Deck Removal for the I-75 Bridge over the Rouge River

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ABSTRACT: The Rouge River Bridge carries eight lanes of I-75 in Detroit and is the largest bridge in Michigan. A major deck replacement project for the entire bridge was undertaken starting in 2017 which was planned and performed over a two-year period. The deck removal and replacement operations were performed in phases while maintaining three lanes of traffic during the entire project. Deck removal operations required large-scale operational planning to remove existing deck from the composite steel plate girder system.

INTRODUCTION

The Rouge River Bridge carries eight lanes of traffic on I-75 over the Rouge River in Detroit, Michigan. I-75 in this area is a critical highway connecting to Canada and is very heavily used by the traveling public with Average Daily Traffic of approximately 104,000.

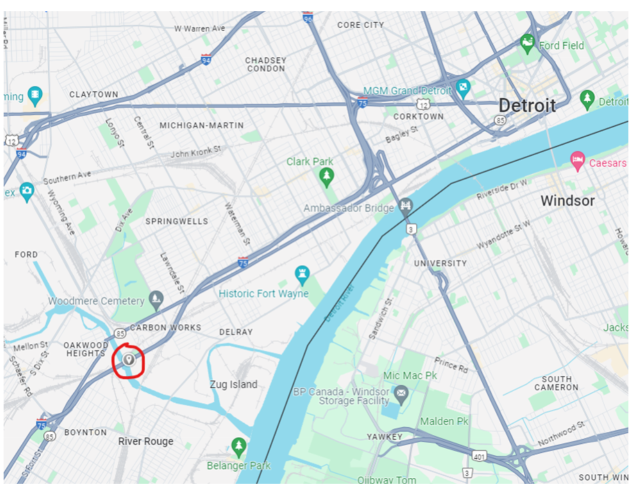

Figure 1 – Project Location

Based on length and surface area, the I-75 over the Rouge River Bridge is the largest bridge in Michigan and was originally built in 1967. The bridge consists of 106 steel plate girder spans and is 1.63 miles long, including five spans over railroads and three spans situated high over the Rouge River.

Figure 2 – Site Location

The Rouge River Bridge consists of several units including spans over six sets of railroad tracks, the Rouge River, local roadways and other terrain.

Figure 3 – Sample Spans Elevation

Figure 4 – Zone of Bridge over Rouge River

BRIDGE CONDITIONS BEFORE PROJECT

The existing NB and SB bridge structures consist of 106 spans with total length of 8,627 ft. Span lengths vary between minimum 30′-6″ and maximum 300′-0″ over the Rouge River. The deck width for each bridge is 66′-1 ½″ and each bound consists of four 12′-0″ through lanes. Bridges were constructed in 1967 and had several prior rehabilitation projects including placement of latex concrete overlay in the 1970s. Spans are comprised of steel plate girder units and include a variety of configurations including composite deck, continuous units, and pin-and-hanger details included throughout the length.

After years of service with heavy traffic usage, the bridge had deteriorated conditions including severe conditions for the concrete deck. In 2015, the bridge was determined to be "Structurally Deficient" due to bridge conditions.

Figure 5 – Deck Conditions Prior to Project

Figure 6 – Deck Repairs Prior to Project

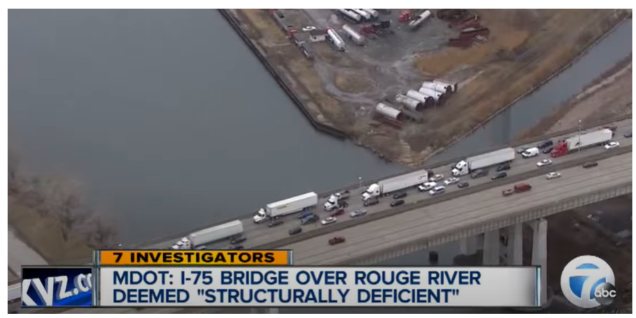

Figure 7 – "Structurally Deficient"

BRIDGE REHABILITATION PROJECT

In Fall 2016, Michigan Department of Transportation initiated a major rehabilitation project for the bridge. The project was planned for a duration of several years and included complete replacement of the concrete deck over both the northbound and southbound bridges. In addition to the deck replacement, the project included several other rehabilitation operations including joint replacement, pin-and-hanger replacement, structural steel repair, bearing rocker re-alignment, bearing replacement, pier cap repair, upgrading existing crash walls and other miscellaneous repairs.

Maintenance of traffic during the project was a major consideration due to the high traffic volume. Each bridge was planned to be repaired in separate phases to maintain traffic flow through the region.

The project was award to C.A. Hull Co., Inc. a local contractor experienced in bridge construction and rehabilitation.

