Williams Erection Company

Providing plans for both design and erection, engineers used support from adjacent new construction to enable large truss erection above a historic structure.

Sky Hooks

BY CLINTON O. REX, P.E., PH.D.

WHEN THE RETIREMENT SYSTEMS OF ALABAMA (RSA) decided to build a new judicial building in Montgomery, Ala., the desire was to create something unique. RSA decided to build the new structure in the same location as its existing historic judicial building. However rather than removing the historic building, which had been the site of several significant events during the civil rights movement of the 1960s, it was to be integrated into the new facility. The resulting vision for the new judicial building consisted of a 12-story building with a portion of the new building built behind the existing building and the rest built above the existing building.

This design vision posed several challenges; however, the most difficult aspect was deciding how to build eight floors and a roof over the top of the existing building. Concrete construction is typical for buildings of this size in this area; consequently, the portion of the building built behind the existing building was constructed in cast-in-place concrete. However, given the challenge of building over the existing building, it was decided early in the design phase that structural steel was the right construction material for this portion of the building.

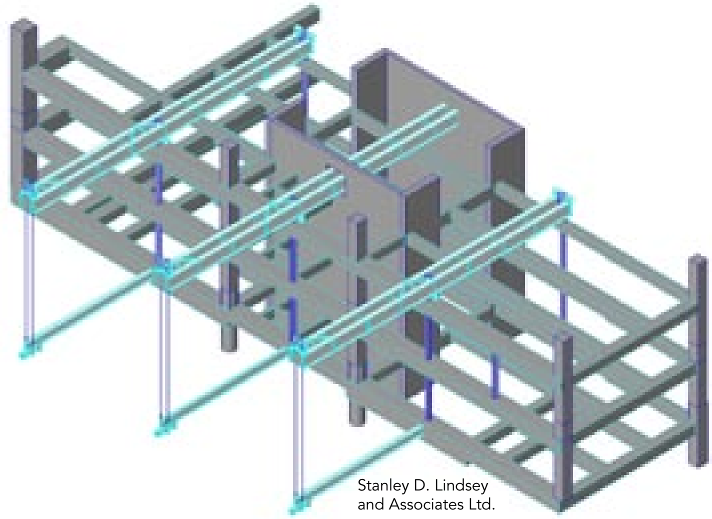
The final design for the portion of the building over the existing building relied on three large transfer trusses. Each truss is 144 ft long and two stories high with the bottom chord supporting the fifth floor of the new building (the lowest floor over the existing building) and the top chord supporting the seventh floor of the new building. The truss weights vary from 225 tons to 250 tons each. Erecting trusses of this size over an existing historic building presented the next big challenge.

Erection Challenge

RSA had a strict bid protocol that the design team had to follow. This protocol would not allow the design team to discuss the design with potential fabricators and erectors until after contracts had been awarded. As such, the original plan for erecting the trusses over the existing building was a fairly straightforward and simple approach that all the potential bidders could understand. It consisted of erecting the first story of the two-story truss in a single pick and then erecting the remaining pieces of the two-story truss on top of this one-story sub-truss. Although this erection concept was fairly straightforward and simple, it was not easy: the sub-truss that would be erected first weighed in excess of 150 tons. This sort of pick would require one of the largest mobile cranes

Opposite page: Steel transfer trusses being constructed piece by piece over the original historic judicial building. The use of temporary shoring outriggers to support the truss construction allowed the trusses to be erected safely, economically, and quickly without having to touch the historic building below.

Right: BIM model of the partial concrete structure and initial position for the twin-girder outrigger system. The system was designed to cantilever far enough out from the partially complete concrete structure behind to suspend temporary seats attached to the ends of the floor framing members. The three seats provided the needed shoring points required to assemble the truss in the air over the existing building.



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in the country. Although this was possible, there were additional concerns including:

- Risks associated with any schedule changes that would affect when the large crane would be on site.
- Complications with mobilizing the crane and need to shut down access on adjacent streets.
- Safety concerns with such a single large pick over an existing "to remain" roof/building.
- Amount of camber required in the sub-truss as a result of the staged truss construction.

Team Solution

Once all the subcontractors were selected, Stanley D. Lindsey & Associates (SDL) was free to discuss the design with the project steel fabricator, SteelFab, Inc., and erector, Williams Erection Company. SDL took on the role as the erection engineer for the project. That allowed SDL and the construction team to work out alternative means of truss erection without getting bogged down by the typical project documentation that occurs when acting only as a representative of the design team.

