STATE OF CALIFORNIA

DEPARTMENT of TRANSPORTATION

**DIVISION OF
ENGINEERING SERVICES**

**MATERIALS ENGINEERING
AND TESTING SERVICES**

**OFFICE OF RIGID PAVEMENT
AND STRUCTURAL CONCRETE**

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The Tappan Zee Bridge

LESSONS LEARNED FROM THE TAPPAN ZEE BRIDGE, NEW YORK

STATEWIDE

January 2003

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ACKNOWLEDGEMENTS

The Office of Rigid Pavement and Structural Concrete would like to express their gratitude to the following for their participation, assistance, and support:

APPLIED RESEARCH ASSOCIATES, INC.—ERES CONSULTANTS DIVISION

APPLIED MATERIALS ENGINEERING, INC.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

Background

The Governor Malcolm E. Wilson Tappan Zee Bridge carries the New York Thruway's mainline across the Hudson River and connects Westchester and Rockland Counties about 13 miles (21 km) north of New York City, as shown in figure 1. The bridge spans 3.03 miles (4.87 km) and was built between 1951 and 1955. The bridge was opened to traffic in December 1955 with six lanes of traffic, three each in the northbound and southbound directions. In addition, the bridge had an open curb-height median with a single lane-width. Table 1 gives a summary of significant facts and figures for the Tappan Zee Bridge.

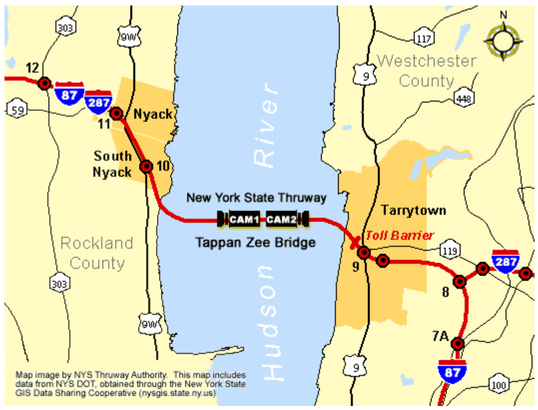


Figure 1. Location of the Tappan Zee Bridge (1).

Table 1. "Facts and figures" summary of the Tappan Zee Bridge (2).
(1 inch = 25.4 mm; 1 foot = 0.3048 meters)

Type of bridge	Cantilever and truss
Initial test pilings	June 1951
Construction started	March 16, 1952
Opened to traffic	December 15, 1955
Length of main cantilever span	1,212 feet (369.5 meter)
Length of side cantilever spans	602 feet (183.5 meter)
Length of bridge, main and side spans	2,416 feet (736.4 meter)
Number of secondary deck truss spans	19 spans
Length of secondary deck truss spans	235 feet (71.6 meter) to 250 feet (76.2 meter)
Total length of bridge and approaches	16,013 feet (4880.7 meter)
Width of bridge	90 feet (27.4 meter)
Number of traffic lanes	7 lanes
Clearance at center above mean high water	138.5 feet (42.2 meter)
Height of towers above mean high water	293 feet (89.3 meter)
Concrete used in eight caissons	42,702 cubic yards (32,648 cubic meter)
Concrete used in entire structure	153,900 cubic yards (117,664 cubic meter)
Reinforcing steel used in entire structure	14,610 tons (13 million kg)
Structural steel used in entire structure	59,250 tons (53 million kg)
Timber piles used in bridge foundations	1,602,200 feet (488,350 meter)
Cost of original structure	$80,800,000

The bridge experienced its first full year of traffic in 1956 and carried approximately 18,000 vehicles per day—well within its design capacity of 100,000 vehicles per day. However, by 1991 the bridge had an average traffic of 105,000 vehicles per day, and current estimates show that the traffic has increased to 135,000 vehicles per day. This increase is typical of traffic increase patterns in urban areas in the rest of the country.

To accommodate the increase in traffic, in 1987 the median lane was converted to a southbound traffic lane. The addition of this extra lane eased congestion in the morning traffic heading towards New York City but could not alleviate congestion in the evening commute in the northbound direction. In 1992, this problem was resolved by employing a movable barrier system that changes a three-lane northbound and four-lane southbound configuration in the morning to a four-lane northbound and three-lane southbound configuration in the evening, as shown in Figure 2. Shifting the movable barrier twice a day provides a "customized" lane configuration with four lanes in the direction of heavier traffic.

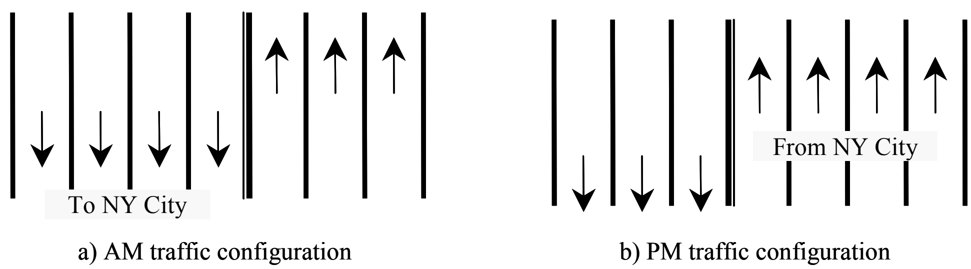


Figure 2. Traffic configuration on the Tappan Zee Bridge.