DECK REMOVAL LOGISTICS PLANNING

The scale of the project and overall size of the bridge required system planning and management in preparation for the work. In the early planning phases of the project, the Contractor team and demolition engineering team worked together to discuss the deck removal operations and work through strategies for performing the work. The planning team performed several field visits to gain familiarity with the project, identify critical points of the bridge site and inspect the overall condition of the structure. The deteriorated structural condition was a major consideration in planning.

After processing the overall scale of the project, the Contractor and demolition team worked together to develop initial strategies for the deck removal. Preliminary studies were performed to investigate the size and configuration of equipment that could be used in the deck removal operations based on load-carrying capacity of the bridge elements and the existing conditions. To perform the work over such a large bridge required the use of many pieces of construction equipment including multiple pieces and sizes of excavators, wheel loaders, sand blaster recycler, deck saws, sweeper trucks, skid steer machines and various service trucks.

After discussions and planning, the operations were organized into Equipment Groups planned to perform specific operations:

- Equipment Group 1 – Cut Barrier and "score-cut" top of deck
- Equipment Group 2 – Install exterior overhang fascia support system
- Equipment Group 3 – Remove barrier and exterior overhang slab
- Equipment Group 4 – Remove deck slab panels and remove concrete from top of girders

Multiple pieces of equipment were included in each group and each group had spacing and operational limits within the group. Spacing limits were also established between the equipment groups.

The equipment details, spacing and operational limits were used in performing demolition engineering.

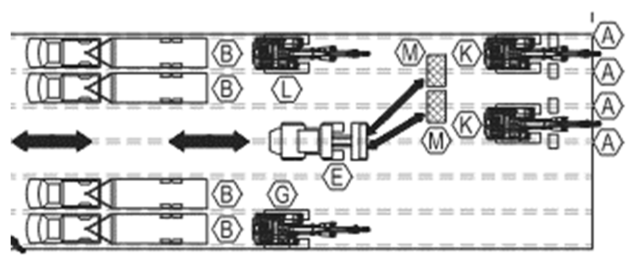

Figure 8 – Equipment Group 4

DECK REMOVAL ENGINEERING

The objective of the engineering for the deck removal operations was to verify bridge system adequacy in support of the deck removal equipment during the deck removal operations. The engineering evaluations included several considerations as follows.

SYSTEM ADEQUACY LIMITS – The Contract Documents specifically noted that deck removal engineering was required to show that applied loads do not exceed the Operating Level stress limits based on the AASHTO Manual for Condition Evaluation of Bridges. This requirement suggested that the bridge demolition operations be evaluated similar to a bridge rating, specifically treating the demolition operation as a single-use load condition similar to a rated truck passage. This evaluation method allowed for a higher level of component utilization than the original design (equivalent to inventory-level limits) by considering the demolition operation as a unique condition.

Since the time of this project, the method of evaluation using Operating-Level as the applicable allowable stress limits has been widely accepted as industry-standard for bridge demolition engineering methods.

The utilization of Operating-Level allowable stresses results in allowed flexural stresses which are up to 36% greater than the basic allowable stresses for the original design and for Inventory-Level ratings. While this allowable level of stress is safe when engineered properly, it results in lower factor-of-safety in the system during the work. Based on this reduced factor-of-safety, the operational controls and management are critical to verify that the work is performed in accordance with the limits and restrictions associated with the evaluation. With this plan, the management of the work is critical to work within the limits of the engineered plan.

MECHANICS OF DECK REMOVAL – For deck removal on steel-concrete composite spans as existed on this bridge, the deck removal operation fundamentally has duplicate effects. The more straightforward effect of the deck removal is the removal of the weight of the concrete deck. This affects the structural system and must be monitored and controlled, specifically in span configurations with pin-and-hanger connections or other configurations that may be susceptible to load imbalance and instability. The more complex consideration of the deck removal is that the fundamental mechanics of the superstructure unit is transformed from a composite system to a non-composite system with only the steel girders acting to resist loads. This change in behavior is significant because the load-carrying capacity of the system is significantly reduced. In the non-composite state, the flexural capacity of the steel girder units is based on local flange buckling (dependent on compression flange aspect ratio) and lateral-torsional buckling with bracing based on the remaining diaphragms. Consideration of this effect was critical in evaluating the bridge system for conditions during demolition.

