lowest floor serviced. It's rarely convenient to place an elevator in the middle of a bay, so the elevator pit often interferes with an existing column footing. Additionally, if the original building drawings have been lost, identifying the size of the existing footing typically can't be done before design is complete and construction begins.

In this case, our client received drawings with a note indicating "existing footing, field determine if depth and extent prior to placement of elevator foundation, underpin and cut existing footing as needed to install elevator." This is a fairly vague statement for a contractor. How much underpinning? How to provide stability during construction? Once again, the contractor needed help from a structural engineer.

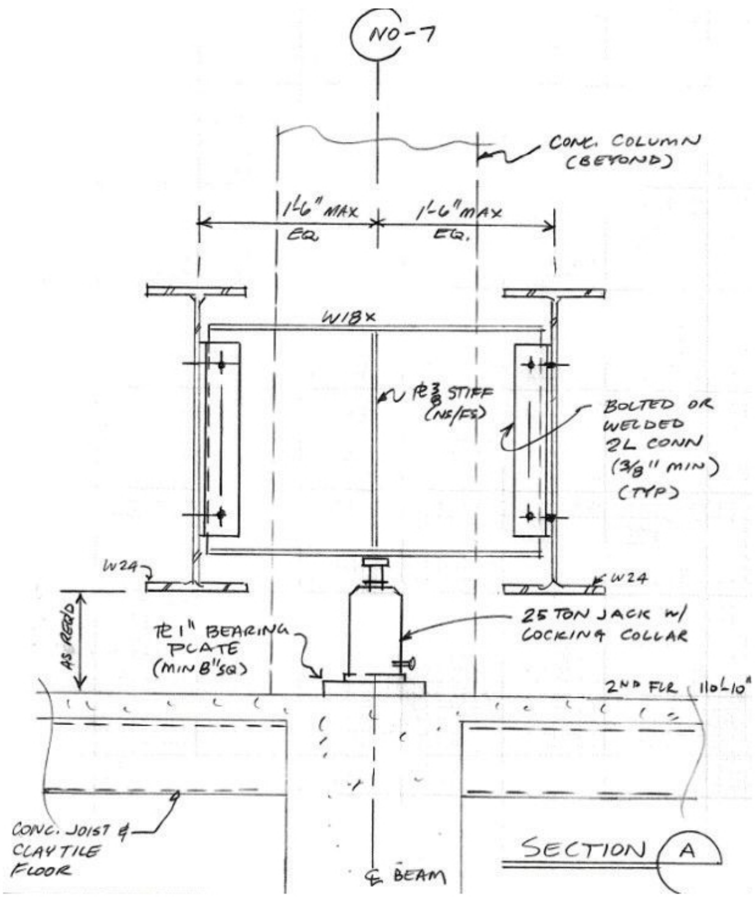
We came in and looked at the problem with the contractor, who revealed that there were additional space limitations in the basement that

The framing for the transformer hoist system, in place.

prevented increasing the footing size. As such, providing support in the basement during undercutting would be even more difficult.

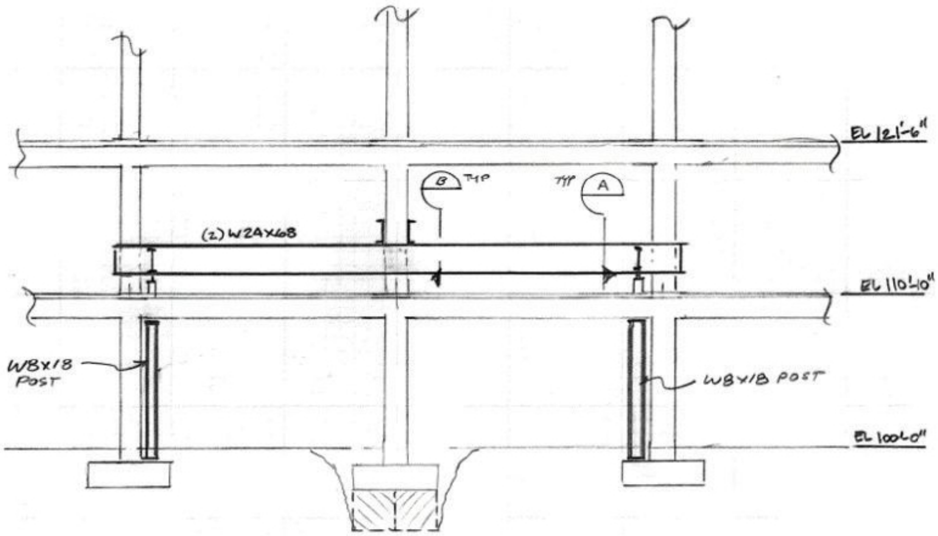
The solution we came up with was to provide shoring—but from above. Looking at the load on the concrete column during construction and the capacity of the adjacent footings, we determined it would be possible to spread the column load using structural steel beams at the first floor.

