Demolition Challenges of the Harry W Nice/Thomas “Mac” Middleton Bridge

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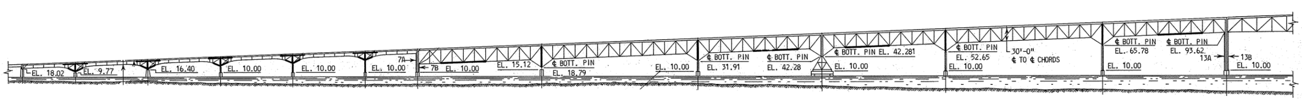
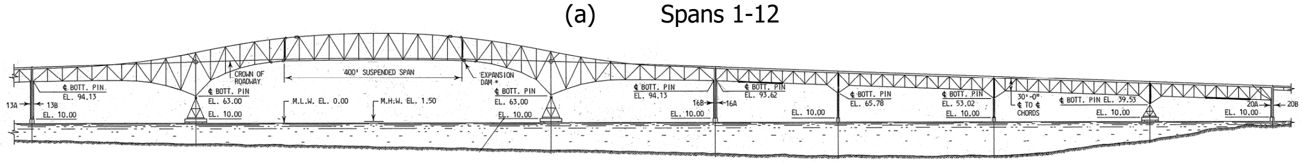
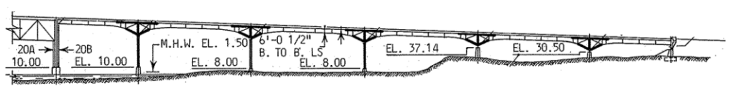
ABSTRACT: The Harry W Nice/Thomas “Mac” Middleton Bridge was a uniquely designed and built structure from its birth in 1940 and posed some very unique challenges during its removal nearly 100 years later. With superstructure types ranging from simple span precast bridge units, to deep plate girder spans, to continuous deck trusses, to the main channel consisting of a 3-span continuous arched support truss; each structure type required specialized demolition analysis and processes to safely remove the aging structure.



(a) Spans 1-12



(b) Spans 13-19



(c) Spans 20-25

Figure 1 – Bridge Elevation

The unique design of the rhomboidal regions developed interesting load distribution within the system when subjected to irregular loading coinciding with demolition operations. This presentation will highlight the various demolition methods considered for these different structure types and the decision process that led to the selected removal methods. The presentation will conclude with review of the demolition activities on the bridge, including large demolition equipment, precision structural element removal, and explosive demolition, including a lesson in expecting the unexpected when bridges decide to defy the laws of physics.

INTRODUCTION AND PROJECT BACKGROUND

The original structure was constructed in 1940 and consisted of five different structural systems that carried US 301 over the Potomac River and stretched nearly two miles long. The structure consisted of the following structural types:

- 60 trestle spans
- 12 continuous haunched girder spans
- 10 deck truss spans
- 2 anchor truss spans
- 1 suspended truss span

Unfortunately, the original highway was only a two-lane road and experienced frequent congestion issues since the late 2000s. Therefore, the construction of a new four-lane highway bridge to replace the aging structure was deemed necessary by the Maryland Transportation Authority (MDTA). The new bridge was constructed and opened to traffic in Fall of 2022 and the demolition of the original structure followed in the Spring of 2023.

Due to the age and unique design of the existing structure, the demolition engineering to meet the needs of the contractor and maintain a stable system proved to be challenging.

ORIGINAL BRIDGE CONSTRUCTION – Construction of the Potomac River Bridge began in mid-1939 and was competed in late-1940, a total construction duration of approximately 18 months. This is impressive considering the structural complexity of the bridge. Pinned 2D plane frames (as shown in Figure 2) were used as the primary substructure elements for the bridge along with fixed towers (as shown in Figure 3) at discrete locations within each structural system. Additionally, unique rhomboidal regions at the pier locations required a strict erection plan to maintain structural stability. Similar design considerations were critical for the demolition.

Figure 2 - View of 2D Plane Pier and Rhomboid Region

Figure 3 - View of Fixed Pier Tower

The suspended span was supported by two fixed tower piers and adjacent anchor spans. The original construction employed an elaborate network of temporary frames, struts, and cable supports to provide stability of the truss prior to erection of the suspended and anchor spans as shown in Figure 4.

