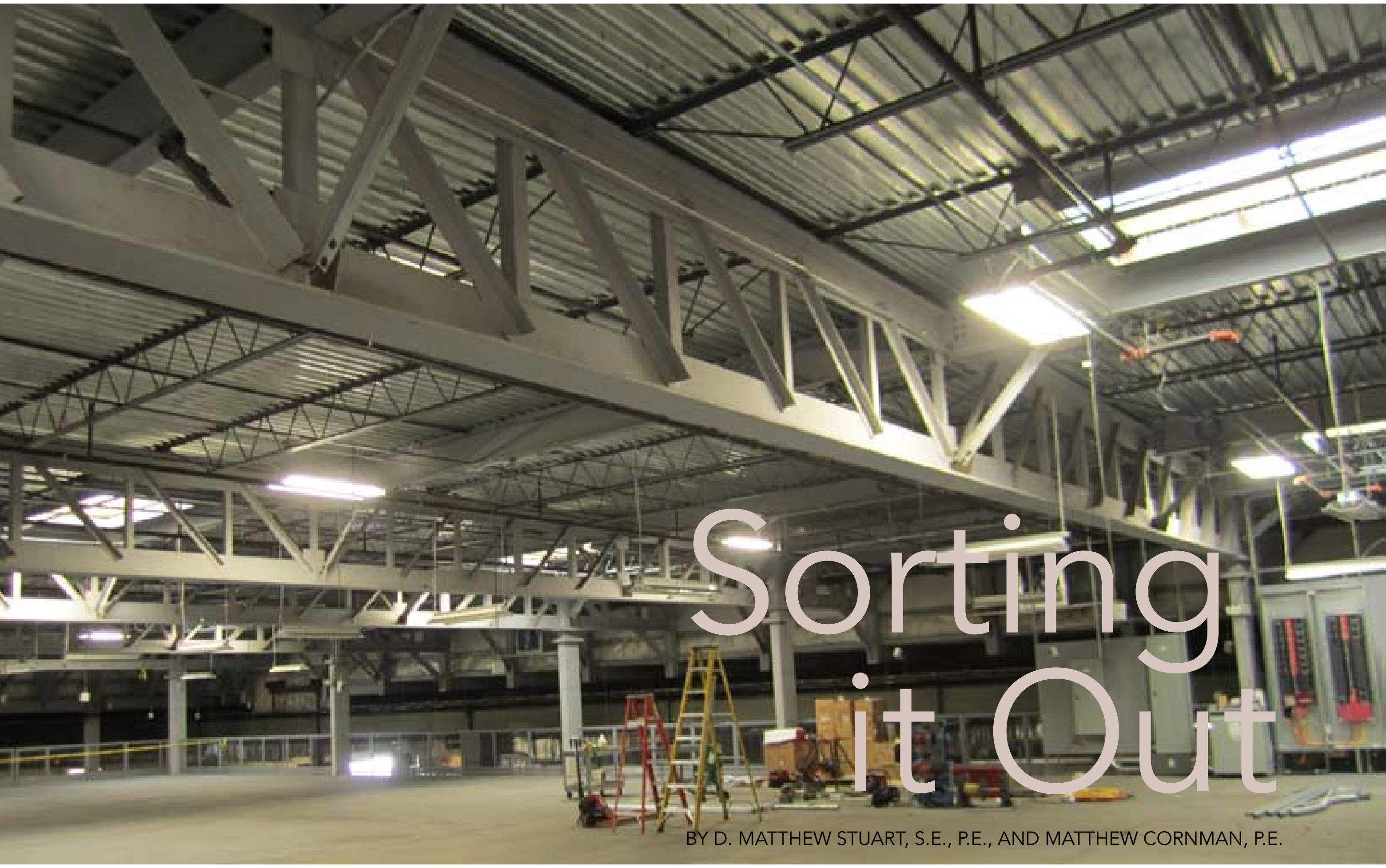
The recent structural expansion of a package sorting facility didn't get in the way of business as usual.



