Tri-chord HSS trusses made from ASTM 1085 steel optimize a rebuilt transfer station on a tight waterfront site in Seattle.

Waste NOT

BY IGNASIUS SEILIE, SE, PE, AND LINDSEY BURNS

All photos: Integrated Design Engineers, unless otherwise noted

SEATTLE'S NORTH TRANSFER STATION may be one of the most beautiful and community-friendly dumps in America.

Sited adjacent to a residential neighborhood with waterfront views, the rebuilt station fulfills Seattle Public Utilities' goal to both modernize the 1960s facility and also be a good neighbor—despite processing 750 tons of waste and recyclables on-site every day.

The station's new $12 million, 67,000-sq.-ft tipping and transfer building superstructure was designed by a structural engineering partnership between Integrated Design Engineers (IDE) and CDM Smith. The building collects and sorts waste destined for the landfill using the flat-floor unloading and sorting method, and is equipped with noise and odor reducers and a mist sprayer that reduces dust. And a 150-kW solar array and green roof cover 80% of the building's roof area.

Due to diagonal bounding streets, the new structure was built along a corner of the site that is cropped like a dog-eared page. The building's lower-level southwest corner had to be clear of columns and walls to allow trucks to enter the building after driving down the ramp from the street. In addition, the upper level of the building had to be column-free for its full 200-ft span.

The project's location on a tight, congested site in a residential area prompted steel fabricator Fought & Company to look at various member lengths and truck sizes. Test runs were performed, which helped determine the proper number and locations of splices (e.g., three splices were needed for some members/assemblies where previously only two were expected) and the limited laydown area required trucks to be staged at strategic locations.

Building a transfer station to facilitate transfer trailers at the lower level, in addition to hosting both public vehicles and commercial garbage trucks at the upper level, presented some interesting geometric challenges. The maximum ramp slope for the transfer trailer and the maximum ramp length (defined by the site dimension) limited the building's total depth. In addition, a community agreement also limited the building's height. These two limits, as well as the required height clearance for vehicles at the upper and lower levels, determined the maximum structural depth. The solution for the structure was to combine the full-depth exterior walls at the south and west to create a deep truss system to support the building without losing the required space clearance. In addition, in order to accommodate


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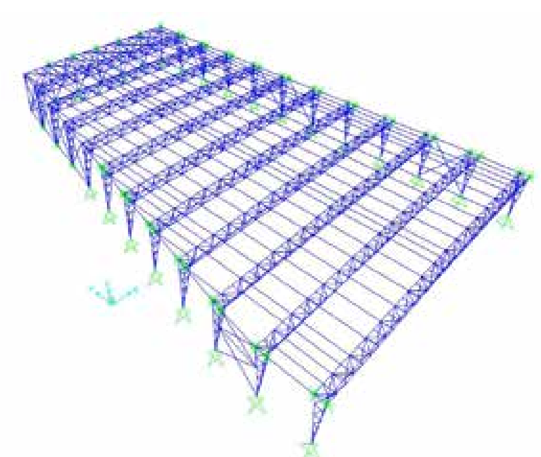


