Construction and Movement of the Torrence Avenue Truss

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ABSTRACT:

The Torrence Avenue Truss carries rail traffic over a busy roadway in an industrial area in southeast Chicago. The truss was assembled at-grade in a staging area adjacent to the final bridge position, then lifted onto Self-Propelled Modular Transporters (SPMT's) for transport to the final position. At 394' and approximately 4.75 million pounds, this is believed to be the largest truss bridge ever to be moved into place after being assembled off-site.

INTRODUCTION

The Torrence Avenue Truss is a 394' railroad bridge located in southeast Chicago. The truss is a key component of the grade separation project near the intersection of 130th Street and Torrence Avenue.

Figure 1 – Site Location

Part of both the 'Building a New Chicago' infrastructure program and the CREATE partnership transportation program, the overall grade separation project relieves public and industrial inconvenience due to high-frequency train traffic occurring at the former at-grade crossing by carrying two rail tracks over the roadway below.

Figure 2 – At-Grade Roadway & Railroad Intersection Prior to Project Completion

Construction and erection of the truss bridge was performed using Accelerated Bridge Construction (ABC) techniques, implemented to minimize public and railroad inconvenience during construction. The truss was assembled at-grade in a staging area adjacent to the final bridge position. Following completion of truss assembly, the entire truss was lifted approximately 22’ vertically using specialty self-climbing jacking towers and loaded onto frames supported by Self-Propelled Modular Transporters (SPMT’s). The bridge was then moved approximately 450’ across the intersecting roadway and railroad tracks into final position during a 24-hour period, including an 8-hour rail closure.

Weighing-in at approximately 4.75 million pounds, this is believed to be the largest truss bridge ever to be moved into place after being assembled off site.

TRUSS ASSEMBLY

The truss was assembled in a staging yard adjacent to the final bridge position. Availability of the staging yard was important to the implementation of accelerated bridge construction techniques as this made the truss assembly convenient and the travel path from assembly to final position very short.

The truss was erected at ground level with temporary supports located at every-other panel point.