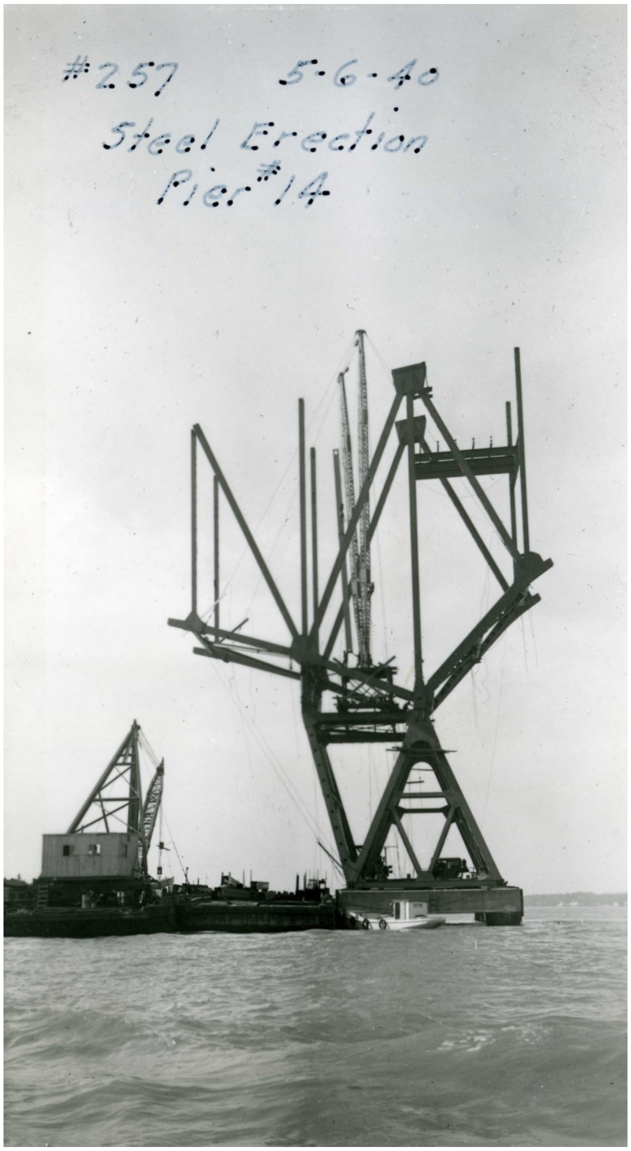


Figure 4 - Anchor Span Truss Construction

REMOVAL METHODS – The demolition engineering of the structure was carried out in multiple phases based on the various structure types, environmental constraints and sequenced to meet the schedule needs of the contractor. Each structural system was evaluated for various demolition operations based on coordination with the contractor and revisions to the construction timeline. The deck removal was performed using a combination of hammering with an excavator, sawing and slabbing with an excavator, and lifting operations with a crane. This is discussed in more detail in the following sections.

Similarly, the steel removal (superstructure and substructure) was performed using several different methods. An excavator operating on a barge was used for removal of the trestle span steel. Heavy Lift Cranes performed lifting operations for removal of the girder span steel. A combination of explosive demolition and crane lifting operations were used for the deck truss, anchor truss, and suspended truss spans.

TRESTLE SPAN REMOVAL

STRUCTURAL SYSTEM – The trestle spans were replaced during rehabilitation work performed in 1985. The new spans consisted of 60 individual simple spans which were comprised of a 9 in. lightweight concrete deck composite with three supporting 42” plate girders as shown in Figure 5. The plate girder design consisted of a 7/16 in. by 9 in. top flange, a 3/8 in. by 42 in. web, and a 11/16 in. by 12 in. bottom flange.

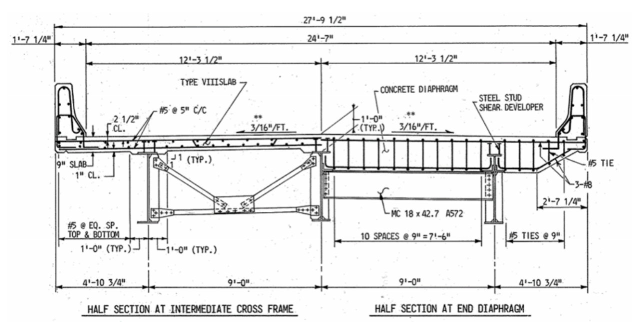


Figure 5 - Section of Trestle Span

PRELIMINARY EVALUATION – The demolition analysis evaluates the adequacy of the structural components for the anticipated load effects during the demolition operations. This includes the existing dead loads and the live loads (plus impact) of the demolition equipment.

