Building Outside the Box for a New School

A charter high school in Northern California planned to make a large commercial building its new permanent home, but first the structure needed to be given a seismic upgrade without disrupting the other tenants.

By Nik Blanchette, SE; Steve Heyne, SE; and Chris Warner, SE

How do you navigate the requirement to retrofit an entire building when access is only readily available to a quarter of the floor plan due to the remainder being occupied? A charter high school in Northern California was looking for a permanent home. A great option was found in a large commercial building, however one caveat of using this space was that the introduction of a K-12 education occupancy meant that the entire building required a mandatory seismic upgrade to meet current code requirements. The IEBC notes that any increase in risk category triggers a current code update, though this may be enforced differently per your Authority Having Jurisdiction. The engineering challenge was how to design this seismic retrofit while minimally disturbing the tenants that occupied the other three quarters of the building.

The Existing Building

The building is a single-story, steel-framed structure built in the mid-1980s as part of a technology campus. The floorplan includes a sprawling 115,000 square feet of space with some smaller concrete-over-metal-deck mezzanines for mechanical systems and maintenance catwalks throughout. The roof is framed with bare metal deck over open web steel joists spanning to steel beams and girders, and solar panels cover a majority of the roof area. Perimeter walls are non-bearing, cold-formed metal stud walls with some non-structural precast concrete cladding panels. Ceiling spaces are full of mechanical ducts and piping.

Figure 1. Base of existing braced frame column retrofitted with new gusset plates and anchor bolts.

The lateral force-resisting system is ordinary steel concentric braced frames. The ground floor braced frame connections are often partially embedded in the concrete floor slab (Fig. 1). The foundations consist of grade beams spanning to concrete piers with an interior slab-on-grade.

At the beginning of design of the upgrade project in 2017, the building was divided into multiple tenant spaces, including a food processor subject to frequent health department inspections. Any work outside of the vacant school tenant space needed to be performed on nights and weekends. Work inside of the food processor space was difficult to perform at all, due to the health department inspections and requirement to fully protect the space from construction debris contamination.

The space that the charter school wanted to occupy is approximately 30,000 square feet (Fig. 2), and due to the occupancy type and expected number of students, the introduction of this occupancy type changes the entire building from Risk Category II to Risk Category III, requiring the entire building to be upgraded to current seismic and wind requirements.

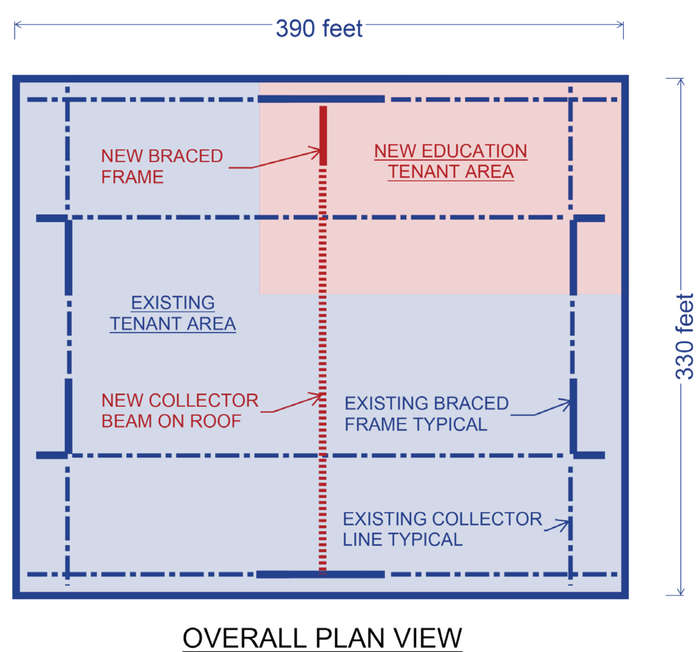

Figure 2. Plan view of existing building, including lateral system layout and new versus existing tenant spaces.