The Tappan Zee Bridge is managed by the New York State Thruway Authority (NYSTA) and is on the toll-supported Thruway system. The toll is collected from the southbound traffic on this bridge ($3 per passenger car and higher for trucks, depending on the load level). It is estimated that the NYSTA collects about $250,000 per day at the toll plaza.

Need for Deck Replacement

The original deck in the Tappan Zee Bridge was a 6.75-inch (171.4 mm) thick reinforced concrete panel. Over the years, a 2-inch (50-mm) asphalt concrete overlay was added to the deck. The bridge showed signs of deterioration from the early 1990s. Damage due to increased traffic levels, chloride ion penetration in the concrete deck, and other environmental factors indicated that the bridge deck had outlived its design capacity and was in need of rehabilitation or replacement. The NYSTA has since undertaken a series of deck replacement projects at different stages.

The lane operations and traffic management discussed in the previous section are testimony to the importance of the Tappan Zee Bridge as a main connector to New York City and a critical commuter route. The NYSTA requires that any rehabilitation, restoration, or maintenance work carried out on the bridge should be scheduled so as to put seven lanes of traffic back on the bridge between 6 AM and 8 PM. Contractors are penalized $1300/minute if all seven lanes are not opened by 6 AM.

Deck Replacement Alternatives

Given the critical location and traffic volume on the Tappan Zee Bridge, conventional rehabilitation alternatives pose logistical problems for traffic detour. The NYSTA utilized the advantages offered by precast slabs for deck replacement to overcome the limitations typical of in-place deck casting alternatives. An evaluation of deck replacement alternatives for a bridge of this category should factor in issues related to:

- Geometry of the structure
- Time, nature, and level of effort in demolishing the existing structure
- Construction scheduling
- Economic feasibility

The following features in precast decks make them a natural choice in such applications:

a) <u>Speed in Construction</u>: Precast units allow rapid construction and, with careful planning, deck rehabilitation can be performed overnight, allowing regular traffic flow throughout the daytime period.
b) <u>Versatility</u>: Precast decks can be molded into any required size and can be customized for each application. In cases where the underlying stringers need to be replaced, composite deck panels with a precast beam can be used. Precast deck units can be cast such that the elevation requirements resulting from the profile and cross slope of the roadway can be accommodated.
c) <u>Elimination of Traffic Rerouting</u>: With the use of precast deck panels, normal traffic patterns can be maintained during peak hours.
d) <u>No Compromise on Quality:</u> Precast units have the same structural capacity and are no less durable than cast-in-place concrete, provided the precast concrete manufacturer has followed strict quality control and quality assurance measures. Further, precast units have less construction variability and are often more reliable than cast-in-place units.
e) <u>Economic Feasibility</u>: It is economically feasible to select more expensive, yet quick and efficient precast deck replacement techniques. Often, the high costs incurred upfront can offset the problems encountered from traffic disruption caused in conventional deck replacement using in-place casting.

Precast Panel Deck Replacement – A Timeline

In 1992 and 1994, deck replacement was performed on the Tappan Zee Bridge in local areas of extreme deterioration where simple patching operations were an inadequate repair technique. These repairs were mostly in the west deck truss spans. However, the need to further replace the deck on major areas of the bridge was well foreseen at this point. Precast deck panels were used to replace damaged deck areas in both 1992 and 1994. In these emergency operations, the steel stringers underneath the deck were not removed. In addition, in 1994, the NYSTA also evaluated the *Exodermic*™ and half-filled grid deck panel systems for their potential to be used as a composite deck system in future deck replacement projects.

Between 1996 and 1998, the NYSTA replaced the entire deck of the 13 east deck truss spans and along the median of the west trestle spans between Piers 1 and 81. Two different types of precast deck units were used in these operations, *Inverset*™ and *Exodermic*™. The *Inverset*™ and *Exodermic*™ systems are two precast deck units that can be used for rapid reconstruction or repair of bridge decks without disrupting traffic. The *Inverset*™ is a composite concrete deck on steel girders, while the *Exodermic*™ is a composite deck on a steel grid. Sections 5 and 6 of this report provide brief descriptions of the two precast deck systems, as used on the Tappan Zee Bridge.

The width of the deck between the curb lines is 84 feet (25.6-meter) in the Tappan Zee Bridge. The replaced concrete deck on the east truss spans covered an area of 258,500 square feet (24,015 square meter), extending between the curb lines along the 13 spans, each 235 to 245 feet (71.6 to 74.6 meter) in length. The *Exodermic*™ deck system was used in this location.

On the other hand, in the west trestle spans, beginning from the west abutment, the deck was replaced only along the median up to Pier 81. The extent of deck replacement was across a width of 13 feet, 7 inches (4.14 meter) and a length of 4,116 feet,, 3 inches (1,254.6 meter), as shown in Figure 3. The *Exodermic*™ system was used between the west abutment and Pier 1 along a length of 100 feet (30.48 meter). The *Inverset*™ deck system was used between Pier 1 and Pier 81, covering 80 spans of approximately 50 feet (15.24 meter).