Additionally, the evaluation considers the variation in section strength due to the loss of composite action along the length of the span as the deck removal is performed. For a simple span, the critical zone is typically at the location where the steel girder section transitions from composite to non-composite, as this location has a significant reduction in section strength while being subjected to higher demands due to the proximity of the demolition equipment.

Upon review of the contract plans, it was discovered that the trestle spans were designed and constructed as pre-built units. This indicated that the steel girders and deck were constructed using shoring to lock in the stresses on the composite section. Additionally, the individual spans were installed as a single unit using crane lifting operations.

DEMOLITION ENGINEERING – The barrier sections were removed from the entire span prior to deck removal. The overhang deck regions were removed first followed by the interior deck regions within a given row. The deck removal consisted of a combination of hammering operations at the end diaphragms and over the girder flanges and saw-and-slab operations for the remaining deck portions as shown in Figure 6. The maximum size excavator used was a 25 ton excavator.

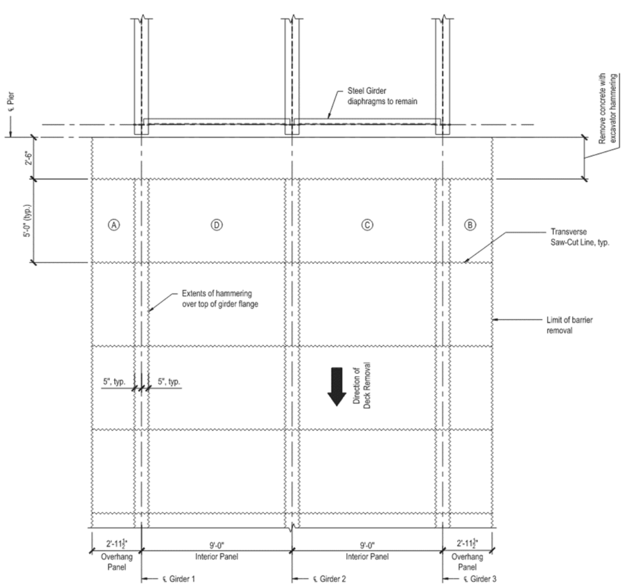


Figure 6 - Trestle Span Deck Removal Detail

Once the deck was removed from the entirety of the span, the steel superstructure was removed using a barge-supported excavator to lift the beams out as shown in Figure 7.

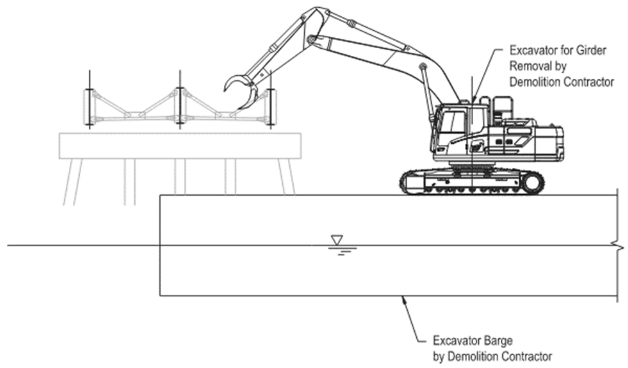


Figure 7 - Trestle Span Steel Removal Detail

Figure 8 shows the in-field demolition operations for the trestle span. As engineered and detailed, a series of excavators positioned on the deck removed deck sections while excavators positioned on a barge removed steel superstructure once the deck was entirely removed from a span.

Figure 8 - Trestle Span Demolition

GIRDER SPAN REMOVAL

STRUCTURAL SYSTEM - The girder spans (Spans 1-6 and 20-25) were comprised of a 4 in. steel grid deck on W12 cross-beams which were supported by two variable depth plate girders and a W26 stringer supported by a W30 floorbeam as shown in Figure 9.