Analysis Methodology

Two options for the seismic upgrade were considered: Using ASCE 7 provisions, similar to the design of a new building, or using ASCE 41 to evaluate and justify each existing element of the building individually. A preliminary analysis was performed, and ASCE 41 was selected to most efficiently capture the capacity of existing elements and reduce the work required to meet the performance objective. It was also helpful that no material sampling was required in accordance with ASCE 41 provisions since the original drawings specified all materials of interest. Material sampling can often add significant cost and schedule time when required.

Seismic Retrofit

Existing collector lines consist of wide flange beams. Approximately half of the collector lines required new bottom flange braces to increase compression capacity of beams. Existing bolted beam-beam and beam-column connections were generally acceptable as-is.

There are six existing braced frames in the building (Fig. 2); four in the east-west direction and two in the north-south direction. The brace members have a relatively high width-to-thickness ratio. To improve ductility of these members, grout was pumped inside. This reduces the "soda can" effect of wall crushing during a cyclic tension-compression seismic event. Only one brace type lacked adequate tension capacity; cross-sectional area was added by welding plate material to increase the cross-section.

Almost all existing braced frame connection details required strengthening. Deficiencies included cross sectional steel area being inadequate, weld strength being inadequate, and plate buckling strength being inadequate. Beveled bars were used to add weld over the top of existing welds without introducing new weld directly to the existing (Fig. 3). This also kept the new weld sizes smaller, allowing fewer passes.

Some existing columns at braced frames lacked adequate compression capacity. This was remedied by increasing the radius of gyration with a welded WT section along the weak axis of the existing wide flange column.

Existing shear transfer to the foundation was adequate, however tension capacity of the anchor bolts was not. New anchors were added to existing base plates either by drilling new holes or adding gusseted plate extensions (Fig. 1). Fortunately, the existing foundations worked for the braced frames, precluding disruptive interior slab removal and foundation excavation.

East-West Frame Lines

In the east-west direction there are four existing braced frame lines in the building, one on each edge and one at each third point of the diaphragm span. Fortunately, the diaphragm was adequate in this direction, however the diaphragm attachment to the interior collector lines was not. Retrofit would involve removal of an 800-foot-long strip of roofing and insulation to add connections via welds or power actuated fasteners. Retrofit from below was considered, however, due to the tall height of the roof above finish floor as well as the presence of the ceiling and myriad mechanical