Sorting it Out

BY D. MATTHEW STUART, S.E., P.E., AND MATTHEW CORNMAN, P.E.

PEOPLE LIKE GETTING packages. And in today's world of online shopping, they're getting more of them than ever.

But they likely don't think much about what happens between when they click "Purchase" and when their new bowling ball, DVD or suede boots arrive at the front door. At some point, their purchases or gifts make their way through one or more massive sorting facilities that the major delivery services operate. One of these facilities, in Shrewsbury, Mass., recently underwent an expansion to facilitate a new conveyor platform within the existing building.

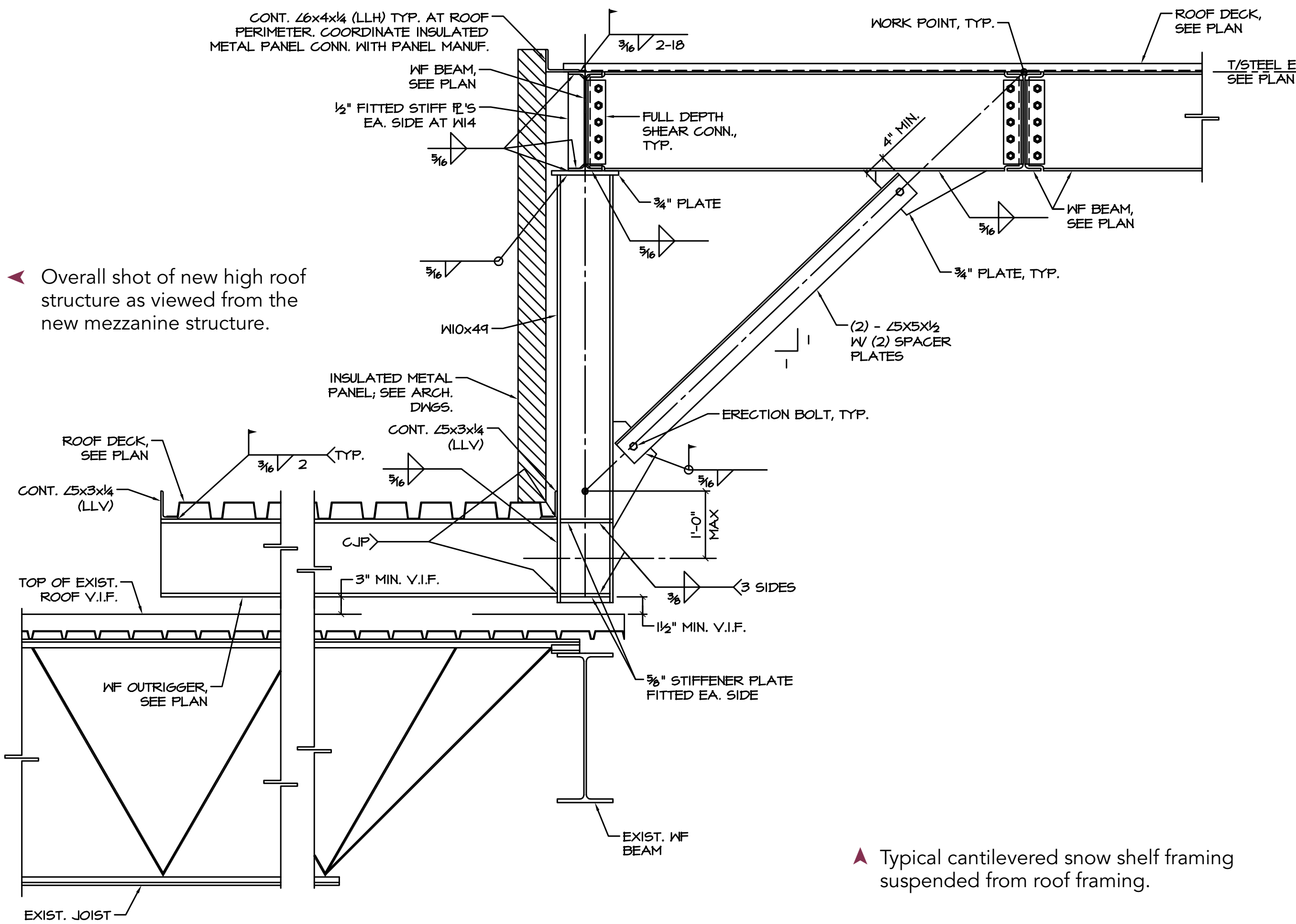
The expansion, completed in May, involved installing a new structural steel mezzanine platform to support additional conveyor and sorting equipment, as well as a new high roof to facilitate the vertical clearance required for the mezzanine equipment. The existing warehouse facility was approximately 85,000 sq. ft, and the expansion added 11,000 sq. ft of mezzanine platform and an additional 16,000 sq. ft of new roof structure. Total steel tonnage for the expansion was 350 tons.