The variable depth plate girders were the main load carrying structural members and made up a

6-span continuous system. At each pier location, the girders framed into the top of the substructure through diagonal struts and posts while containing a hinge at the top of the girder to allow for rotation. Figure 10 illustrates the structural layout of the girders at the pier locations. These regions are referenced as the rhomboid regions due to the unique rhomboidal shape created by the change in girder depth and framing struts. The vertical posts seen in Figure 10 were not part of the original design and were added during the rehabilitation work in 1985.

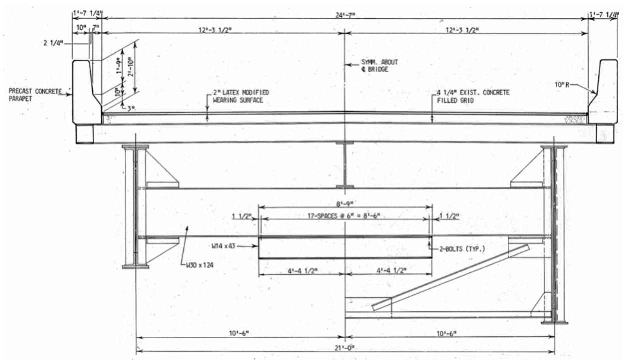


Figure 9 - Typical Cross-Section for Girder Spans

Figure 10 - Girder Span Pier Framing

STRUCTURAL ANALYSIS – A finite element model of the girder spans (Spans 20-25) was developed using LUSAS to evaluate the load effects from the demolition operations on the structural system. The FEA model consisted of a combination of thick beam elements and thick shell elements to idealize the various components of the structural system.

Multiple demolition methods and sequences were evaluated to meet the needs of the contractor, however, the main challenge for all scenarios for the girder spans was the load effects at the rhomboid regions. The installation procedure for the vertical posts during the 1985 rehabilitation work induced minimal dead load into the post members. The majority of the loading is from the application of live loads on the structure. Therefore, any imbalance of dead load from the adjacent spans induced tension in the vertical posts. Unfortunately, the connection details of the vertical posts were not adequate for this loading, and therefore, the deck demolition required a unique sequence to minimize the tensile loading in the vertical posts.

Similarly, in the steel removal planning, the vertical posts were the critical structural detail, as they became the primary load path for shear transfer when adjacent spans were removed. In the existing condition, the vertical post is only subjected to compression loading when live load is applied to the structure, while the existing struts serve as the primary load path for transferring the dead load to the substructure. During sequenced demolition of the steel superstructure, removal of an adjacent span eliminates one-half of the rhomboid region and re-directs the load path for shear transfer of the dead load through large compressive loads in the vertical posts. These high compressive loads required that the vertical posts be strengthened, as shown in Fig. 11, by the addition of chain bracing to prevent buckling of the post.

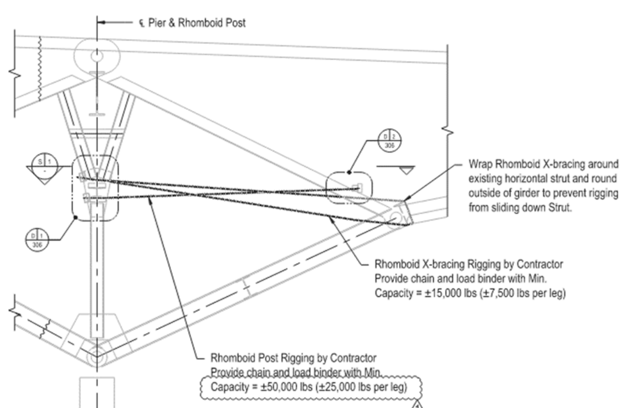


Figure 11 - Girder Span Vertical Post Strengthening

DEMOLITION ENGINEERING – The initial deck removal was completed using a 330Ton crane to lift 130,000 lbs. deck slab sections that included the cross-beam sections. The deck slabs were removed in a specified sequence to minimize the tensile loading in the vertical posts at the piers as shown in Figure 12 and to minimize the environmental impacts of saw-cutting slurry containment and slabbing the bridge deck is not preferred when the deck is supported on transverse stringers. The interior deck panels were removed in an initial pass followed by the panels over the piers.

