S.F. Airport Roof Truss Erection

Roger E. Ferch, P.E., is a Vice President with The Herrick Corporation. Patrick M. Hassett, S.E., P.E., has 12 years experience as a consultant on the fabrication and erection of major structural steel construction projects and currently heads up his own consulting engineering firm. This article is based on their scheduled presentation at the 2000 North American Steel Construction Conference in Las Vegas.

The architects for the San Francisco International Terminal described their design as a dramatic 860' long "winglike" roof that presents its profile to cars arriving on the access road while soaring 60 to 90' above the floor of a cavernous ticketing hall. Couple this architectural statement with the high seismic design requirements of northern California, and the result was the massive structural steel bid documents for the new terminal. AISC-member Herrick Corporation was the successful bidder on the 30,000-ton project and signed the contract with the airport in May of 1996.

The main roof structure, with a total weight of 4,200 tons, included five sets of trusses at 40' centers. Each truss incorporated two 320' long double cantilever one-way sections resting atop spherical bearings and a two-way 180' long three-chord center section. The tubular truss members range from 12 to 20" in diameter and with wall thickness from 7/8 to 2". All joints were complete penetration welds. The final erection tolerance was one inch in any direction.

The project site contributed to the project challenges. The new 2,000,000-sq. ft. facility provides 26 gates for Boeing 747 and 777 jumbo aircraft. The structures that housed the aircraft gates were constructed before the new terminal building. The center truss section spans the existing ten-lane airport entrance road. This roadway had to remain open during construction and the contract was very restrictive on activities in the vicinity. Any total road closure had to be limited to a maximum of five minutes between the hours of midnight and 5:00 AM.

Below the trusses were two floors of conventional beam and column framing. The existing airport terminals and parking structure blocked access from the east. New construction was already in place on both the north and south sides at the beginning of roof construction. Therefore, the only access to the site was from the west and the steel had to be erected from this side.

Erection of Support Trusses

Double cantilever trusses support the center span three-chord "football" shaped trusses. The middle sections were erected first, followed by the outside cantilever and the inside cantilever trusses. Nylon Kevlar slings were used to cradle top chord pipe sections at designated pick points rather than welding lifting lugs to the API pipe and having to grind

them off. The support trusses rested atop two box columns. Special column splice erection aids were designed due to the height of the freestanding 46" box columns that support these trusses. A minimum column splice weld was also specified prior to erection of trusses in order to provide the required lateral strength. Stability during erection of trusses is always a concern. The connection between the truss and the box column is a ball and socket bearing structure; therefore, there was uncertainty as to the stiffness at the supports. The erector was directed to tie the trusses laterally at specified points prior to releasing them from the crane. This required the use of two cranes within the restricted work area.

Shipping and Delivery of Center Span Trusses

The five center span trusses are three chord trusses consisting of two pipe top chords and one pipe bottom chord. The 182', 100-ton trusses were shipped on cradles in one piece from the fabrication plant by barge across San Francisco Bay to the airport. The trusses were loaded onto dollies and towed across the airport runways and service-ways to the site. This operation was performed at night when no flights were scheduled. They were lifted with a Manitowoc M250 crawler crane using nylon slings at four pick points, and walked into position. The crane then rotated to swing one truss end onto the rail system near the edge of the third floor. The opposite end was then connected to a waiting Manitowac 888, and the first crane released the load. The 888 walked forward with the truss, rolling it across the floor on W14 beam-rails on Hillman rollers. The rollers were bolted directly to the shipping cradles. An air-tugger was also connected to the lead end of the truss in the event that any binding of the rollers occurred, which did not. This process was repeated four more times for the remainder of the football shaped trusses. The roof structure purlins and bracing was framed between the "football" trusses while they were resting on the third floor. This allowed the ironworkers to work 25' above a slab floor, utilizing scissor lifts and other tools that would be difficult to utilize at 75' above a working floor. The structural slab would not support high-lift working booms.

Center Span Jacking Operation

With erection of the support trusses complete on both sides, the center span trusses were ready for jacking the 60' to their final position. The original plan was to jack all five trusses into place and pin the ends in one operation. This plan was feasible, however, for the benefit of the project schedule, and to allow other trades to begin work, it was more advantageous to do the lifts in two phases. The first two trusses at the east side would be left unattached to the other three in order to jack them into position first. This would allow work on the east window wall to proceed, as well as other tasks. An additional benefit was the jacking towers and pinning platforms could be reached for removal by the cranes at the completion of the lift.

The jacks were positioned just inboard from the ends of the football trusses. This allowed the erector to use the nylon slings to cradle the bottom chord of the truss near the pin casting. Each jack lifted the trusses up using a 200-ton Hollow Ram Jack with a 4" diameter threaded rod. The rod sections were 20' long and were uncoupled and removed after passing through the jack. The hydraulic system was coupled to provide the same lifting rate at all four jacking points. Even with this precaution, each jacking point was continuously monitored and measured during the lift. Any time the differential exceeded 1", the individual jacks were adjusted.

The jacks required support platforms designed for 150 kips each at 80' above the working floor. These "jacking towers" consisted of W36 columns on each side of each jack. Struts and double angle bracing were framed between the columns for lateral strength and stability. A pinning platform was also built on the jacking towers for safe access during the pinning operation. The jacking towers were supported on the third floor steel. Some members were added and some permanent member sizes were changed in order to sustain the loads imparted by the lift. The entire erection procedure and design was submitted to the owner for review prior to beginning the operation.

The first lift of two trusses as well as the second lift of three trusses were completed and pinned without incident. The jacking took approximately 10 hours each lift. The tolerances were tight, but the pinning went smoothly, using a tapered lead pin attached to the permanent pin in order to mate the two members. Upon completion of each lift, the few remaining roof purlins were installed and the jacking towers removed.

The San Francisco International Terminal was a very challenging fabrication and erection project. However, the fabrication and erection of the tubular roof trusses on a constricted site with an active 10-lane road underneath was the greatest of these challenges. Herrick began to address this challenge during the bidding phase and spent over a year adapting this plan to changing site conditions, needs of subsequent trades, and revisions in the scope of work. Herrick's contract called for the delivery of over 30,000 tons of structural steel and installation of the metal decking. Erection of the terminal began in November 1997 and continued through December 1998. The terminal is scheduled to open in early 2000. The successful erection of this roof structure is a credit not only to Herrick and its lead consultant, Hassett Engineering, but also to the entire San Francisco Airport project team and the steel construction industry.