There were several parameters to be addressed during the project design process, including the heavy snow load (P_g = 55 psf), restrictions on the structural column locations, member depth constraints (due to the equipment and truck clearance requirements) and the need to continue normal operations in the facility throughout construction.

Managing Snow

While a partial set of structural drawings for the facility were provided by the owner, Pennoni Associates, the structural engineer for the expansion, visited the site to confirm the accuracy of the existing drawings and to obtain measurements for members that were not included on the drawings. On Pennoni's initial visit we obtained field measurements of the existing roof structure in order to determine the impact of the snow drift loads imposed by the new pop-up high roof. (The existing warehouse facility roof was constructed of wide-flange beams and columns and open web steel joist members, and the perimeter of the facility was enclosed with precast concrete wall panels.)

After our initial analysis of the existing structure, we discovered that the existing open web steel joists did not have adequate reserve capacity to support the magnitude of snow drift imposed on the low roof structure by the presence of the new higher roof. After considering several schemes for supporting the snow drift,



◀ Overall shot of new high roof structure as viewed from the new mezzanine structure.

▲ Typical cantilevered snow shelf framing suspended from roof framing.

we determined that the high roof framing would have to include a 16-ft structural steel cantilevered "snow shelf" in order to support the new snow drift loads directly above the remaining low roof.

Consideration was also given to the additional lateral wind load created by the new high roof structure sail area. The magnitude of additional lateral load could not be resisted by the existing structure; therefore the addition to the facility would have to be designed and built so that the lateral stability of the new framing was independent of the existing warehouse. In addition, the new high roof meant that a portion of the existing low roof would need to be demolished, leaving a large opening in the existing metal deck diaphragm of the warehouse. To account for this new opening, steel reinforcing plates were installed at the opening in the low roof to strengthen the existing diaphragm and therefore allow for the continued proper distribution of the lateral loads within the remaining structure.

Fully Operational

As the facility needed to remain operational during the construction phase, all new column locations had to be coordinated with the original truck docking layout, and special attention was necessary to assure that the column locations would not interfere with the future truck unloading operations. The typical column width was limited to 8 in. in order to facilitate truck parking on either side of the member. The new conveyors and truck positions also dictated a column-free clear span mezza-

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◄ Cantilevered snow shelf framing suspended from roof structure.

▼ The new structural columns were coordinated with existing truck docking layout. The column widths were limited to allow docking on each side of the column.

nine of 71 ft. Additionally, because the new supports could not encroach into the existing conveyors, the columns were located directly adjacent to and inboard of the existing conveying equipment, which created the need for cantilevered roof and mezzanine framing.

The required column locations and proximity to the existing conveyor belt also created an eccentric loading condition for the new foundations. This condition in turn led to the need to use HSS micro-piles (9.625 in. OD; 53 piles in all, each with a capacity of 100 tons) to resist the imposed overturning forces. This foundation scheme was also selected due to the limited operational space associated with the pile installation equipment, which had to fit within the restrictive clear height, approximately 20 ft, within the existing warehouse facility. The piles were installed during normal working hours with minimal impact to the warehouse operations.