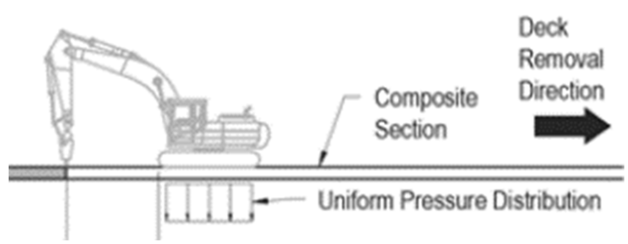

Figure 9 – Composite / NC Zones

EQUIPMENT LOADING – The load effects of the various equipment were computed based on available product information, consideration of supported materials and operational impact. Loading due to excavators was based on machine geometry and weight, considering scenarios of the machines working over-the-front or over-the-side and also considering the weight of attachments and supported loads. The effects of dynamic loading effects (impact) due to the demolition operations were estimated based on observed severity of operations with values of 1.10 applied for the panelized deck removal operations and 1.05 applied for conditions of equipment moving without loads. Loading was developed for other equipment based on actual equipment weight, geometry and operational considerations. Final determination of equipment loading required intense communications and collaboration with the Contractor to verify consistent equipment was used in the evaluations and planned for field operations.

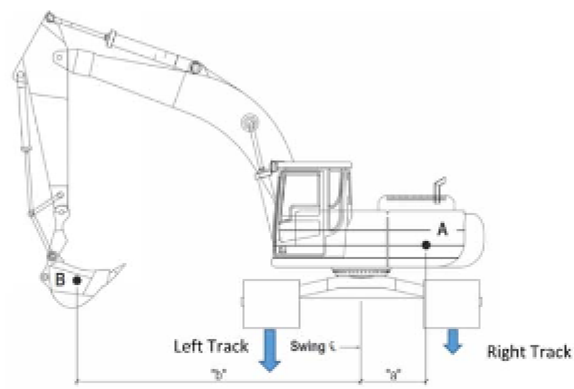

Figure 10 – Excavator Track Loading

BRIDGE CONDITIONS CONSIDERATIONS – The significant deterioration of the deck was a design consideration. Based on the known condition of the deck, the top layer of the reinforcing steel was considered to be only 75% effective based on the presence of deck deterioration at the top of the deck prevalent over the length of the bridge. The de-rated top reinforcing was used to evaluate the local deck adequacy in support of equipment between girders.

Based on observation, the steel girders were found to be in satisfactory condition and full section properties were used in the evaluation.

SPAN CONFIGURATIONS & STABILITY – The presence of pin-and-hanger details throughout the bridge resulted in conditions which were potentially subject to uplift during deck removal. For spans with pin-and-hanger details, the system stability is dependent upon maintaining sufficient downward load on the supporting anchor spans while equipment loading is on the suspended spans. As a part of the engineering work, this effect was considered through tracking reactions to verify stability in the system during all stages of work.

FALSE DECKING & SURFACE PROTECTION

False decking was used under the entire length of the bridge to protect the surface from miscellaneous falling debris resulting from the demolition operation, as well as to provide a work platform to facilitate deck reconstruction.

For most of the interior bridge bays, SafeSpan corrugated metal decking was used as false decking.

For the exterior bays, a unique false decking system was utilized which also functioned for the new deck construction to support the deck forming machine. A series of custom-fabricated beams were used to cantilever from the fascia girder and support false decking outside the bridge. The cantilever beams were hung from the bottom flange of the fascia girder and the adjacent interior girder. Installation of the system required specialty articulating excavator attachments supported by precise and coordinated operator movements.

See Fascia System Forming section for more details of this system.

FIELD DEMOLITION OPERATIONS

The deck replacement was performed over a period of two years. In 2017, the SB bridge deck was removed and replaced with traffic maintained on the NB bridge. In 2018, the same operation was performed on the NB bridge with traffic maintained on the SB bridge.

Deck removal operations were staged and managed to work within the limits and restrictions associated with the evaluation. Based on the scale of the bridge and operation, the management and control of the work was a major effort to coordinate the activities and work of many field staff working together in the operation.

Figure 11 – Equipment on Deck

Figure 12 – Equipment during Deck Removal

Figure 13 – Deck Removal Operation

Figure 14 – Deck Removal Operation

Figure 15 – Deck Removal Operation

NEW DECK CONSTRUCTION

CONCRETE DELIVERY -

One of the first challenges the construction team recognized pre-bid was the difficulty in delivering new concrete to the bridge deck. With six railroad crossings, spans over water (and at heights of over 100') and significant bridge skews, traditional pump truck concrete delivery to the deck was not a feasible option.

After reviewing all available industry options, C.A. Hull coordinated with Illinois-based Rotec Industries to design and build a custom "bridge plow" conveyor system. The system allowed ready-mix concrete trucks to deliver concrete from the construction haul road directly into the plow's hopper, with the conveyor belt then used to spread concrete transversely across the bridge deck. As the full width of the deck was covered, the plow would advance along the bridge down the screed pipes and repeat the process along the bridge. A traditional deck forming (Bidwell) paving machine followed behind the concrete placing plow, utilizing the same screed rail. This operation was utilized to efficiently cast the new bridge deck for a majority of the bridge spans.