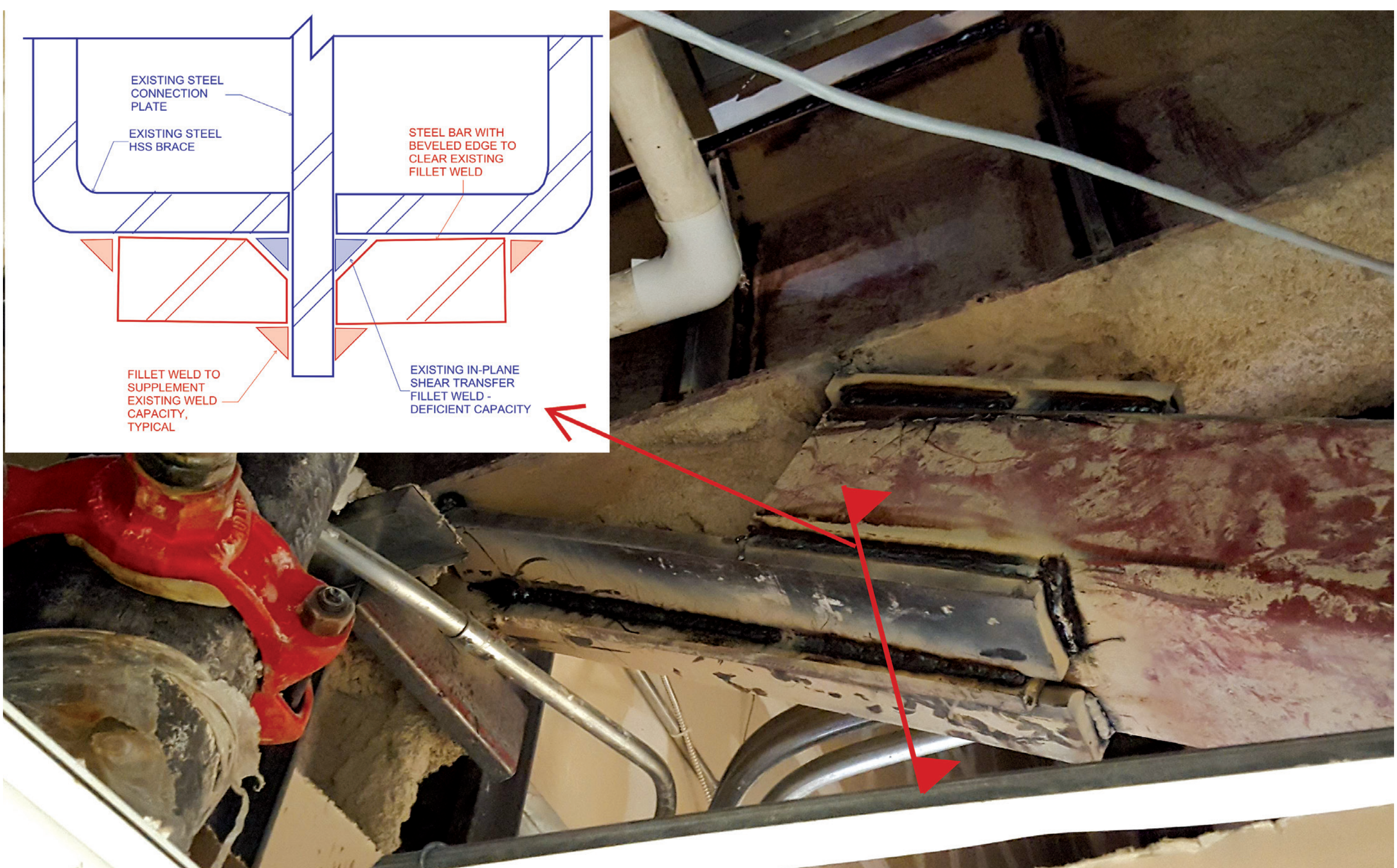

Figure 3. Top of existing braced frame brace retrofitted with additional weld and beveled drag bars.

obstructions in the ceiling space, it was decided that installation from the top was the best option. Power actuated fasteners (PAFs) were chosen to reinforce the deck-to-collector connection. Due to stiffness compatibility issues between existing welds and new PAFs, the existing welds were neglected, and full load put on the PAFs.

North-South Frame Lines and an Unconventional Solution

In the north-south direction, the only existing lateral force-resisting lines are located at the edges of the building; there are no interior lines of support. The entire load path from metal deck diaphragm through to base of braced frame was significantly overstressed. Therefore, a new line of resistance was added down the middle of the building in this direction. New braced frames fit the programming of the new school tenant space well. The area was already completely open, allowing for clear construction space to install the long interior steel elements, as well as new foundations, including micropiles. However, the new school tenant space reached only a little less than half the length of the building in this direction. The remaining length was occupied by other tenants, primarily the food processor, for which installing overhead beams in their space was a nonstarter. The existing steel roof framing along the new collector line was a typical open web joist, only designed for gravity loads. The design team opted to install new framing on top of the roof to collect load from the diaphragm over the other tenants' space and drag the load to the new braced frame (Fig. 4). A tee-shaped beam section was used for this new collector by installing one wide flange in a traditional, vertical orientation, but placing a second wide flange sideways on top of the first. This allowed for fewer top flange bracing connections down through the roofing. The two stacked beams were placed atop the existing roof diaphragm to continue the collector line across the width of the building.

This solution was not without its own challenges. The building owner lost a number of photovoltaic panels where the new collector was placed. Existing surface-mounted utilities had to be lengthened to jog over top of the new several-feet-tall collector. New roofing penetrations were required to connect the new framing to the existing framing below. However, these tradeoffs were outweighed by the ability to allow the new tenant to occupy the space without disturbing the existing tenants.

To support the new braced frame, new hollow bar micropile foundations were installed. The demands to these foundation elements were high as the frame line resists the force from half of the existing building. Micropiles were a good fit for the soil type and for modular installation within existing building versus a traditional cast-in-place pier foundation that would have required a tall drilling mast and reinforcing cage.