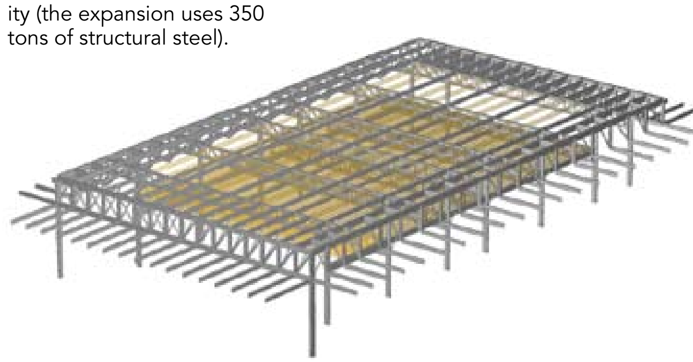
Due to the magnitude of the spans involved, steel trusses were deemed the most economical approach for supporting the main mezzanine and roof framing. The truss design provided resistance to both the lateral loads and imposed gravity loads from the mezzanine and roof, including the cantilevered snow shelf. The snow shelf framing consisted of wide-flange cantilevered members and related support hangers that were suspended from the high roof framing. Heavy gage 3-in. roof deck was used to form the snow shelf between the framing members, which allowed for increased spacing between the horizontal cantilevered members. The roof trusses were constructed with WT top and bottom chords and angle web members. The roof trusses (nine total, 9 tons and 4 ft deep each) spanned 71 ft and cantilevered 12 ft, 6 in. at each end of the clear span. The trusses supported the significant snow drift loads imposed by the snow shelf; therefore the design was driven by unbalanced snow loading. The remainder of the high roof framing was constructed with wide-flange steel beams and open web steel joists, which in turn supported 1½-in. metal roof deck. Angle kicker braces were also required to help resolve the forces associated with the snow shelf into the high roof diaphragm.

Because of the vertical clearance requirements associated with the truck unloading operations and conveyor platforms, the depth of the mezzanine trusses was limited to a maximum of 4 ft. Similar to the roof trusses, the mezzanine trusses (six total, 12 tons each) spanned 71 ft and cantilevered 12 ft, 6 in. at one end of the

Cantilevered snow shelf framing during construction as viewed from existing roof.

Cantilevered joist framing at the mezzanine.

New high roof structure during construction as viewed from existing roof. The new high roof structure was installed with the existing roof in place to allow the space below to remain operational.



A model of the entire facility (the expansion uses 350 tons of structural steel).

clear span. The mezzanine was intended to support the new conveyor and sorting equipment, which was equivalent to a uniform superimposed load of 125 psf. Because of the depth restriction and heavy loading requirements, the design team chose wide-flange chord members with double-angle web members as truss configuration for the mezzanine framing. The remainder of the mezzanine framing was constructed with open web steel joists spaced at 2 ft on center and ¼-in. steel floor plate, which spanned between the joists. However, a portion of the mezzanine was framed with 40-in.-deep open web steel joists that, as with the trusses, spanned 71 ft and cantilevered 12 ft, 6 in. at one end of the clear span.

Through the Roof

Keeping the facility open during the expansion also affected the erection sequence of the steel. In an effort to keep the existing low roof in place as long as possible, 2-ft by 4-ft holes were cut in the existing roof to allow the new columns to be erected in place at their full height (approximately 32 ft). The high roof framing was then erected above the existing roof so as to not interfere with the ongoing facility operations below. Once the high roof was fully erected and watertight, the existing low roof below was then demolished. By sequencing the erection and demolition in this manner, the facility below was never exposed to the outside elements, and normal operations within the building enclosure were not interrupted.

Because the columns were installed full-height, a more complicated erection process was required for the mezzanine trusses than what was possible at the roof. Due to the erection restrictions and significant end reactions at these trusses, the design of their field connections was also very challenging. The solution was to use shop-installed brackets on the columns and field-installed flange plates; the last vertical web member of the trusses was also installed in the field rather than shop fabricated. MSC

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