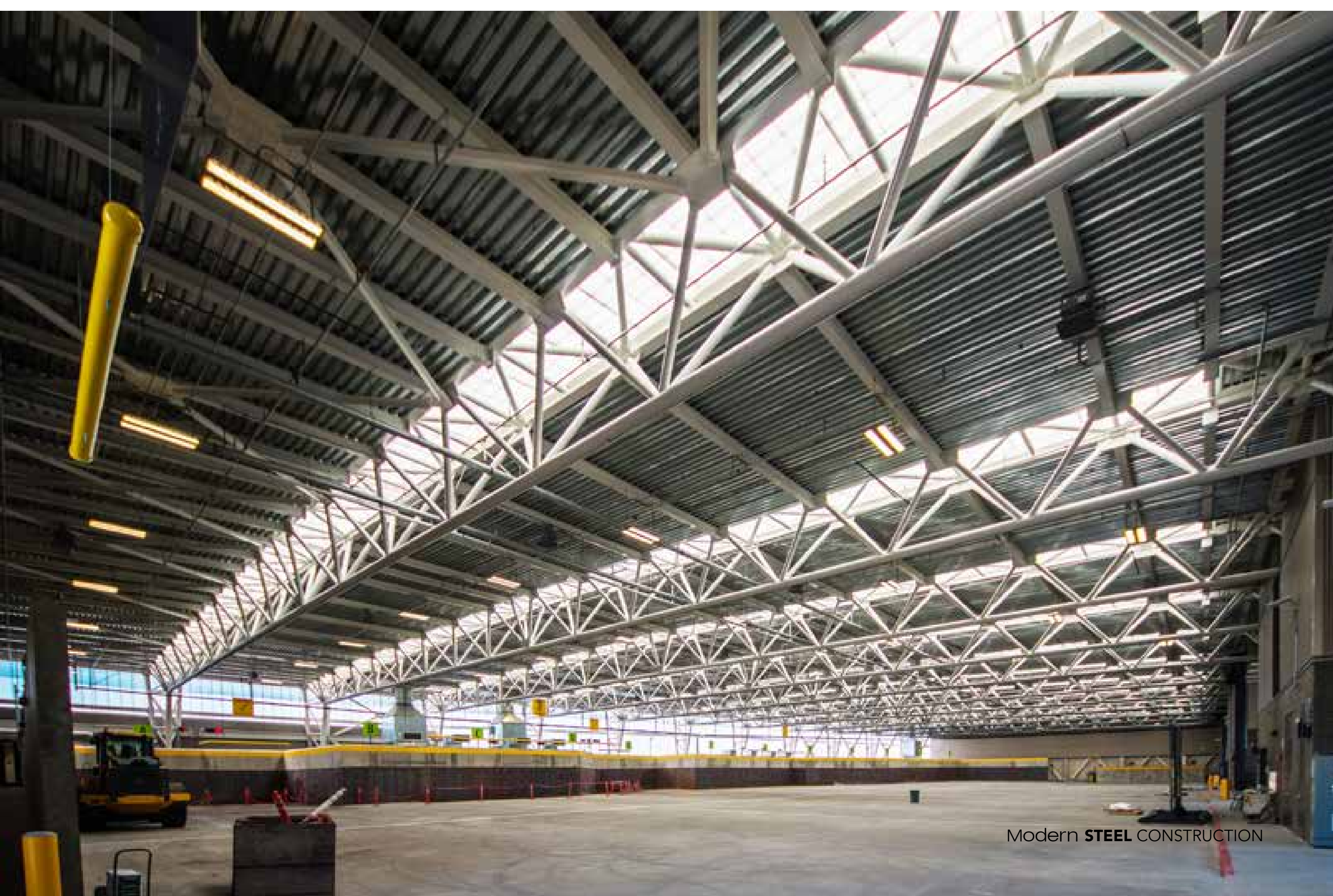
◄ An aerial view of the project, as seen from Lake Union.

▼ Driving down the ramp into the tipping and transfer building from the street.

◄ The southwest view of the floating corner transfer trusses and truck access ramp.

◄ A completed SAP2000 model of the facility.

▼ An interior view, showing the tri-chord trusses and transfer trusses.



the turning radius of the transfer trailers, several support columns at the lower level along the south face needed to be removed.

▲ Tri-chord trusses, in the shop.

▼ The trusses were painted using a shop-applied three-coat system.

Floating Corner

Responding to these parameters, IDE and CDM Smith worked together to design a solution now called the "floating corner," a 50-ft cantilever truss and 120-ft main transfer truss system that supports the weight of the entire building at its southwest corner. The main transfer truss at the south face is supported by a double W30 beam embedded in the concrete slab on the east and a full-story cantilever truss on the west. The full-story truss depth was selected to optimize the structural weight and allow top and bottom chord stabilization. This allowed open access for the transfer trailers to maneuver at the lower level when going in and out to the facility.

The complexity of these trusses lies in the multiple-stage camber to ensure that the trusses would be at the correct elevations when the building was completed and loadings applied, as any unpredicted deflection would impact the tri-chord roof trusses.

"The tri-chord truss roof structure coupled with the large transfer trusses on the west side of the building made the cantilever and the truck entry possible," explained Luke Pulliam, project architect with Mahlum, the building's architect. "The building would be inoperable without them."

The building's bounding streets were not only a challenge for building access but also contained private residences that wanted to preserve views of nearby Lake Union. The upper level of the building had to somehow allow for a 200-ft span of open space without exceeding a roof structure depth of 7 ft (a span-to-depth ratio of L/28).