Initially, the issue of the new school tenant invoking a mandatory building-wide seismic retrofit seemed infeasible. However, with some creative engineering and an unconventional solution that included adding a building-wide collector member on top of the roof framing, the school tenant was able to occupy this otherwise great space in an existing building. ▪

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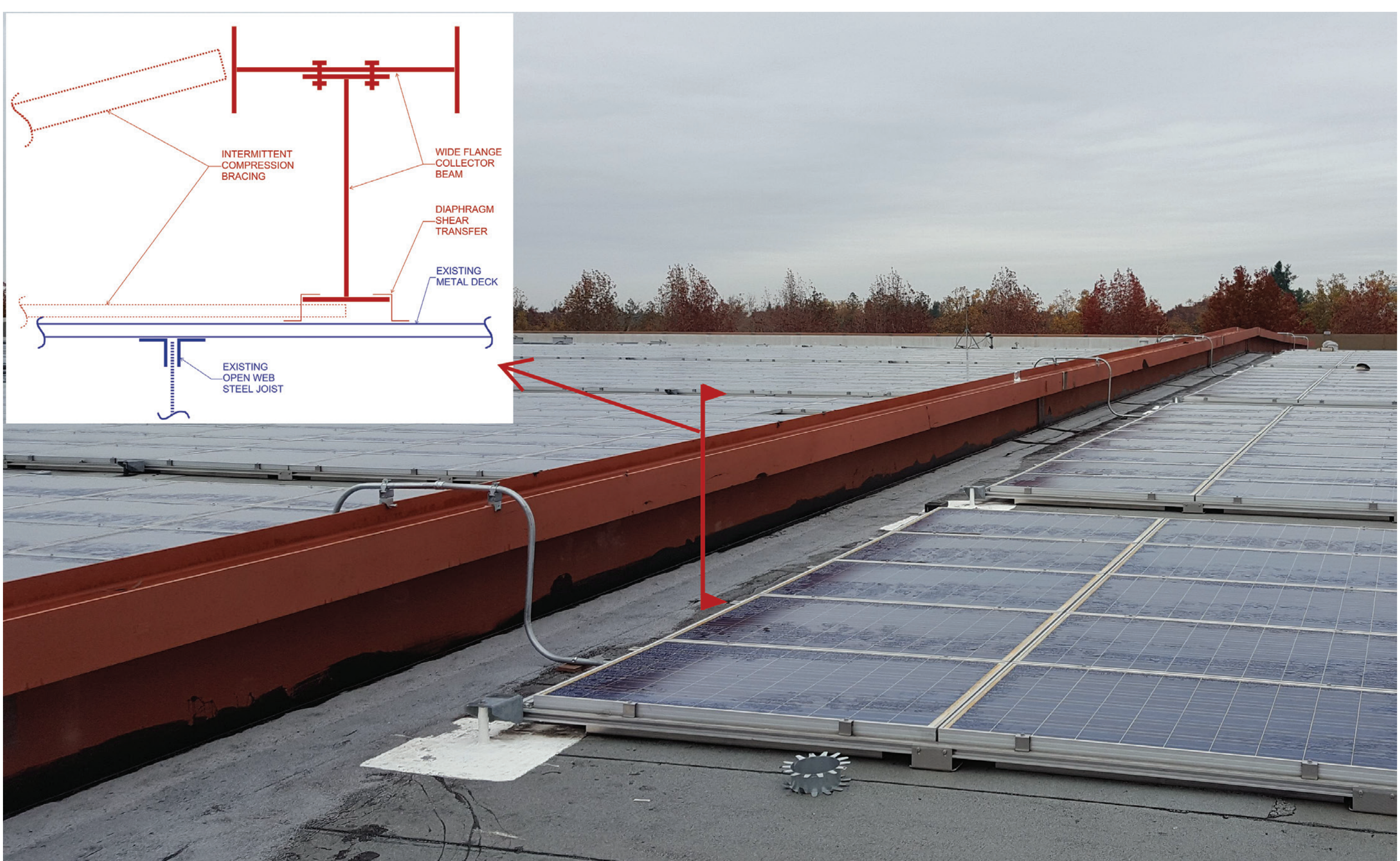

Figure 4. The new collector element installed on the top of the roof.