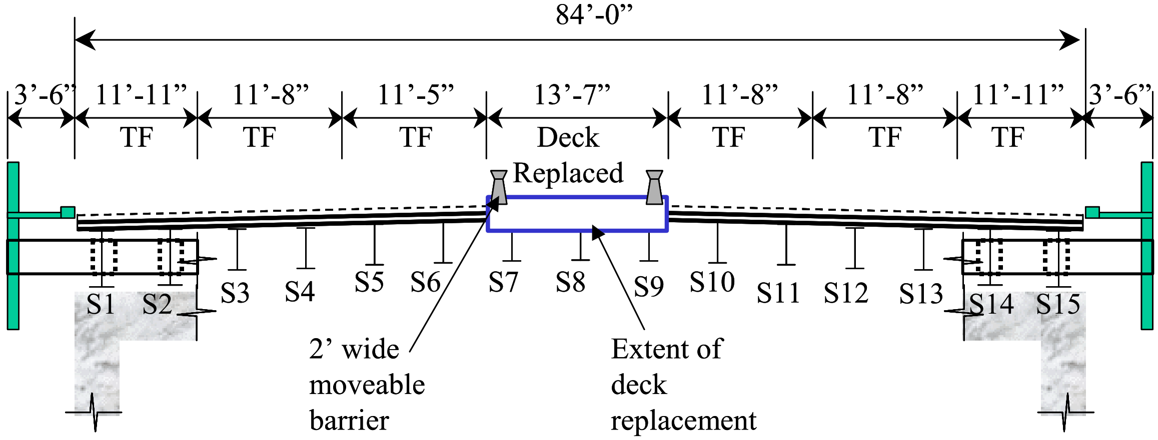


Figure 3. Extent of deck replacement on the west trestle spans (not to scale).

(1 inch = 25.4 mm and 1 foot = 0.3048 meters)

The *Inverset*™ Precast Deck Unit

Inverset™ is a proprietary product developed by Stanley Grossman, P.E., from Oklahoma, in the early 1980s. "*Inverset*™ is defined as a precast, precompressed, concrete/steel, composite superstructure made up of steel beams (typically two or more) and a concrete slab, which act as a composite unit to resist its own dead load" (3). A typical cross section of an *Inverset*™ section is shown in Figure 4. Shear studs are used to transfer shear forces between the slab and the steel beams, identical to conventional composite construction.

Unlike conventional steel beam-concrete deck composite construction, where the steel beam resists the dead load of the superstructure and the composite section supports the live loads and superimposed dead loads, the composite section of the *Inverset*™ system supports the entire dead, live, and superimposed loads of the bridge. This results in improved efficiency of the system as a result of lighter and shallower steel beams. The *Inverset*™ deck system utilizes a unique upside-down casting of the composite section.

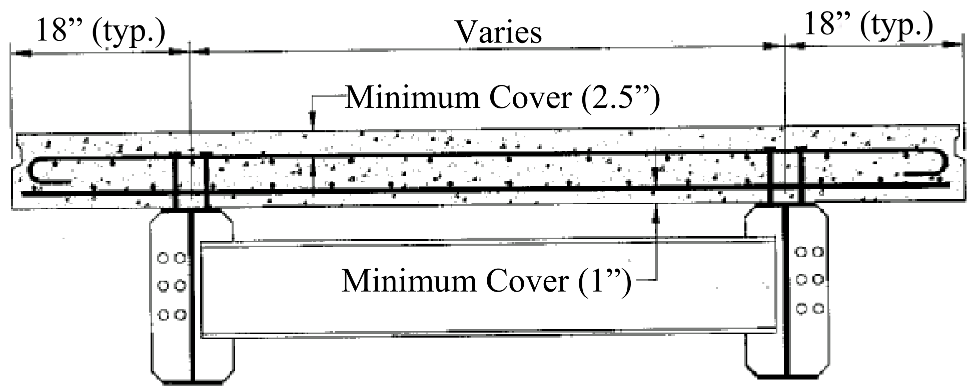


Figure 4. Typical cross section of an *Inverset*™ deck unit (3).
(1 inch = 25.4 mm; 1 foot = 0.3048 meters)

Casting Process:

The designed number of steel beams for the composite section is placed at the designed spacings in the casting process. The beams are placed upside-down with the shear studs facing downward. The concrete deck is cast (upside-down relative to the final position of the deck unit) in formwork supported underneath the steel beams, as shown in Figure 5 and Figure 6. Cross members are placed at regular intervals of the deck unit at the top and bottom in matching locations. This upside-down assembly of the entire unit causes the steel beam to be prestressed with the force of gravity acting on the dead weight of the entire assembly itself. The presence of cross members ensures a uniform level of prestress in the beams.

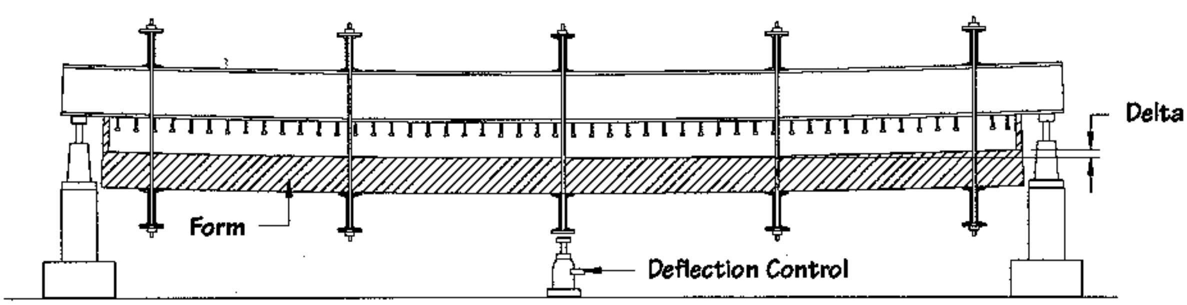


Figure 5. Schematic of the *Inverset*™ casting process (3).