There was a strong desire to erect each truss in pieces with a single 500-ton crane. Because of the lift radius, this constraint limited maximum picks to approximately 25 tons each. This approach had several advantages including:

- Reduced potential critical lifts from one critical lift in excess of 150 tons to 12 smaller lifts under 25 tons, which allowed the use of a single 500-ton crane with a 25-ton pick capacity.
- Reduced the possibility of rigging mishaps due to the simplicity of the rigging required for 25-ton lifts versus 150-ton lifts.
- Reduced the possibility of worker injury due to pinch points.
- Allowed for flexibility in the original connection due to the number of smaller connections versus the one-piece truss that would have to be hard bolted to the exterior columns.
- Greatly reduced the suspended time per erectable piece associated with the stick-built alternative.
- Reduced truss camber requirements.

This approach also meant that some type of temporary shoring would be necessary to hold the individual pieces in place until the truss assembly was complete. The challenge was that there was no way to shore off or through the existing historic building below. SDL, SteelFab and Williams Erection developed, analyzed, and reviewed several options for temporarily shoring the structure that did not rely on support from the historic structure. After weighing the pros and cons and receiving critical input from the general contractor, a twin-girder outrigger system was chosen.

Shoring Structure Details

The column grid above the transfer girders has a 36-ft spacing. This results in three panel points along the truss, one at each quarter point. Three outriggers were used to support these panel points. A pair of rods suspended from the end of each outrigger supported the end of one fifth floor beam that was originally framing along the column grid line. A temporary steel seat extension was added to the end of the floor beam to provide the actual shoring surface off of which the truss was built.

Each outrigger consisted of a pair of W36×256 steel beams spaced 3 ft apart. The beams were tied together with torsional braces at 9-ft centers, allowing the beams to brace each other to prevent lateral-torsional buckling. Global buckling of the twin-girder outrigger initially was checked based on guidance provided by Yura et. al. (2008). However, Todd Helwig, Ph.D., from the University of Texas at Austin was retained to develop and analyze a more advanced 3D finite element analysis model. His analysis, which included assumed initial imperfections in the twin girders, indicated that the girder system was stable but likely to translate laterally at the cantilever tip nearly 2.5 in. While the torsional braces between the girders prevented twisting of the individual girders, they did not prevent twisting of the combined girder system. To reduce that twisting, angle bracing was added to the top and bottom of the outrigger in two of the 9-ft panels. This bracing reduced the expected lateral translation to less than ¼ in.

Typical ground-up shoring has very little vertical movement as loads are applied; however, this was not the case for the outrigger shoring structure. Vertical deflections on the order of 7 to 8 in. were expected at the cantilever tips of the outriggers. To control the deflections of the shoring seat that was attached to the end of the floor beam, the hanger rods were passed through hollow hydraulic jacks located at the tip of each outrigger. Each rod had its own hydraulic jack; however, one pump was used to control pressure in each pair of hydraulic jacks so that the load in each rod could be equalized. The hydraulic jacks were carefully calibrated and paired so that each pair of jacks had calibration

Clinton O. Rex, P.E., Ph.D., is a principal with Stanley D. Lindsey and Associates, Ltd., Atlanta. He is a member of the AISC Specification Task Committees TC4 and TC10, the Seismic Manual Committee, and the ASCE Committee on Design of Steel Buildings.

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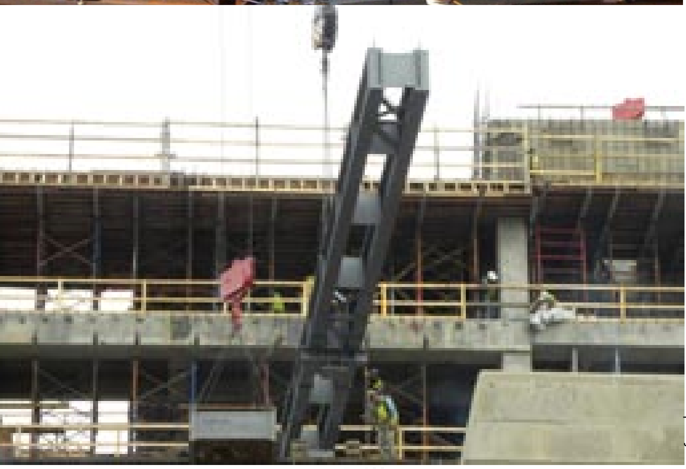