Initial designs explored the use of a deep girder system, but IDE determined that a primary lateral system of tri-chord steel trusses would have greater load capacity and

A New Experience

The Seattle North Transfer Station took advantage of the relatively new ASTM A1085 grade of HSS.

This project was the first time we used ASTM A1085, and we enjoyed working with it. Using this product for the truss chords provided added ductility in the system while satisfying the architectural limitations of member size. It allowed the use of a reduced diameter size for the roof truss bottom chord and interior element of the downturned leg. The main benefit was that we could use the properties 100%, with no reduction of the HSS wall thickness. It was a win-win situation.

In addition, the new ASTM A1085 specification was very advantageous when designing the round HSS-to-HSS connections per AISC *Specification* (ANSI/AISC 360) Chapter K and AISC Design Guide 24: *Hollow Structural Section Connections* (both available at **www.aisc.org/publications**). The welded connections were designed to fulfil the all the applicable limit states, and under the new ASTM A1085 specification it is acceptable to use the full cross-section area and a higher yield strength value for HSS members. — *Ignasius Seilie*

The tri-chord trusses, under construction. Transluscent panels above the truses allow sunlight to penetrate the building.

Lifting the first truss into place.

The fabricator built the trusses as if they were for a bridge, not a building.

greater stability and be easier to erect than a deep-girder system. The open trusses could also allow better distribution of light girders as compared to deep girders.

"The tri-chord truss and column solution kept the depth of the long-span roof structure to a minimum and provided an elegant daylighting strategy that earned the project LEED daylighting credits," noted Pierce McVey, lead architect with Mahlum. "Overall, the steel elements create an organizational framework and visual interest that define the open space and thus become a significant part of the architectural aesthetic."

HSS Upgrade

Given the limitations for truss depth, IDE realized traditional ASTM A500 HSS (hollow structural sections) did not meet the building's architectural and structural requirements. Instead, the building's tri-chord roof truss system contains 90 tons of ASTM A1085 HSS steel—the largest and most complicated use of this steel type on the West Coast at the time of construction. Close collaboration with HSS manufacturer and AISC member Atlas Tube was crucial during the design phase to understand this new material.

"One of the industry goals for the developing the new ASTM A1085 specification was to increase the efficiency and performance level for HSS, and I think IDE took full advantage of that," said Bradlee Fletcher of Atlas Tube.

Using ASTM A1085's optimum properties and improved ductility, IDE was able to reduce the size of the bottom chord HSS and create a ductile trussed frame to resist seismic loading in the north-south direction. Each 11 tri-chord roof truss is composed of two wide-flange top chords that are 10 in. deep and located 6 ft apart parallel to each other, with a ridge at mid-span sloping 2% downwards on both ends.

The single bottom chord is a round ASTM A1085 10.75-in. HSS situated 6 ft below the top chords in the closest location. These elements integrate the basic triangular structure of the truss. A series of 6-in. round HSS form the diagonal bracing and web members between the top and bottom chords. The down-turned leg that supports the roof truss and connects to the building floor follows an inverted pyramid shape, with an interior 12.75-in. round ASTM A1085 HSS and two exterior 10-in.-deep wide-flanges that join together at the floor to a single node.

While 3D modeling was not a project requirement, IDE prepared its own 3D model to study the complex geometry, connection and orientation of the roof truss members. During fabrication, it shared this model with Fought and detailer Steel Systems Engineering (SSE) as a tool to communicate the complexity of the trusses, and SSE used it as a reference for the final model built with Tekla.

"Never was direct access to the engineer needed more or better performed by IDE for this project," said Steve Fugate of Fought. "The first column and node connection seemed like it took a month, but between the learning curve and hands-on collaboration, we doubled our productivity to fabricate one column every two to three days and one truss every week-and-a-half."

In addition, Fought built the steel as if the project were a bridge, not a building. In bridge fabrication, it is common to test-assemble the entire structure in the shop so that all connections are verified and aligned before construction at the job site. This approach of building each truss to theoretical perfect down its length, without using up any of the tolerances, vastly reduced misalignment and led to smooth erection in the field. ■

▲ Truss assembly, in the shop.

▼ An assembled tri-chorded truss downturned leg.

Owner
Seattle Public Utilities

General Contractor
Lydig Construction, Bellevue, Wash.