Deflection control is critical in the casting process, as it influences the amount of prestress induced in the member. A deflection control device is used at midspan during the casting process, as shown in Figure 5. The stress distribution in the section during casting can be seen in

Figure 7. The top flange of the beam is in compression and the bottom flange in tension, as is typically the case with any beam subjected to vertical loads. As the concrete in the forms hardens, the beam is maintained at the predetermined deflection level and the linear stress distribution is locked into the beam as an initial prestress.

Figure 6. Casting of an *Inverset*™ deck (at Fort Miller plant).

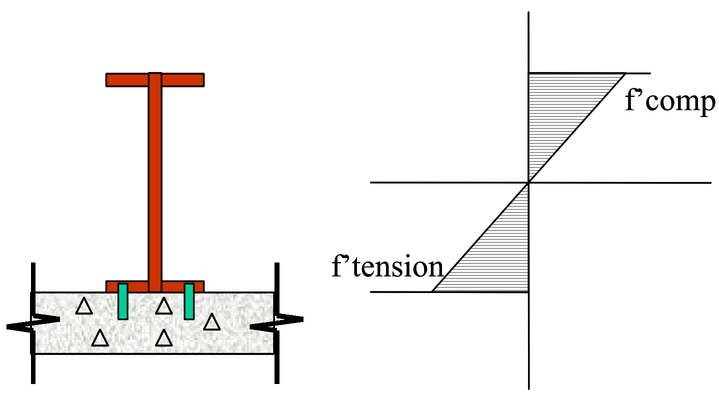


Figure 7. Stress distribution in *Inverset*™ during casting (3).

After the concrete cures and attains its design strength, the entire unit is turned right side up (i.e., turned 180 degrees), with the concrete deck now compositely cast over the steel beams. In this new position, the section now undergoes stress reversals, as shown in Figure 8. The concrete deck is in compression, the top flange of the steel beam (which was the bottom flange during casting) remains in tension, and the bottom flange of the beam (the top flange during casting) is decompressed to a near zero stress. Note that the top flange of the beam in the composite section is at the neutral axis. References 3,4,and 5 have a very detailed explanation of the product – its casting process, design considerations, and installation.

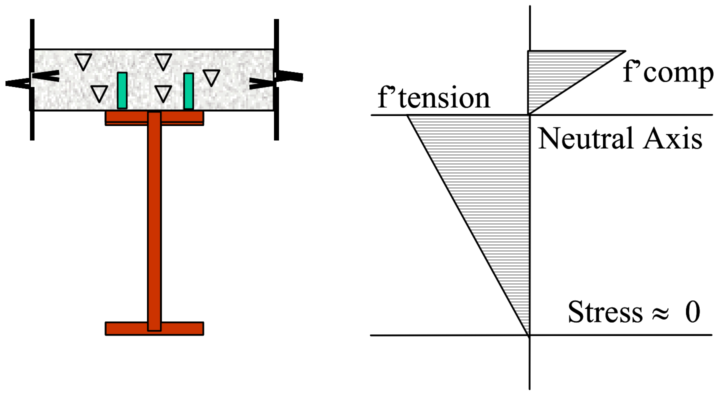


Figure 8. Stress distribution in the composite section (with only dead loads).

Inverset™ is essentially a precast composite deck unit with prestress forces induced to support its own dead loads, making it a very efficient, light, and shallow section. The entire tension capacity of this composite section is further utilized to resist the superimposed dead loads and the live loads acting on the bridge. As seen in Figure 4, the *Inverset*™ deck units have a keyed slab that forms a double-grooved keeway in the longitudinal direction when the deck units are placed adjacent to each other. These keeways are filled with a sealing material, such as grout, after installation at the job site.

The *Inverset*™ deck unit also offers many other features that make it very adaptable for different applications. The units can be cast to suit all geometric and elevation requirements. Each unit can be cast with a unique camber and skew to meet the profile and cross slope characteristics of the roadway the deck unit has to "fit" into. The top surface of the concrete deck can be textured as desired. The *Inverset*™ unit can be fabricated with a rough texture if it is used as a direct riding surface on the bridge, or can be finished smooth if it is overlaid on the bridge. The span and width of each *Inverset*™ deck unit are limited by practical handling and shipping considerations, making them less than 12 feet (3.66 meter) in width and 100 feet (30.5 meter) in length. Finally, precast *Inverset*™ units can also be made aesthetically compliant with an existing structure. Figure 9 through Figure 13 show pictures of *Inverset*™ units cast and stored at the Fort Miller plant in Schuylerville, New York.

Advantages of the InversetTM Deck Unit:

The following advantages are noted in using the *Inverset*™ deck units:

- Rapid construction: Construction can be completed within a few hours, under traffic conditions.
- Durability: The unit is cast under controlled conditions, and the densest concrete is at the surface.
- Design flexibility: The unit can be cast in a standard size or customized to fit any application.
- Easy handling: The units are designed to withstand handling and shipping operations. The units can be transported easily to the job site, picked up at any point, and even rolled into place.