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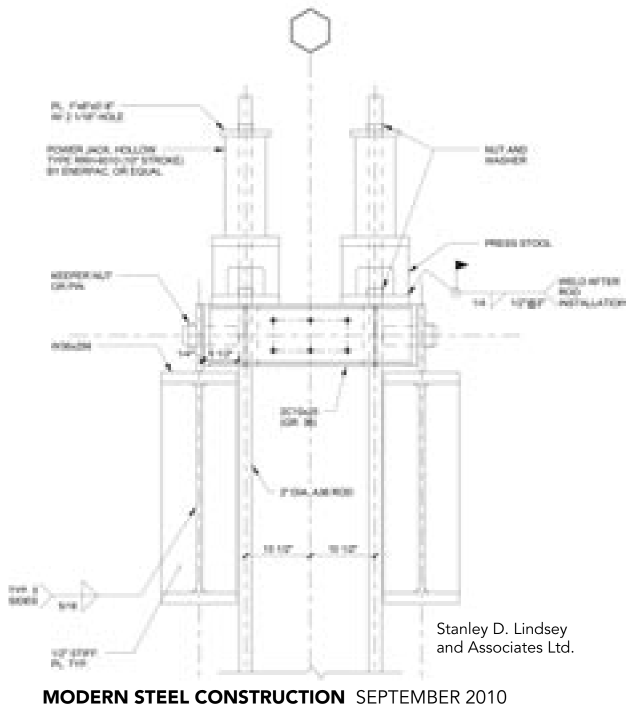

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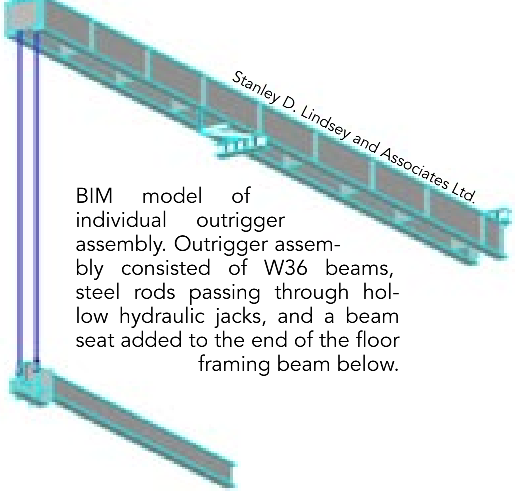
Left, top: The twin-girder outrigger system cantilevers out from the partially complete concrete structure behind to provide shoring points that allow for the piece-by-piece construction of each transfer truss.



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BIM model of individual outrigger assembly. Outrigger assembly consisted of W36 beams, steel rods passing through hollow hydraulic jacks, and a beam seat added to the end of the floor framing beam below.

curves as close as possible to each other. The jacks allowed the elevation of the shoring seat to be adjusted up or down as needed in order to maintain fixed shoring seat positions as each piece of the truss was erected. This resulted in the truss being erected in an undeflected and unstressed condition.

Another complication associated with the vertical deflections of the outriggers was the amount of rotation expected at the tips. The jack assembly and the hanger rods needed to remain essentially vertical while allowing the outrigger tip to rotate as it deflected vertically. This was accomplished by building a jack assembly that was supported by pins that could rotate in steel saddles as the outrigger tips rotated.

Each outrigger assembly had two support points. The front support had to sustain compression loads that were essentially twice the shoring load, given that the cantilever portion of the outrigger system was approximately the same length as the back-span portion. The back support had to sustain tension loads that were approximately the same as the shoring loads. The initial position for the outriggers was within the partially completed concrete building behind. The support points did not correspond with columns in the concrete building, therefore the outrigger support loads had to be carried by the concrete beams. The original beam designs were reviewed for the temporary shoring loads and adjustments to the reinforcing and post-tensioning were made to ensure that the concrete beams could carry the support point loads. In addition, temporary steel shoring posts were installed in line with each support point so that the outrigger support loads were distributed over three concrete floors. This was another case where it was advantageous for SDL to be both the erection engineer and the EOR for the building.

The outrigger assembly connections at each support point were detailed with bolted connections. Once the first truss was completed, each support point was unbolted and the entire outrigger assembly, including the supports, was moved out one bay. Thus, the original compression support in the concrete building now became the tension support, and the newly completed truss became the compression support. The entire assembly was bolted down once again in its new position and was ready to start erecting the second truss. After that truss was complete, the entire process was repeated to move the outriggers into position to erect the final truss.

Erection Plan

Successful erection of large trusses starts with a good plan. SDL prepared full truss erection plans and details that included everything needed

Left, center: Outrigger beam assembly being moved from its original position to its new position to erect the next truss. The assembly was detailed with bolted connections at all supports so that it could be unbolted, moved, and then bolted into its next position.

Left, below: Detail of the rod hanger assembly at the tip of the outriggers. The rods pass through the hydraulic jacks which allows for adjustment of the shoring seat height as the trusses are erected. The rocker assembly allows the hanger rods to remain vertical while the tip of the outrigger rotates under the weight of the truss.

Photo of the rod hanger assembly at the tip of the outriggers. Both hydraulic jacks run off one pump, equalizing the load in the two rods.