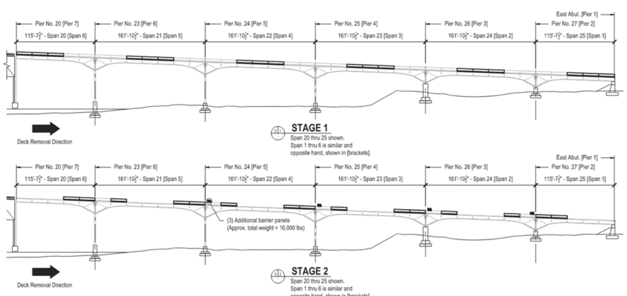


Figure 12 - Girder Span Deck Removal Sequence

The initial steel removal was completed using crane lifting operations to lift entire spans off the structure (See Figure 13) with the heaviest span having a pick weight of 300,000 lbs. In order to maintain structural adequacy, strengthening was required for the vertical posts within the rhomboid regions to increase the compression capacity once the rhomboid region was decoupled (Figure 11). Additional bracing was required to secure pier towers during steel removal prior to removing the pier towers.

As demolition progressed, the contractor requested an alternate sequence for deck removal for Spans 20-25.

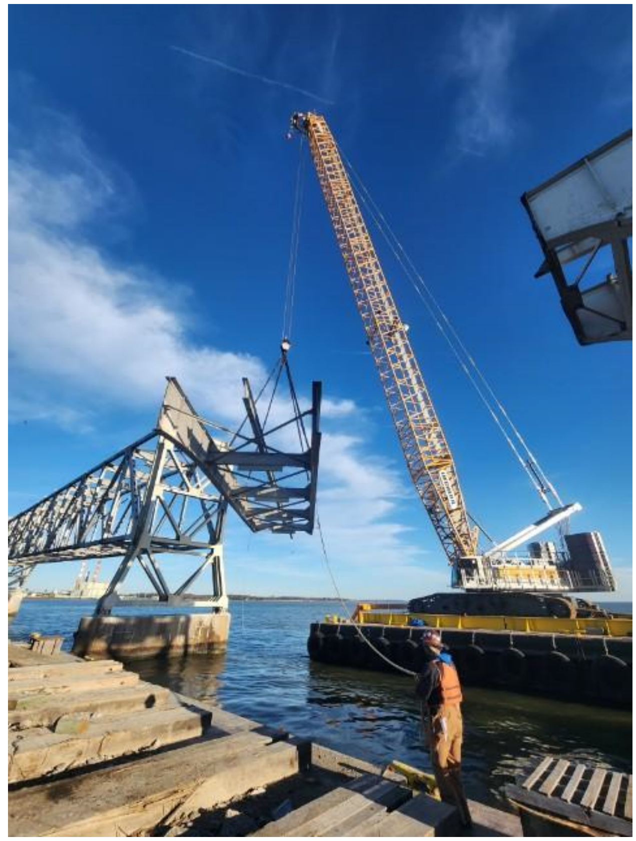


Figure 13 - Girder Span Steel Removal

DECK TRUSS SPAN REMOVAL

STRUCTURAL SYSTEM - The deck truss spans (Spans 7-9, 10-12, and 16-19) were comprised of a 4 in. steel grid deck on W12 cross-beams which were supported by three W24 stringers and W33 floorbeams that framed into the deck truss as shown in Figure 14.

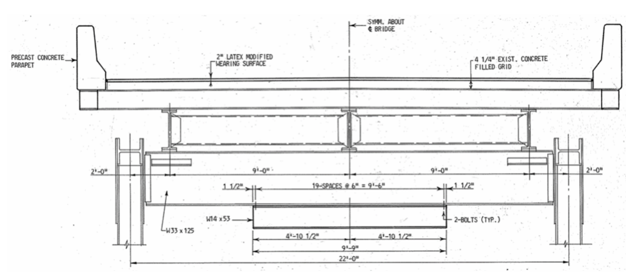


Figure 14 - Typical Cross-Section for Deck Truss Spans

The stringers were continuous over the floorbeams and the trusses were continuous over the piers in a 3- or 4-span configuration. Similar to the girder spans, the deck trusses framed into the top of the substructure through diagonal struts and posts, while containing a hinge at the top of the truss to allow for rotation. Figure 15 illustrates the structural layout of the trusses at the pier locations.

Figure 15 – Deck Truss Span Pier Framing

STRUCTURAL ANALYSIS – A finite element model of the deck truss spans (Spans 16-19) was developed using LUSAS to evaluate the load effects from the demolition operations on the structural system.