- Cost effective: Time savings using this precast deck construction can result in overall cost effectiveness.
- Year-round installation: Construction operations can be scheduled all through the year, and the units may be installed even in cold winter months, day or night.
- Reduced superstructure depth: The use of an efficient system with shallow depths allows more clearance underneath the superstructure while maintaining the roadway profile.
- Minimal cracking: Prestressing minimizes cracking and chloride intrusion.

Figure 9. *Inverset*™ deck unit stored at the precast plant – cross section.

Figure 10. *Inverset*™ deck unit stored at the precast plant. Note camber induced during the casting operation.

Figure 11. Cambered *Inverset*™ deck unit.

Figure 12. *Inverset*™ deck unit with provision for utilities.

Figure 13. *Inverset*™ deck unit with galvanized steel beams.

Installation at the Tappan Zee Bridge:

The deck replacement project essentially involved the removal of the stringers, S7 through S9, removal of the 13-foot, 7-inch (4.14-meter) wide deck along the median, and the placing of the new *Inverset*™ deck unit, as shown in Figure 3. Deck replacement work was initiated from the west and progressed eastward. Between 8 PM and 11 PM, two lanes were open to traffic in both northbound and southbound directions, while between 11 PM and 6 AM, two lanes were open to traffic in the northbound direction and one lane was open in the southbound direction. As required by the NYSTA, all seven lanes were open to traffic and the concrete deck returned to existing elevations by 6 AM.

Figure 14 shows a brief schematic of the efficient construction and scheduling operations adopted in the deck replacement project. The extent of work accomplished in the overnight deck replacement is shown in Figure 15. The deck on the median along with the three stringers underneath was removed and replaced with an *Inverset*™ deck unit. The deck unit was placed between two successive piers in each installation.

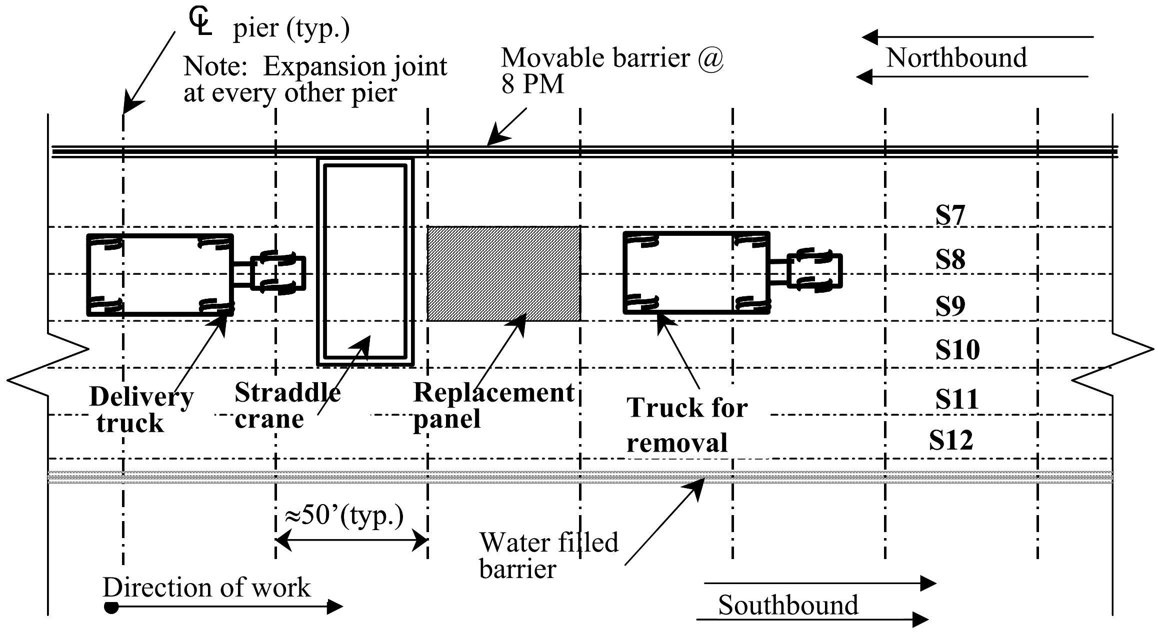
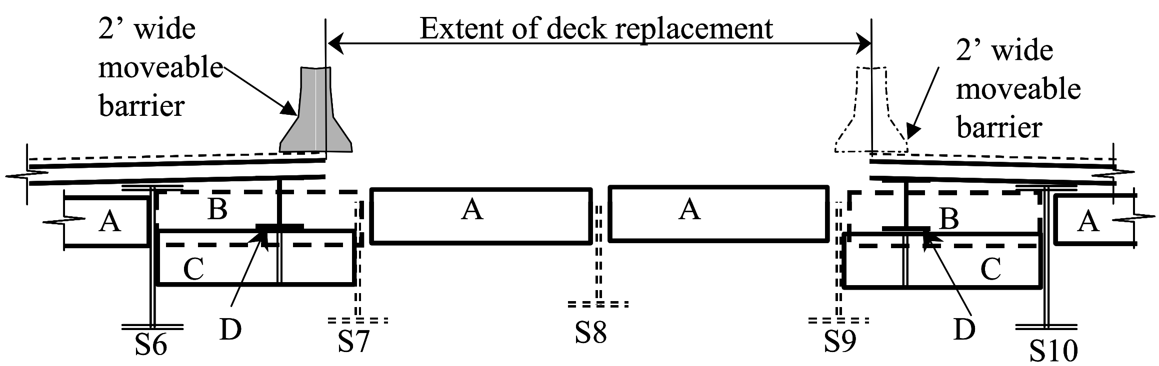