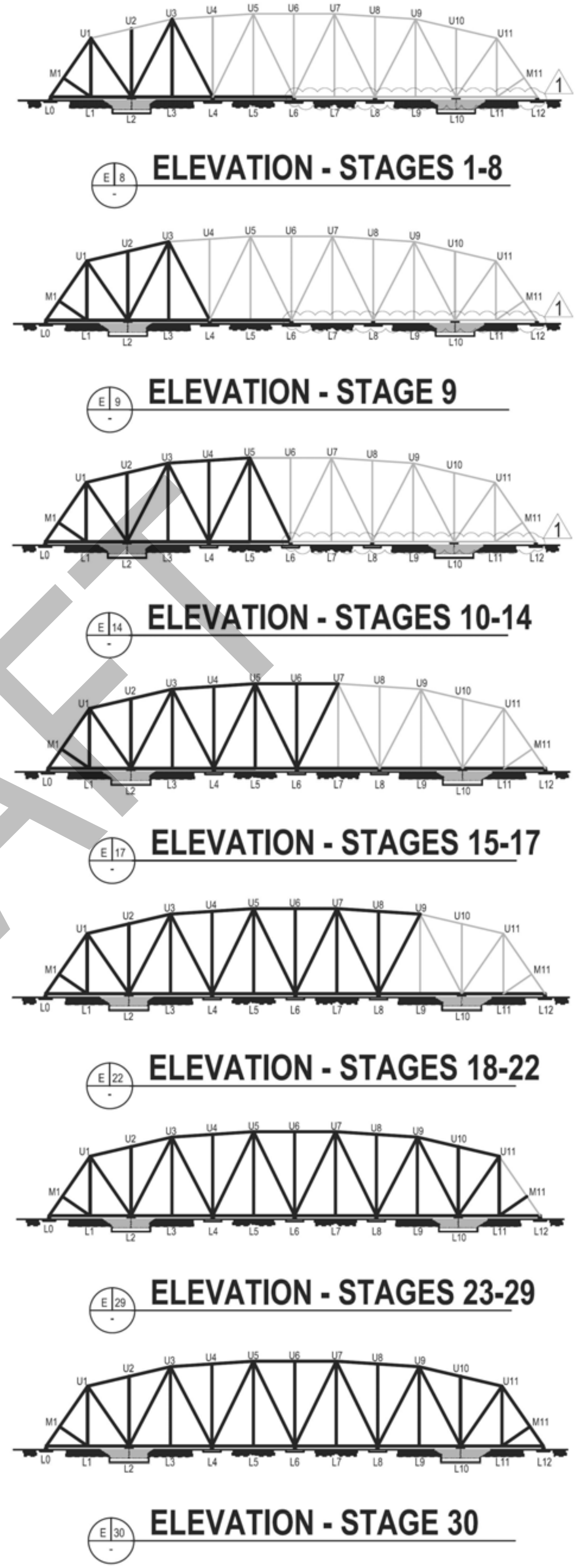


Figure 3 – Truss Assembly Diagrams

At-grade truss erection introduced several important benefits:

- Convenience for iron workers

Assembling the truss at ground level allowed unlimited access to the overall work site and allowed for easy access to bolted connections for the bottom chord and the entire floor system. Iron workers were able to move freely above and crawl under the structure in order to access handholes for bolt installation and temporary rigging locations, all without the need for personal fall-protection equipment which would be necessary for erection at an elevated work site.

The isolated yard used for truss assembly also allowed for material storage and minimized issues related with a congested work site.

- Safety

At-grade truss assembly eliminated potential safety hazards inherent with erection on falsework or other elevated work platforms.

- Duration

Construction site conditions and convenience of the assembly yard allowed the assembly crews to erect the truss very quickly and efficiently.

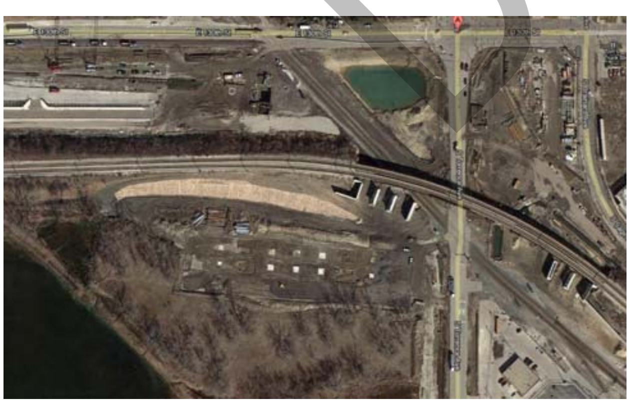


Figure 4 – Truss Assembly Yard

Temporary support of the truss during erection was provided by traditional cribbing structures supported on spread footings located at every other typical panel point. Cribbing structures were designed to support the anticipated compression loads and were arranged to match the fabricated (cambered) shape of the truss bottom chord.

Spread footings were sized to support anticipated compression loads based on site-specific allowable bearing pressure values. Cribbing elevations were monitored throughout the truss erection process by surveying the support locations at regular intervals. A few truss jacking sequences were required at specific support points during truss erection to correct cribbing elevation shifts due to spread footing settlement. The truss was assembled with relative ease.

Figure 5 – Cribbing Supports for Truss Assembly

Temporary support conditions during truss erection at panel points L2 and L10 were arranged in anticipation of positioning future lifting equipment. The spread footings at these locations were sized for support conditions during truss lifting, thus were oversized for load demands during truss assembly. Based on the physical height of the lifting equipment, the elevation of the supporting spread footings were set approximately 6.5 feet below grade. Simple temporary column posts were used to support the truss assembly and were buried with backfill material to level the site during truss erection. The temporary column posts were eventually removed and replaced with truss lifting equipment following completion of the truss assembly.

Figure 6 – Temporary Column Posts at Panel Points L2 & L10

Crane access was provided with a single improved crane runway. Crane capacities were verified for lifting all truss pieces from the crane runway location.

Figure 7 – Crane Access and Positioning

The completed 394' truss was assembled in approximately 13 weeks. Following erection, the truss was painted in-place.