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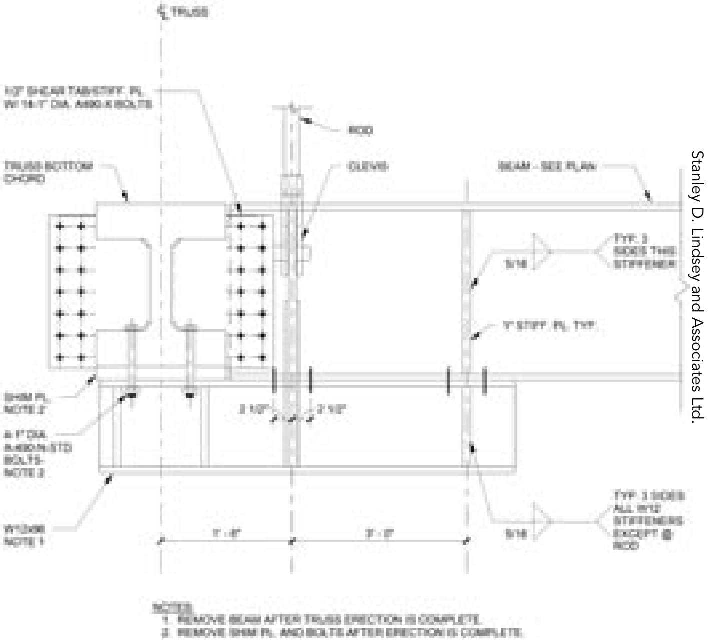
to fabricate and erect the temporary shoring system including complete connection details. In addition, a step-by-step erection sequence with both 2D and 3D erection keys was prepared for each truss erection. Each truss erection sequence included from 56 to 66 erection steps that were carefully coordinated among the fabricator, erector, and SDL to ensure an efficient, safe, and stable erection process. The truss erection sequence indicated not only when each piece of the truss was to be erected, but also when each piece of the primary floor framing was to be erected. The primary floor framing members were used to stabilize the partially completed truss as erection proceeded.

In addition to the erection sequence, SDL also prepared estimates for shoring loads and outrigger deflections for each of the key truss erection steps for each truss. Because the entire shoring and truss system was not statically determinant, it was easily possible for the structure to redistribute loads in ways that were not consistent with the shoring design if the correct outrigger loads were not maintained at each step. After each key truss erection step, the loads in the outriggers were adjusted to accommodate the new truss load. The outrigger deflections and loads were measured and compared with the estimates. Those estimates were given with upper and lower bounds, and field adjustments to the outrigger loads were made to keep within these ranges.

Before the truss pieces were brought to the site, each truss was completely assembled at the fabrication yard. This pre-assembly allowed for final adjustments to be made to the truss camber and truss connections in order to ensure a perfect fit-up in the field. In fact, certain key connections were intentionally not completed prior to the pre-assembly but were welded in place in the pre-assembled position. This level of preparation before shipping to the jobsite resulted in a near perfect fit-up in the field.

Because most people involved had never encountered this type of erection process, communication among the owner, designers, and general contractor was critically important. The fabricator, erector, and SDL made several presentations to all parties involved that walked through the entire erection process step by step. Revit Structure was used to model all the critical members of the building associated with the erection process. The model was then used to prepare the erection plans and detailed PowerPoint presentations. The 3D graphics within the PowerPoint presentations were used to walk everyone through the erection procedure so that they could see the entire erection plan being carried out in an animated fashion that made it crystal clear to all parties involved. Communicating the erection plan in 2D views and details could have been done; but the 3D communication allowed by the use of Revit Structure made it much easier for everyone to understand.



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Detail of the temporary beam seat extension. The short section of W12 was temporarily connected to the end of the floor beam to provide a shoring point from which to erect the truss. Once the truss erection was complete the W12 was removed and the floor beam was then supported by the completed truss.

Erection Success

The entire truss erection process went as planned and on schedule. The success of the truss erection was a real life example of what is possible when the fabricator, erector, and engineer work together as a team to think outside of the standard box of solutions. Being both the EOR for the building design team and the erection engineer for the steel fabricator and erector enabled SDL to adjust the design of the building as needed to accommodate the erection plan as it evolved. MSC

Owner
Retirement Systems of Alabama, Mobile, Ala.

Architect
2WR Holmes Wilkins Architects, Montgomery, Ala.

Structural Engineer / Erection Engineer
Stanley D. Lindsey & Associates, Atlanta (AISC Member)

Steel Fabricator
SteelFab Inc., Charlotte, N.C. (AISC Member)

Steel Erector
Williams Erection Company, Atlanta (AISC Member)

General Contractor
Bailey-Harris Construction Co., Auburn, Ala.

Structural Software
Revit Structure, SAP2000