Marrying Steel *to* Concrete

A Case Study in Detailing

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Figure 2: Galvanized steel louver supports attached to new concrete shearwalls.

Structural designs that include post-installed, bolted connections between steel and concrete elements can lead to challenging field issues and RFIs because:

- The steel and concrete elements are typically fabricated and installed by different subcontractors, who don't necessarily coordinate their work prior to installation.
- Steel construction requires tolerances on the order of 1/16-inch, while concrete construction is built to larger tolerances, usually on the order of 1 inch.
- Drilling holes in concrete for post-installed anchors frequently results in the drill bit hitting steel reinforcement.

One method of avoiding these problems is to accomplish attachments from steel to concrete with embedded plates, with field welding of the structural steel elements to the plates. However, this is not an ideal solution because the embedments can be mis-located and for exposed galvanized steel the field welding compromises the protection offered by galvanization.

The authors faced this dilemma in different forms during design of the J. Paul Leonard and Sutro Library at San Francisco State University. The design included a complete seismic upgrade of the existing building, a four-story building expansion featuring architecturally exposed structural steel, and an adjacent new building housing a high-density automated retrieval system for the majority of the library's collection. Both the existing and new buildings are concrete shear wall structures.

The design-build delivery system allowed the design team to work closely with the steel and concrete subcontractors and enabled development of creative, practical solutions, described below.

Figure 1: Installation of the high-density automated storage system.

Reinforcement Layout

The high-density, automated retrieval system required a large space (approximately 14,000 square feet, three stories high), filled with steel storage racks. These storage racks were to be anchored to the new mat foundation with thousands of post-installed anchors. Because the mat required a significant amount of top reinforcing steel, this was a potential nightmare for the installer.

For the top mat, rather than using the typical convention for specifying reinforcing steel (e.g., simply specifying #9 bars at 12-inch on center, each way), the location of each bar was specifically dimensioned such that it would avoid the locations of the post-installed anchors by a comfortable margin. (This was only possible because the exact

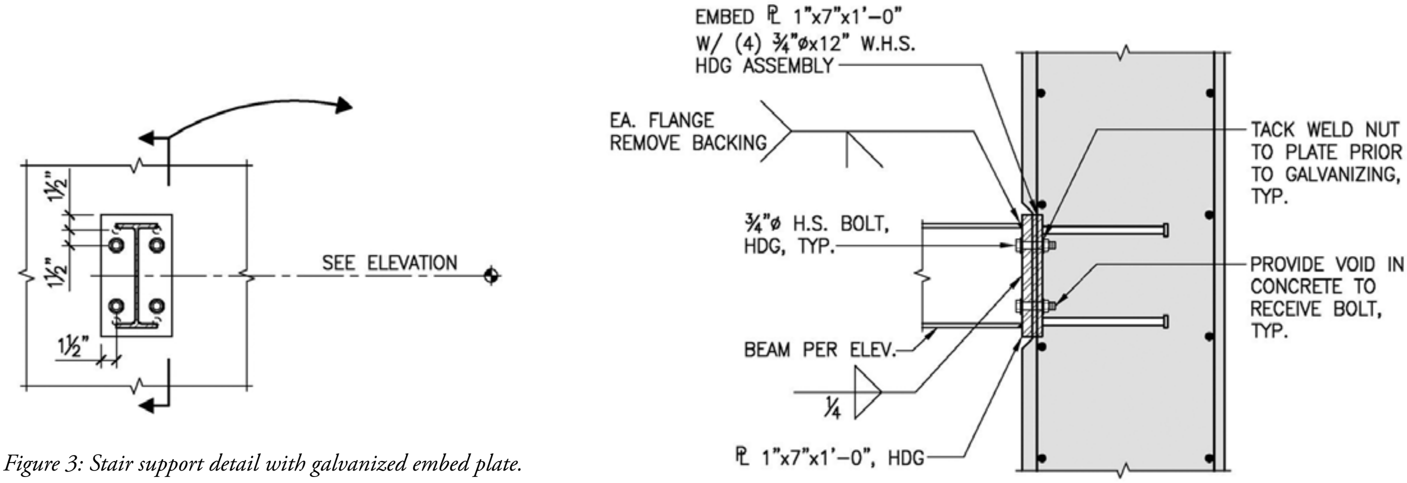

Figure 3: Stair support detail with galvanized embed plate.

locations of all the posts for the storage racks were known in advance.) This solution was successful; the contractor installed 6,700 anchors without hitting a single bar. *Figure 1* shows the steel storage racks under construction; the anchor bolts are visible in the bottom right.