TRUSS LIFTING

The first stage in moving the bridge from the assembly yard to the final position was to lift the bridge approximately 22 feet vertically from the ground level for loading onto the transport equipment. The lifting operation was performed using specialty lifting equipment located at panel points L2, L2', L10 and L10'. Specialty cribbing structures at these locations were designed to support the entire self-weight of the steel truss. The specialty cribbing was sized to transfer the reaction forces in bearing and shear through the flange-to-web welds of the truss box section.

Installation of the lifting equipment required excavating the backfill at the L2/L2' and L10/L10' "pits" and replacing the temporary column posts with the lifting equipment.

Support conditions during the lifting operations were different from the permanent condition, thus checking the truss in the temporary condition subject to self-weight effects was required. For instance, vertical member L2-U2 was subject to a high compressive force during the temporary support conditions, however since this member was designed as a tension hanger for permanent conditions, the member adequacy was verified for compression capacity and ultimately the gusset plate detail was modified to accommodate the high localized compression force.

Figure 8 – Lifting Truss

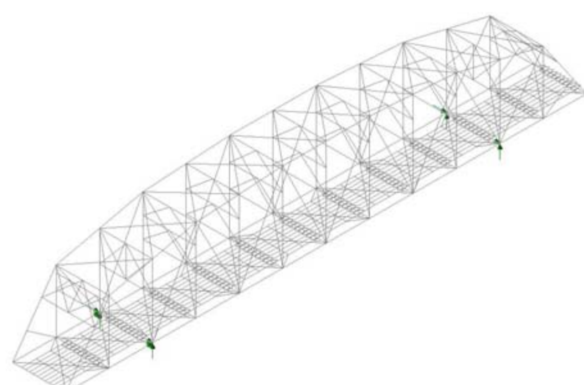


Figure 9 – Analysis of Truss During Lifting

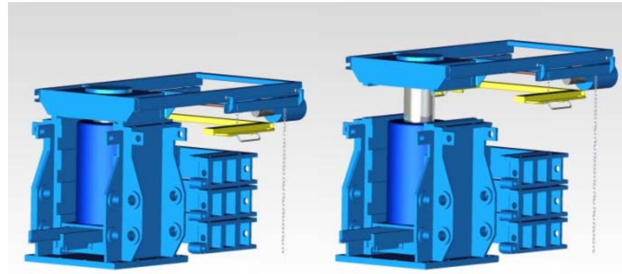
LIFTING EQUIPMENT

The lifting operation was performed using four specialized self-climbing towers – one each placed at the L2, L2’, L10 and L10’ panel points. The bottom of the towers were anchored to the concrete footings, and the top of the towers supported the underside of the specialty cribbing connected to the L2, L2’, L10 and L10’ panel points.

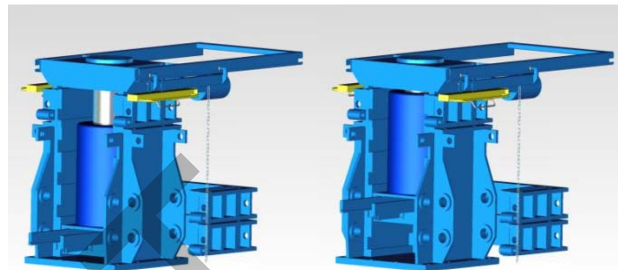
Each tower had a lifting capacity of 600 metric tons, and provided a total lifting capacity of 2400 metric tons [5.28 million pounds] for the four-tower system. Each self-climbing tower was constructed of a series of stacked U-shaped steel segments – each 250mm [9.8”] tall – with a single 600 metric ton hydraulic jack installed in the center of the tower.

The self-climbing capability of the tower was based on a repetitive cycle of jacking and installing a new tower section, to increase the overall height of the tower. When the 600t jack raised the load, a space was created at the top of the tower for installing a new tower segment. After the new segment was installed, the jack retracted upward and locked into the next-higher tower segment, and the jacking-cycle repeated until the required tower height was reached.