Figure 14. Deck erection and removal procedure for the *Inverset*™ deck units (N.T.S.).
(1 inch = 25.4 mm; 1 foot = 0.3048 meters)



A – Existing C 15 x 33.5 Diaphragm – Not removed in the project
B – Existing C 15 x 33.5 Diaphragm – Removed during the overnight operation
C – W 14 x 30
D – New Longitudinal Support beam W 10 x 54
Remove stringers S7, S8 and S9 during the overnight deck replacement

Figure 15. Deck replacement procedure using Inverset deck units on the median (N.T.S.).
(1 inch = 25.4 mm; 1 foot = 0.3048 meters)

The existing stringers in the bridge were W27 x 94 sections. The diaphragms connecting the S6-S7 stringers and the S9-S10 stringers were removed. Longitudinal support beams were installed between stringers S6 and S7, and S9 and S10 to support the overhanging slab after the deck was sawed. The portion of the deck to be removed was removed next, along with the diaphragms between stringers S7-S8 and S8-S9. The new deck unit was then installed. The installation process included erecting the unit in place, completing all diaphragm connections, welding the unit to the bearings and grouting the longitudinal and transverse joints. A detailed step-by-step process adopted is included in Appendix A.

Performance of the InversetTM Deck System:

The precast, prestressed *Inverset*TM deck panel units have performed very well in the Tappan Zee Bridge. They have shown no signs of deterioration during the past 6 years of service. They have been used in several other projects requiring rapid construction in New York and other States in the country. However, it is important to note that the details presented in this section are only relevant to the Tappan Zee Bridge, and the success of this project was largely due to the care exercised in the project planning stages and the careful execution of the construction. Figure 16 through Figure 19 show the installed deck units in service at the Tappan Zee Bridge.

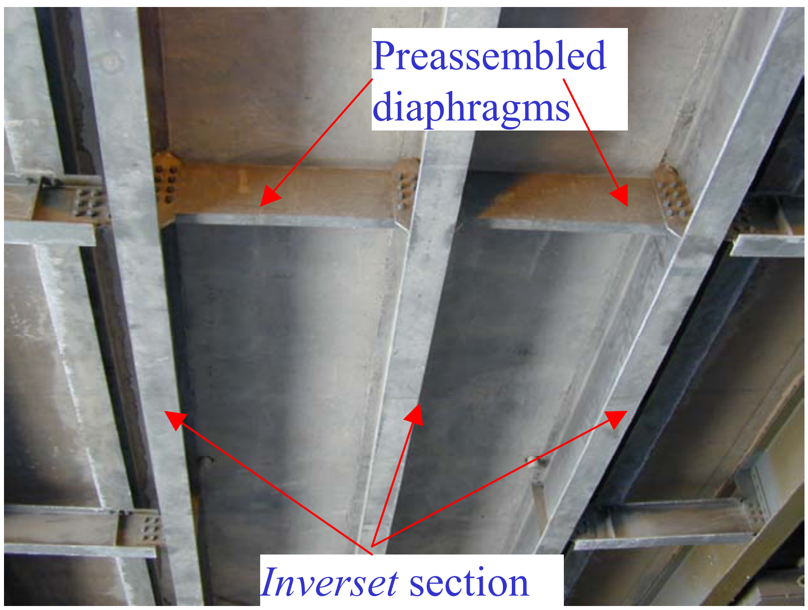


Figure 16. *Inverset*TM section installed in the Tappan Zee Bridge.

a) Connection with existing and new stringers b) Connection with *Inverset*™

Figure 17. Longitudinal support beam between the existing stringer and the *Inverset*™ beam.

Figure 18. Bearing at a pier.

Figure 19. *Inverset*™ sections adjacent to existing structure and performing well.

The *Exodermic*™ Bridge Deck Unit

The *Exodermic*™ bridge deck is a proprietary product developed by Exodermic Bridge Deck, Inc., and is a composite reinforced concrete slab on an unfilled steel grid deck. The original design of an *Exodermic*™ deck system, shown in Figure 20, was an improvement on traditional concrete filled grids. The original *Exodermic*™ system shifted the concrete from within the grid to the top of the grid, making it an efficient composite system with better utilization of the compressive strength of the concrete and the tensile strength of the steel. The concrete deck can be cast in place or precast. Shear transfer for composite action was achieved with shear studs welded to the tertiary bars, as shown in Figure 20.

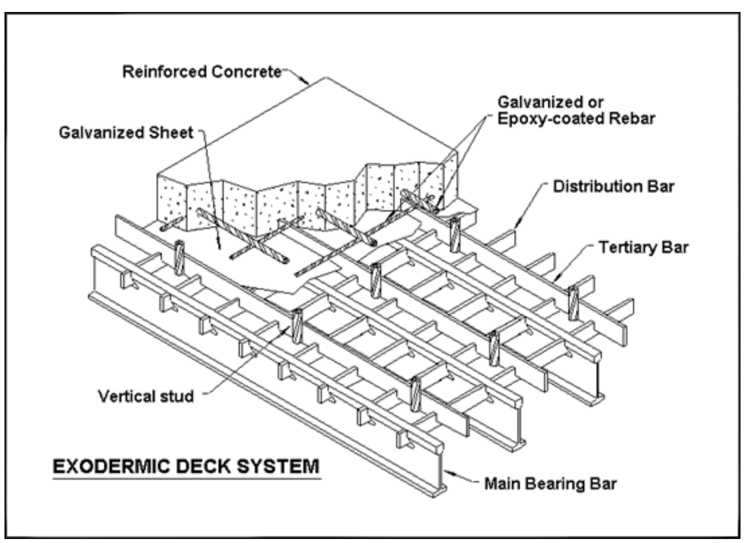


Figure 20. Original *Exodermic*™ bridge deck system (6).