Anchor Hole Layout

The mechanical system required an array of offset louvers, supported by galvanized steel cantilevered beams with shop-welded endplates that attached to new concrete walls. Again, the steel tolerances were very tight and the probability of hitting reinforcement was very high.

In this case, the design-build team opted for a different approach. First, the contractor located and drilled all holes for the louver support anchors in the walls. Whenever a hole was interrupted by reinforcement, the contractor filled the hole with non-shrink grout and drilled another hole nearby. All this was done prior to steel fabrication. For each location with out-of-place anchor holes, the contractor fabricated a special endplate for that specific location. All the endplates were shop-welded to the steel cantilevers and shop galvanized; no field modification was required. *Figure 2* shows the new concrete shear walls and installed louver supports. Note that this is a means and methods issue; in a typical design-bid-build project, this approach would not have been taken.

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Figure 4: Canopy framing with bolted splices.

Figure 6: Steel collars installed in concrete columns.

Bolted Embed Plates

The project also includes numerous exterior steel stairs that cantilever off new concrete walls. The stairs are supported by galvanized steel beams with endplates, similar to the louver supports. However, these connections were to be visible in the completed structure; they were not hidden by the louvers. The challenge then became to connect the galvanized cantilever endplates to the embed plates without field welding.

Each embed plate was fabricated with four headed studs and four standard bolt holes. On the back side of each plate (which is in contact with the concrete wall), welding of a nut at each hole's location was specified. Provision of a void in the concrete at each hole to receive the future bolt from the cantilever endplate was also specified. In order to achieve this, it was recommended to install a greased bolt in each hole prior to concrete placement. After the concrete placement, the contractor removed the greased bolts and installed the cantilever steel beams. Note that steel stairs are very sensitive to vertical tolerances; it was therefore recommended to install the beams ½ inch below the required elevation and then use galvanized steel shims. *Figure 3 (page 35)* shows one of the details for the steel stair supports.

At the main entrance canopy, a similar problem occurred; however, in this case, the steel beams spanned between new concrete columns. In order to accommodate the uncertain distance between the columns, bolted splices near the inflection points of the steel beams were specified. Shim thickness at each splice were specified as ⅜-inch plus/minus ⅜ inch.

Figure 5: Steel collars prior to installation. The steel tab is visible at the bottom center of the photo. The collars were shipped with the internal bolts installed. These bolts were then removed, prior to placing the reinforcing cage, and reinstalled with the cage in place. The nuts that receive the bolts from the canopy framing members are also visible inside the collar.

Figure 4 shows the canopy framing. Portions of the galvanized members remain exposed in the final condition. Primed painted members will remain entirely enclosed in the final condition. Close collaboration between the steel and concrete subcontractors was crucial to the success of this installation.

Steel Collars

Some of the canopy framing members (*Figure 4*) needed to cantilever off two-story, round concrete columns. The decision was to use embedded steel elements at these locations; however, details were modified for two reasons:

- The columns were cast using reuseable fiberglass forms; nothing could be mounted to the forms nor could they be damaged in any way.
- The welded headed studs would interrupt the column reinforcement cages.

In order to meet the first challenge, a circular steel collar was designed, constructed from a 20-inch diameter HSS. The outside diameter of the HSS matched the inside diameter of the fiberglass forms. Welding of small steel tabs to the outside of the collars at the exact elevation of the top of the fiberglass forms was specified. This set the collar at the correct elevation, and prevented it from sliding down into the form.

Structural steel bolts were also specified in lieu of welded headed studs. The bolts are attached to nuts that are welded to the inside of the collar. (These nuts are in addition to those used to attach the steel cantilevers to the collar.) The contractor was able to remove these bolts during placement of the reinforcing cage in the column form and reinstall the bolts after the cage was in place. *Figure 5* shows the steel collars on-site, prior to installation. *Figure 6* shows the installed collars and steel cantilevers.

In conclusion, there are many creative ways to marry steel and concrete that minimize field issues. However, close collaboration with the contractor is essential to implementing these solutions successfully. From this perspective, the design-build process is ideal.▪

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