Figure 10 – Self-Climbing Tower



1. Starting Position 2. Extend Jack - Raise Load



3. Install Segment 4. Retract/Raise Jack

Figure 11 – Self-Climbing Tower Raising Cycle

As the height of the climbing tower increased, bracing was attached at pre-determined locations on the towers. The bracing in the transverse direction (relative to the length of the bridge) was connected between the L2/L2’ and the L10/L10’ column pairs. The bracing in the longitudinal direction was anchored to the concrete footings.

Figure 12 – Self-Climbing Tower With Bracing: Truss at Mid-Height of Lift

Figure 13 – Self-Climbing Tower With Bracing: Truss at Full-height of Lift

The lifting operation was performed over a period of several days, and was paused at mid-height to install the bridge bearings. The average cycle time for installing each tower segment was approximately 20 minutes – not including the time required to install bracing. For the required 22' lift distance, the cumulative time required for jacking and installing braces was approximately two work days.

TRANSPORT EQUIPMENT – SPMTs AND BRIDGE-SUPPORT STRUCTURE

The transport equipment consisted of self-propelled modular transporters (SPMTs), with a bridge-support structure assembled on top of the SPMTs. At four separate locations underneath the truss, four (6)-axle SMPT modules were combined to provide (24) axles of support. The bridge-support structure was built on top of the two adjacent pairs of (24)-axle groups. In total, (96) SPMT axles were used to transport the truss. Each axle had a net capacity of 30 metric tons, which provided a total net capacity of 2,880 metric tons [6.34 million pounds] for the (96)-axle SPMT transport system.

SPMTs are designed to evenly distribute the supported load to all of the axles of a multi-module SPMT system. The SPMT deck is supported by hydraulic jacks connected to the wheel sets, and the hydraulic oil powering the jacks is shared among specific groups of jacks to form independent hydraulic fields. Typically, the hydraulic jacks are grouped to provide three separate hydraulic fields across the entire SPMT transport system – commonly referred to as a three-point hydraulic suspension. This ensures that the loading to the SPMT system remains statically determinate throughout the entire transport operation. In addition to providing even loading to all of the SPMT wheel sets, a three-point hydraulic suspension has the added benefit of equalizing the support loads placed on the item being carried.

The SPMT hydraulic suspension also allows each wheel set to adjust independently to ground surface elevation irregularities. This enables the trailer deck to remain level, and maintains constant loading at each wheel set while traveling over uneven terrain.

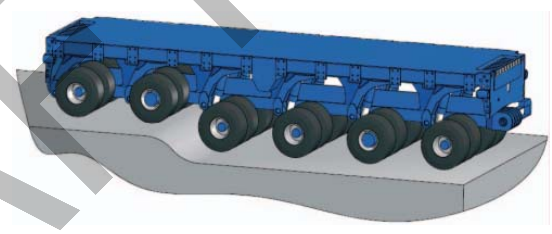


FIGURE 14 – SPMT Suspension on Uneven Terrain

The SPMT system was configured for a three-point hydraulic suspension for carrying the truss. With the three-point hydraulic suspension, and the design and arrangement of the support structure on top of the SPMTs, the truss weight was distributed equally to the eight columns that supported the truss.

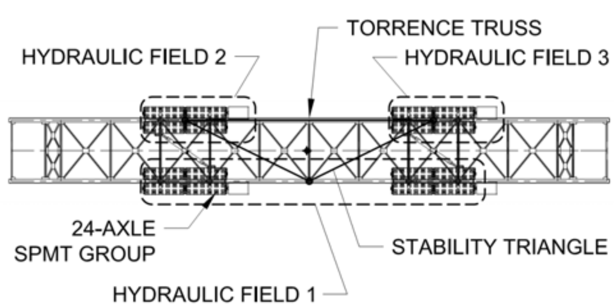


FIGURE 15 – Plan View SPMT Arrangement Under Torrence Ave. Truss. Three-Point Hydraulic Suspension.