Multiple demolition methods and sequences were evaluated to meet the needs of the contractor, however, for all scenarios the rhomboid regions once again proved to be the primary challenge. Differences in detailing of the rhomboid region of the deck trusses compared to those in the girder spans, meant that tension on the deck truss posts was not an issue, and therefore, a unique deck panel removal sequence was not required.

DEMOLITION ENGINEERING – The deck removal was completed using an 330 Ton crane to lift 111,000 lbs. deck slab sections that included the cross-beam and stringer sections as shown in Figure 16.

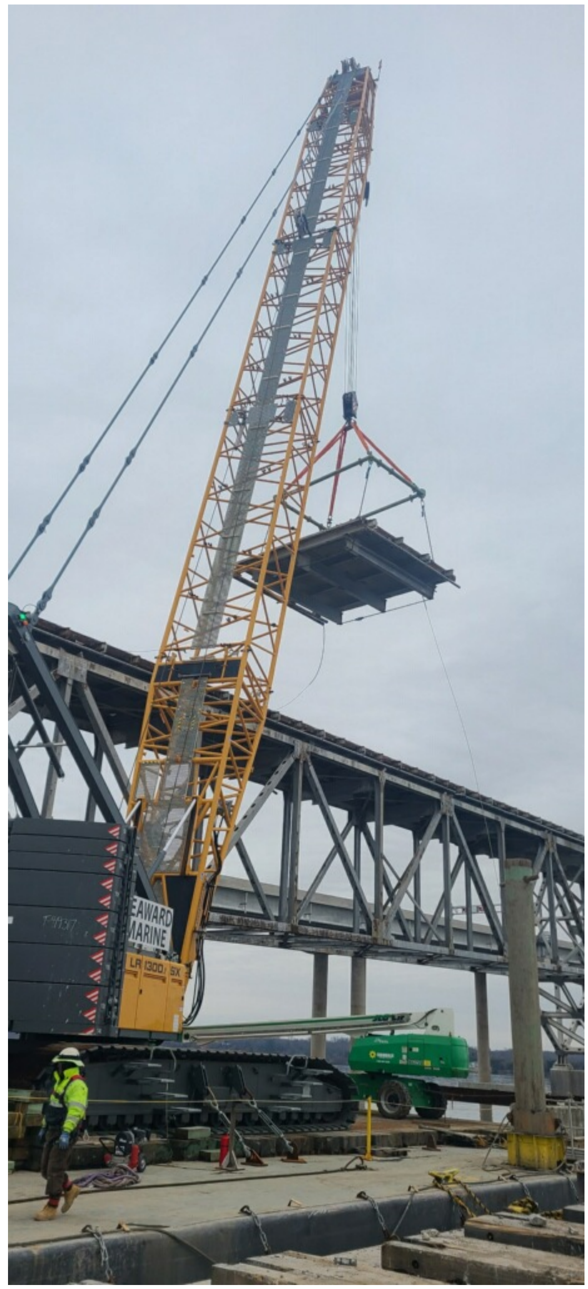


Figure 16 - Deck Truss Deck Panel Removal

The steel truss removal was completed using explosive demolition (See Figure 17). The explosive charge locations were selected such that the individual truss segments would not exceed 100 tons when hoisted out of the river, as well as ensuring that each segment would be stable during hoisting.

Figure 17 - Deck Truss Explosive Demolition

MAIN SPAN AND ANCHOR SPAN REMOVAL

STRUCTURAL SYSTEM - The suspended main truss span and anchor truss spans (Spans 13-15) were comprised of a 4 in. steel grid deck on W12 cross-beams which were supported by three W30/33 stringers framing into 54" built-up floorbeams that framed into the truss as shown in Figure 18.

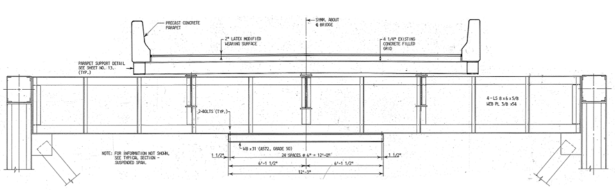


Figure 18 - Typical Cross-Section for Anchor Truss Spans (Similar for Suspended Main Span)

The global structural system was comprised of 367 ft. anchor spans which supported the 400 ft. suspended span off of 200' cantilever arms (See Figure 19). The suspended span weighed approximately 1,400,000 lbs.