The system was eventually modified with revisions in the shear transfer mechanism. The revised design, shown in Figure 21, incorporates an extended main bar that is embedded in the concrete to a depth of 1 inch (25.4 mm). The main bar has 0.75-inch (19-mm) diameter holes at regular intervals to provide a good interlock with the concrete. The revised *Exodermic*™ deck panel was utilized in the Tappan Zee Bridge project to replace the 84-foot (25.6-meter) wide deck on the east deck truss spans on an area of 285,500 square feet (26,524 square meter).

Casting Process:

The fabrication process typically entails the formation of the haunches and casting the concrete deck. The deck areas that will be directly in contact with the top flange of the stringers or floor beams are not precast and are blocked out during the fabrication stage. The transverse edge of the panel has shear keys that form a double female shear key when panels are placed at the site. During installation, the elevation of the panel is set by built-in leveling bolts, and shear studs on the deck unit are welded to the superstructure of the bridge. The opening between the units in the longitudinal direction, and the shear keys along the transverse direction are grouted on-site.

The *Exodermic*™ composite deck is efficient, and the design can result in a substantially lighter structure. A conventional composite deck is not designed to support any tensile stresses under a positive bending moment; however, in the *Exodermic*™ deck system, the concrete on the top resists the compressive stresses, and the main steel bearing bars of the steel grid resist the tensile stresses (see Figure 22). On the other hand, for the *Exodermic*™ section under a negative bending moment, as shown in Figure 23, the steel reinforcement in the concrete bear the tensile stresses on the top (similar to a conventional deck). The compressive stresses are withstood by the main bearing bars of the steel grid and by the full-depth concrete placed on the stringers. The top reinforcement in concrete is therefore critical in *Exodermic*™ decks used in continuous or long spans where significant negative moments can develop. The *Exodermic*™ system thereby provides a means to fully utilize the potential of the steel in tension and the concrete in compression.

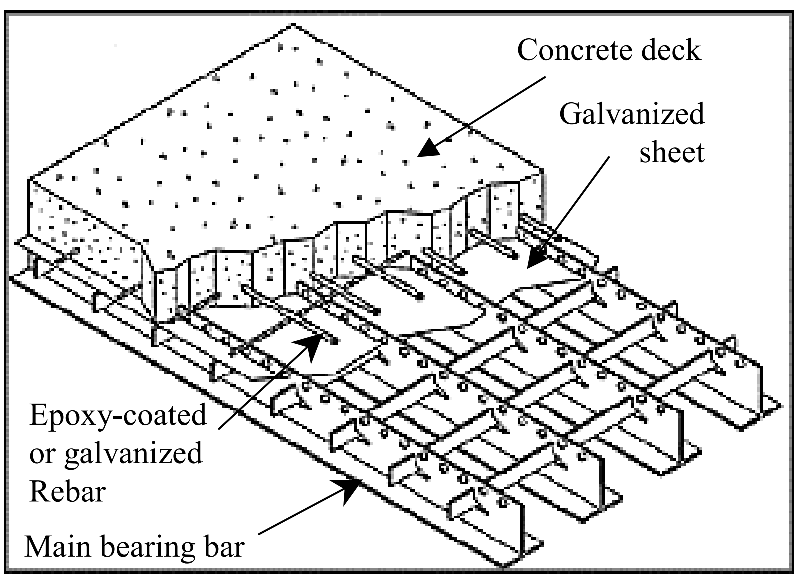
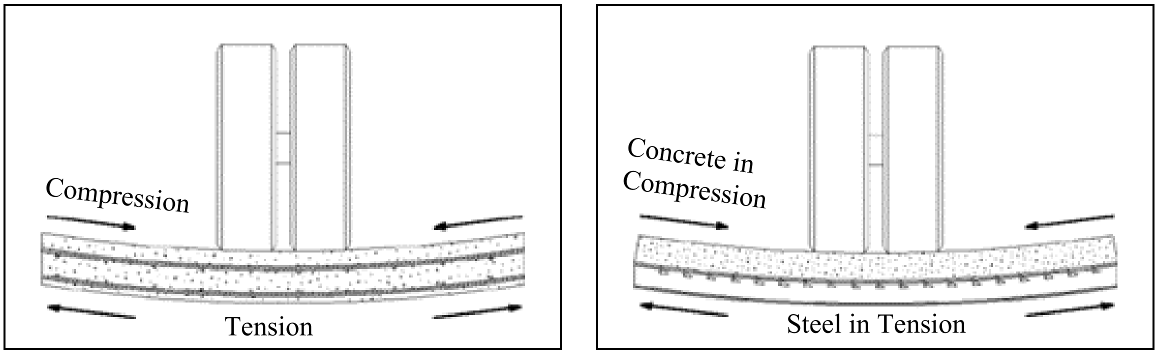
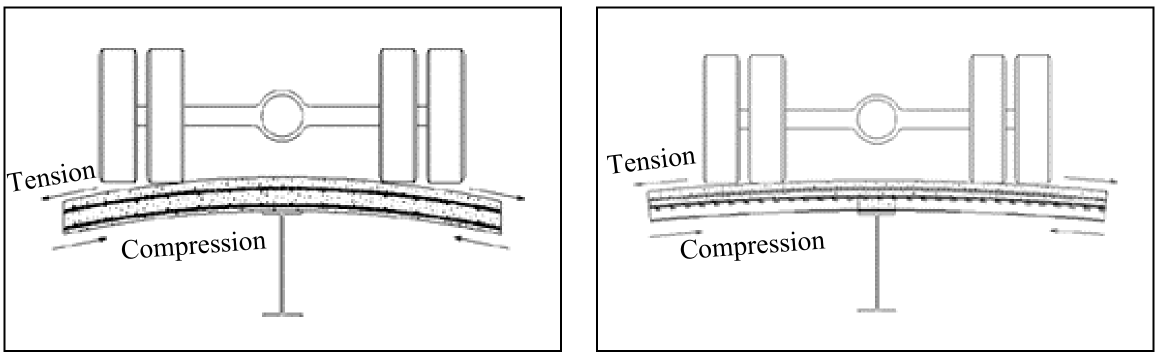