The SPMT system was controlled by a single operator, using a remote control. Each SPMT module in the system electronically communicated with one another, allowing the entire (96)-axle SPMT system to drive, steer, and raise/lower in unison. Each SPMT module was capable of several sophisticated driving modes, and when combined, the single (96)-axle system was capable of very precise maneuvering.

Figure 16 shows the driving modes of a single SPMT module. For a multi-module SPMT arrangement, the entire system (acting as one unit) is capable of the same driving modes.

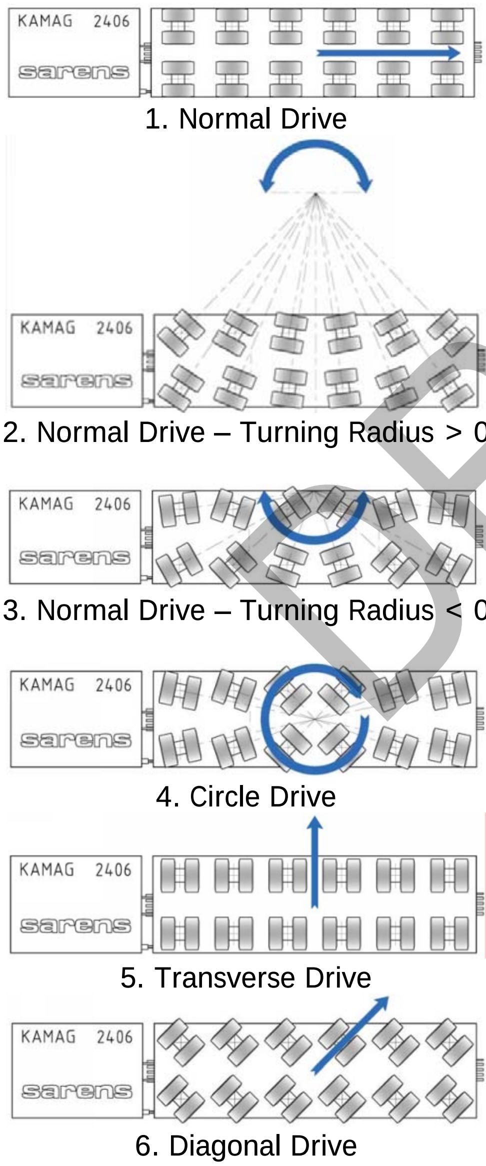


FIGURE 16 – SPMT Driving Modes

The support structure on the SPMTs consisted of specialized shoring columns and braces. There were a total of eight columns supporting the truss. Each column aligned with a bridge panel point and supported the underside of the specialty cribbing installed at the panel point. The support structure was built-up on top of the SPMTs prior to the SPMTs moving underneath the truss to take the load.

With the ability to hydraulically raise and lower the SPMT deck, the SPMT system was moved under the truss while the deck was in a lowered position, and – when ready – the truss was lifted off of the climbing towers by simply raising the deck of the SPMT system.

FIGURE 17 – Support Structure Built-Up on SPMTs – Prior to Move-In

FIGURE 18 – (2) 24-Axle SPMT Groups and Support Structure Positioned Under Truss

PREPARATION FOR BRIDGE MOVE

Preparation for moving the truss involved consideration of several issues and coordination with individual stakeholders. The travel path from the assembly yard was meticulously prepared to specific elevation and grade using earth moving and compaction machines. Because the travel path required rolling over the L10 and L10' jacking "pits", they were backfilled with a controlled aggregate material and compacted to minimize settlement or rutting potential during travel.

Surface conditions at the permanent bridge location and over the L10 / L10' panel points were improved to support the tire loads. DURA-BASE® Composite Mats were placed on the surface at these areas to provide a solid base for tire support. Use of these mats prevented potential local soil rutting on the freshly-compacted soil at L10 / L10' and due to the SPMT tires moving and rotating multiple times in the same location at the set point.

Extensive coordination with the City of Chicago, Norfolk Southern Railroad and local industrial companies was critical to project success.

- The City of Chicago and local industrial companies planned for the closure of Torrence Avenue.

- Norfolk-Southern Railroad planned for re-routing trains, provided protection and reinforcement of their tracks and removed obstructions to accommodate the bridge move.