FASCIA SYSTEM FORMING -

Due to the geometry and scale of the proposed bridge deck, it was critical to evaluate and implement any efficiencies the contracting team could find. A particular challenge for both formwork and deck casting was the large outside fascia width, which averaged about 6'-6" wide.

Recognizing that traditional fascia jacks would not have the required structural capacity to support the plastic concrete on the outside fascia, and that the distance between the screed pipe (assumed to be on the fascia girder top flange) and the fascia form would require an unrealistic amount of hand-finishing of deck concrete, the contractor prioritized the development of a more effective forming system that would allow for the outside screed rail to run on top of the outside fascia wall form, not on top of the fascia top flange as is often standard. This new system would also require significantly more capacity than traditional fascia jacks.

Towards that goal, the contractor and engineer developed the Needle Beam System to accommodate demolition false decking as well as provide the vertical support for loading both plastic concrete during placement, as well as finishing machine and concrete conveyor wheel loading. The needle-beams were comprised of various steel shapes and sections, at either 6' or 8' spacing, and were installed using a 210-sized excavator. The excavator featured a rotating attachment at the end of the boom and coordinated with a crew under the bridge in a man basket to install the bolted connections to the bottom flanges of the girders. The excavator attachment was able to rotate 360 degrees, and the contractor added custom hydraulic controls to pinch, manipulate, and release the needle-beam to facilitate installation from the bridge deck. Using multiple live-feed cameras mounted on the excavator boom with display monitors in the cab (as well as simultaneous communication with the crew in the manbasket over radio), the team worked together to swing the needle-beams from the top of the deck under the bridge, fine tune their positioning, and bolt them into place.

An added benefit to the Needle-beam System was the elimination of any torsion of the fascia girder due to the eccentric loads from the paver and bridge plow riding on the outside fascia. With needle-beams bolting to the fascia and adjacent interior girder, the downward force from the paver and plow was countered by the interior girder, eliminating any moment in the fascia girder.

For the actual deck forming, a 6”x6” vertical timber and a screw jack were mounted on the top face of the needle-beam. The timber would provide the support for the bottom-of-deck formwork, and the screw jack would allow the contractor to make fine-tuned deck grade adjustments. The timber tied into a horizontal joist that reached from the fascia girder to the outside of the fascia walkway.

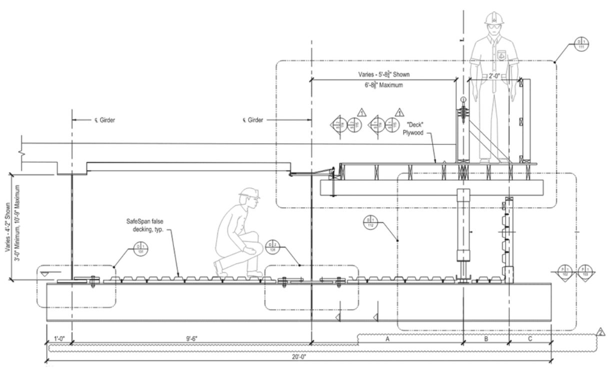

Figure 16 – Fascia Overhang System


Figure 17 – Fascia Overhang System


Figure 18 – Fascia Overhang System


Figure 19 – New Deck Construction

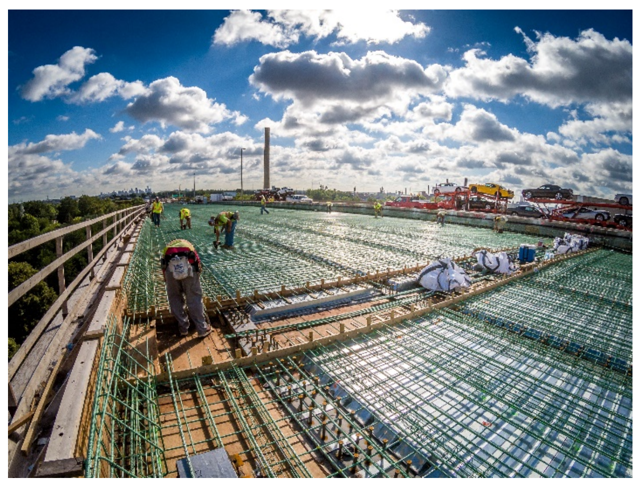
Figure 20 – New Deck Construction

Figure 21 – New Deck Construction

Figure 22 – New Deck Construction

SUMMARY

The deck replacement and overall bridge replacement project was successfully completed over two years, meeting all project objectives.

As a part of the project, the following general quantities were processed by the field operations for the deck replacement:

- Replaced bridge deck over 106 spans for two separate bridges (Northbound and Southbound).
- Performed deck removal in panels over an area of approximately 26 acres.
- Placed approximately 33,000 cubic yards of concrete for new deck construction.

The project was completed safely and on schedule.

The total project investment was approximately $154 Million.

ACKNOWLEDGMENTS

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