Figure 1 - Main Suspended Span and Anchor Spans

STRUCTURAL ANALYSIS – A finite element model of the spans was developed using LUSAS to evaluate the load effects from the demolition operations on the structural system.

The primary challenge for the demolition of these spans was the imbalance of load between the suspended span and the anchor spans. If the deck was completely removed from the anchor spans prior to the suspended span, the end piers would experience large uplift forces.

Additionally, the truss transitioned from a deck truss in the anchor spans to a through truss on the main suspended spans, therefore, deck demolition operations had to account for the presence of the truss over top of the deck. In these regions, the contractor removed deck in panels with an excavator.

One evaluation investigated the effects of removing the suspended span from the cantilever arms through explosive demolition. A dynamic nonlinear analysis was utilized to determine the load effects on the remaining anchor spans and cantilever arms. The dynamic effects of removing the suspended span developed large tensile loads at the interior piers (Pier 14 and 15). The connection details at Pier 14 and 15 contained bearing-only type connections where the truss framed into the pier and were not adequate for the tension loading. Ultimately, a systematic deck demolition plan and explosive demolition were utilized for these spans.

DEMOLITION ENGINEERING – The deck removal was completed using saw-and-slab operations within the through truss region of the main suspended span. As the deck was removed, the excavator would remove the supporting cross-beam sections and the stringers as shown in Figure 20.

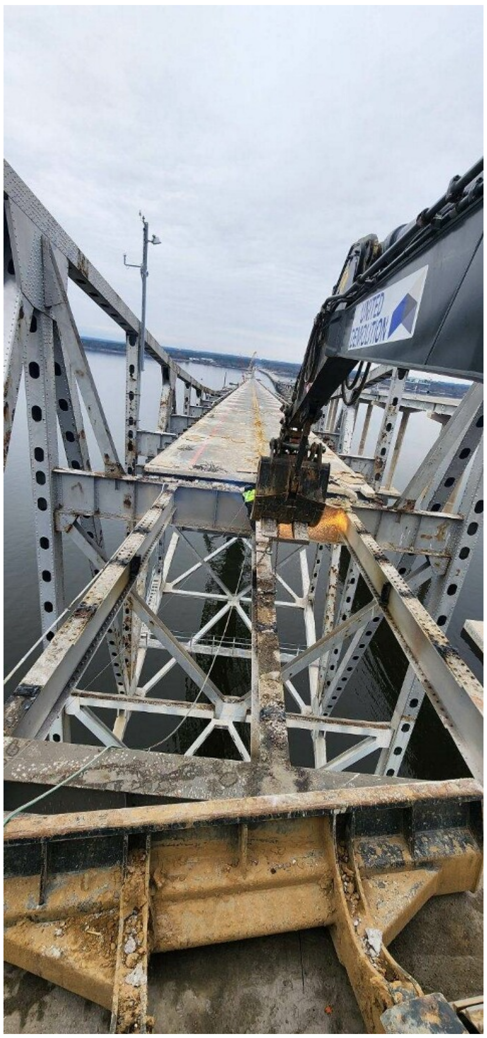


Figure 2 - Main Span Deck Removal

As the truss transitioned to a deck truss, the deck and supporting stringer system was removed using crane lifting operations similar to the deck truss spans.

Lastly, the steel superstructure was removed by explosive demolition similar to the deck truss spans. The explosive charge locations were selected such that the maximum segment weight did not exceed 300 ton. An extensive pre-cut analysis was performed on the steel truss member sections to maintain sufficient member strength and stability leading up to the blast. Due to the system configuration, certain truss members that required pre-cutting were subjected to high load demands even after the deck was removed. As a result, the precut sections could have a 4 in. maximum cut length for explosive charge placement. Figure 21 shows the explosive demolition of the main span and anchor spans.

Figure 3 - Main Span and Anchor Span Explosive Demolition

KEY PROJECT TAKEAWAYS

The unique structural layout and design of the Harry W Nice/Thomas “Mac” Middleton Bridge introduced multiple challenges in the development of an engineered demolition plan. Each demolition stage presented its own set of obstacles that had to be coordinated between United Demolition and Genesis Structures in order to ensure that the structure remained stable and safe throughout the demolition process while being cost effective and maintain the project schedule.