Figure 19 – DURA-BASE® Composite Mats

Figure 20 – Site Preparations Prior to Move

TRAVEL PATH

The straight-line distance between the truss assembly location and the set point was approximately 450'. The travel path was prepared to allow the SPMT system – carrying the truss – to begin traveling east approximately 300', turn to align with the bridge design centerline, and then travel transversely over the bridge piers to the set point. The sophisticated driving and steering capabilities of the SPMT system allowed the transport operation to be executed smoothly, and as-planned.

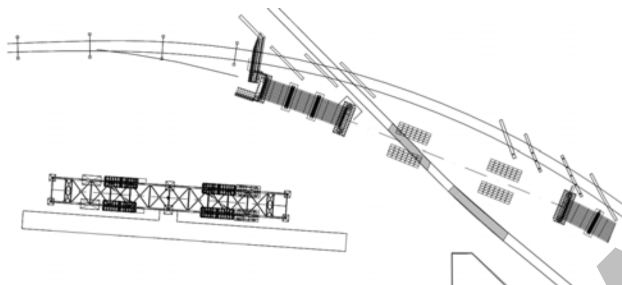


Figure 21 – Travel Path: Start of Move

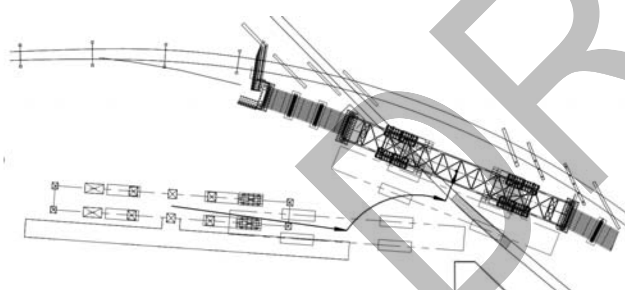


Figure 22 – Travel Path: End of Move

BRIDGE MOVE EXECUTION

Moving the bridge from the assembly yard to the final position was performed on Saturday August 25, 2012. The move started around 7AM and reached the set point around 11AM. Fine-tuning the exact location of the fixed bearings and proper alignment of the rocker bearings took several iterations, with the final set-down performed at approximately 3PM. The entire move process was completed within the scheduled 8 hour window, allowing the City of Chicago and the Norfolk Southern Railroad plenty of time to open the roadway and railroad track on-time.

Figure 23 – Bridge Move

Figure 24 – Bridge Move

Figure 25 – Bridge Move

VIABILITY OF ACCELERATED BRIDGE CONSTRUCTION TECHNIQUES

Implementation of the unique construction techniques used on the project provided several benefits for the public and project stakeholders.

Implementing Accelerated Bridge Construction techniques resulted in initially higher erection costs associated with the specialty construction equipment and activities required for execution. However, the costs associated with implementing these innovative construction techniques were justified by the benefits (i.e. minimum down-time of the busy rail crossing) realized by the project stakeholders.

The specific project conditions that made the implementation of Accelerated Bridge Construction techniques viable include the following:

1. Convenient assembly yard availability

Availability of adjacent truss assembly yard made off-site truss assembly possible.

2. Maximizing Truss Erection Efficiency

If the truss were assembled in the final condition adjacent to and over live tracks, crews would have been required to stop work each time a train passed.

3. Avoided expense of heavy falsework structures

Assembling the truss off-site and moving it into position avoided the cost of heavy falsework structures.

4. Minimized Risk and Public Inconvenience

With the exception of specific steel delivery trucks turning into the staging area, the public's use of Torrence Avenue was interrupted by only a single 24-hour period. Similarly, rail traffic was interrupted only by a single 8-hour closure.

SUMMARY

The 394' railroad truss span weighing approximately 4.75 million pounds was erected off-site and successfully moved into permanent position within the time constraints established by the owner. Accelerated Bridge Construction techniques were utilized on the project to expedite construction, minimize public inconvenience and minimize risk.

Figure 26 – Final Position

ACKNOWLEDGMENTS

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