Two W24×86 beams were brought in through windows at the first floor level and installed to sandwich the existing column. Heavy threaded rods were grouted through the column and connected to bearing channels to load the beams. In order to remove load from the footing, hydrau-



above: A sketch for a temporary shoring system used to modify an existing elevator footing.

right: The system involved spreading a concrete column load using structural steel beams.



For the elevator footing project, W24×86 beams were installed to sandwich the existing column.

lic jacks preloaded the ends of the shoring beams. This allowed the construction crew plenty of clearance—and enhanced safety—to dig out and remove the corner of the existing footing "as needed."

Flying Platform

Construction engineering isn't just for traditional buildings, but also for structures such as oil refineries. These facilities process

Structural, Construction, or Erection?

A branch of structural engineering similar to construction engineering is erection engineering, which deals with the sequencing and stability of a structure during the construction or erection process to ensure the partially assembled structure remains safe until its completion.

The term construction engineering is also used by the Construction Institute of the American Society of Civil Engineers (ASCE CI) to refer to "the designing, planning, management, and delivery of vertical and horizontal infrastructure construction projects. The work performed on the projects may include new work, additions, alterations, or maintenance and repairs."

hundreds of thousands of barrels of crude oil a day, so every day that they aren't operating is problematic. They often have to work months or even a year in advance of an anticipated turnaround to plan, schedule, and make sure everything happens smoothly and without delay.

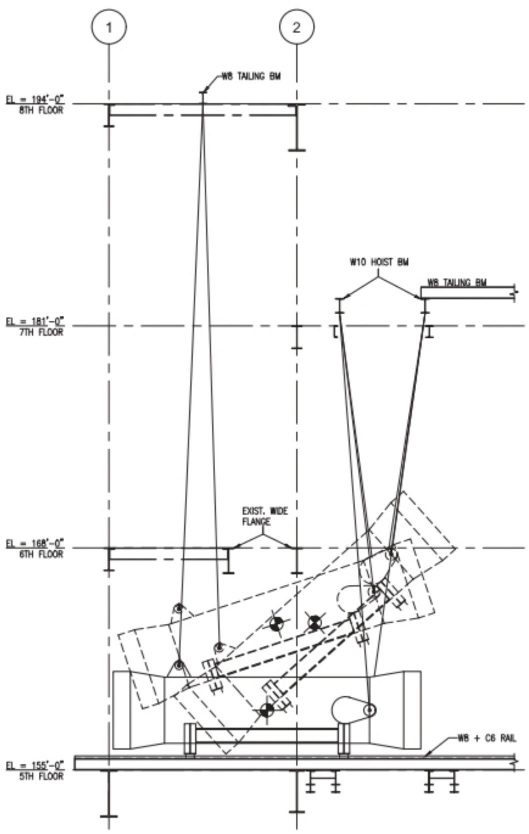
For a recent Ruby construction engineering project, a refinery client was preparing for a large turnaround, replacing a major reactor vessel and many connecting components. Preplanning as much work as possible and staging equipment to save time once the oil stopped flowing was crucial to minimizing downtime.