Architect
Mahlum, Seattle

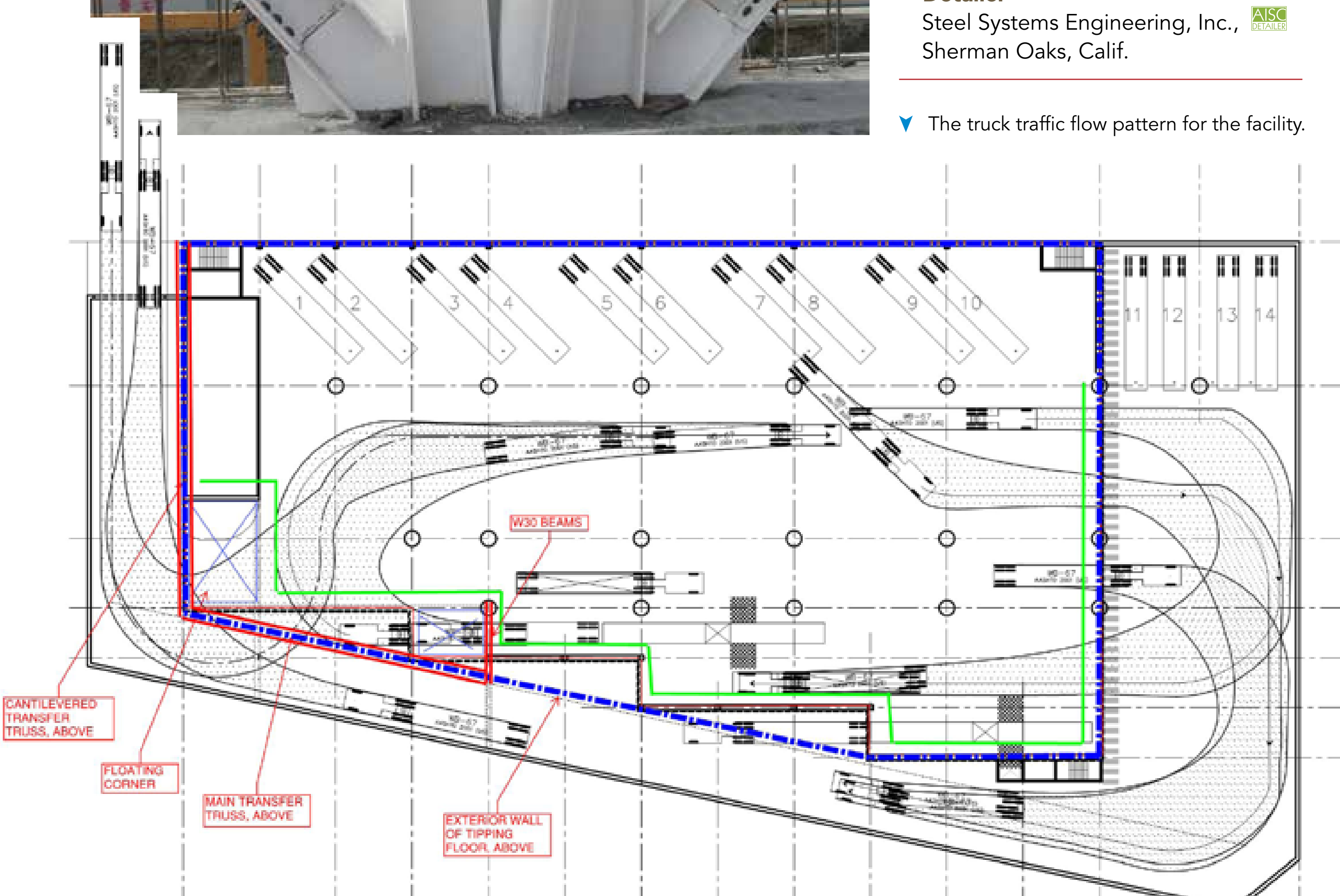
Structural Engineers
Integrated Design Engineers, LLC, Seattle
CDM Smith, Inc., Bellevue, Wash.

Steel Team

Fabricator
Fought & Company Inc., Tigard, Ore.

Detailer
Steel Systems Engineering, Inc., Sherman Oaks, Calif.

▼ The truck traffic flow pattern for the facility.



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