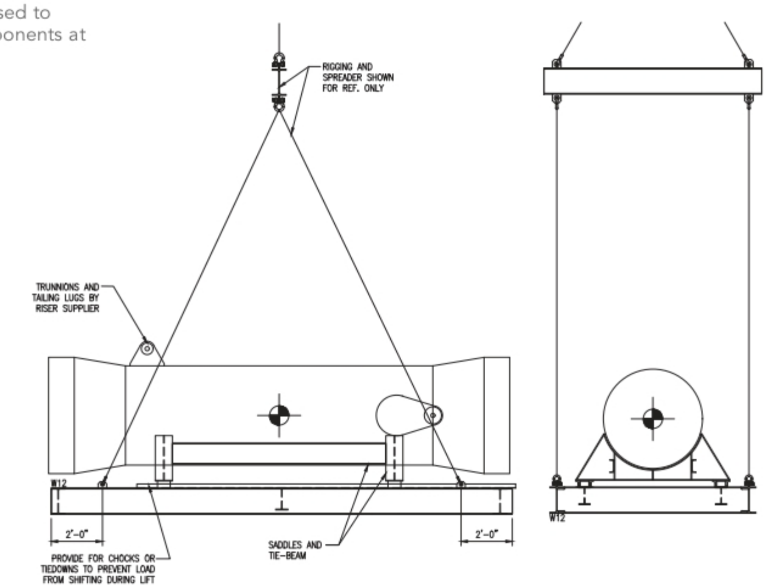
The reactor was fed by two 8-ft- to 10-ft-diameter risers that were to be replaced. Instead of putting the new ones in the same location as the old ones (which could only happen during the turnaround) the new risers were to be installed adjacent to the existing ones and connected as fully as possible in advance—with just a short tie-in piece to be installed when the new reactor was ready. The steel tower around the risers and reactor required extensive modification designed by the structural engineer of record to support the new riser, but the matter of installing sections was up to the contractor.

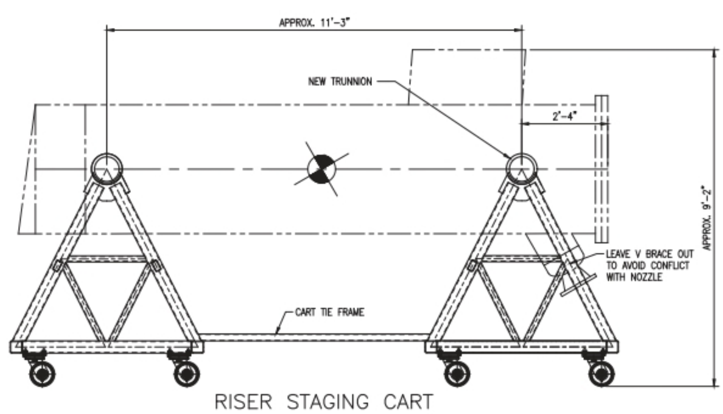
The fifth floor provided the best clearance into the steel tower, but the sections had to come in horizontally. We designed a series of saddles that could be bolted together into a rolling cart for each section. The cart would then ride on a platform with a track of upturned C6×8.2s. Each section was loaded onto the platform at the ground level and tied off, and then the whole platform was lifted to the fifth floor. Once the flying platform was lashed to the structure, the cart was rolled off the platform and onto additional skate beams (with C6s). The matter of "uprighting" the riser sections was accomplished carefully with chain falls from hoist beams designed to span the existing steel at the seventh floor.

To save additional time during the turnaround, the client wanted to stage a cart underneath the lowest piece of the existing riser for removal. We designed trunnions to be welded to the sides of the pipe and triangular hollow structural section (HSS) frames to support the trunnions, with enough clearance for the riser section to be lowered into place—all using industrial casters for easy removal. The new riser section was then ready and waiting on a separate 8-ft-tall custom cart, ready to be rolled in for the installation.

These three projects are just a small example of the variety of work that keeps life interesting and makes construction engineering so much fun. From old buildings to new buildings, industrial facilities, refineries, and power plants, construction engineering provides a myriad of challenges to a structural engineer—as well as a solid, safe plan for bringing projects together. ■







Various views of the steel "flying" platform and rolling cart used to replace a major reactor vessel and multiple connecting components at an oil refinery.