Figure 21. Revised *Exodermic*™ bridge deck system used in the Tappan Zee Bridge (6).



a) Conventional Concrete Deck **b) Exodermic Bridge Deck Unit**

Figure 22. Deck under positive bending moment (6).



a) Conventional Concrete Deck **b) Exodermic Bridge Deck Unit**

Figure 23. Deck under negative bending moment (6).

The *Exodermic*™ deck system also offers designers with flexibility in choice of deck thickness, deck reinforcement size and spacing, main bearing bar steel type, thickness, and grid configuration. Other design features typical of precast deck construction are also applicable to the *Exodermic*™ deck system. Deck thicknesses can be as low as 3 inches (76.2 mm), and the width of the unit is limited to 12 feet (3.65 meter) for ease in handling and transportation. Furthermore, the applicability of lightweight concrete for the deck has been demonstrated in projects where weight restrictions on the superstructure are critical. Figure 24 and Figure 27 show the *Exodermic*™ unit before casting concrete, and the underside of a finished unit ready to be placed in position.

Figure 24. *Exodermic*™ panel before casting concrete.

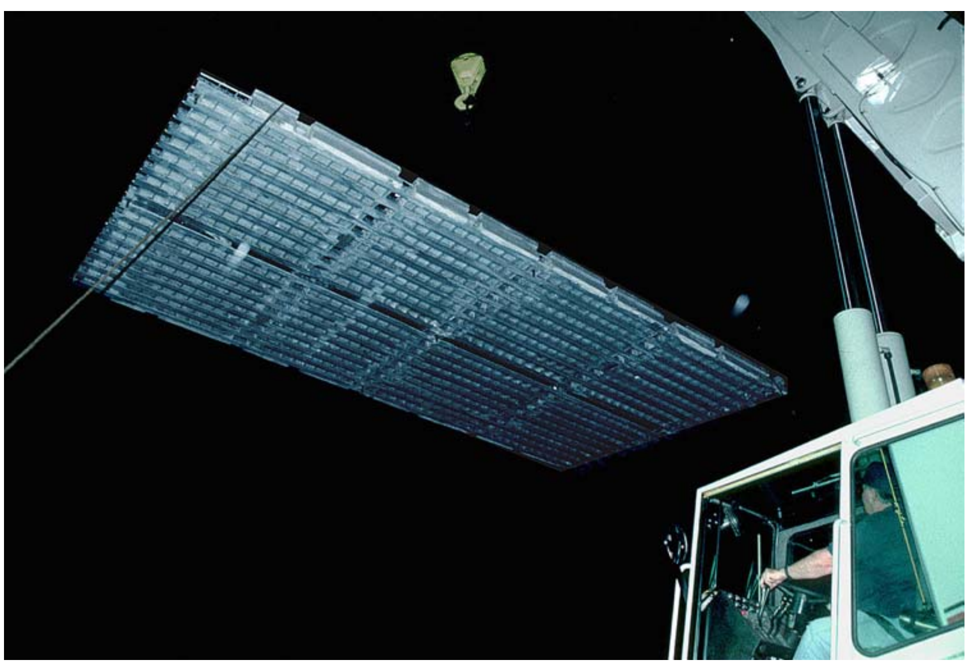


Figure 25. The underside (grid) of a typical *Exodermic*™ panel during installation.

Advantages of the ExodermicTM deck unit:

The *Exodermic*^{TM} deck unit offers all advantages typical of a precast deck panel. These deck units allow rapid construction, are lighter in weight than conventional composite decks, are easy to install, and are easy to maintain. The concrete deck on the *Exodermic*^{TM} unit can be further overlaid in future pavement rehabilitation operations. Further, no special training is required for the construction crew to install these units.

Installation at the Tappan Zee Bridge:

The deck replacement project using the *Exodermic*^{TM} bridge deck units involved removal of the entire width of the deck in stages and replacing it overnight to allow seven lanes of traffic by 6 AM. This work was accomplished in five stages, each covering a particular width of the structure so that the bridge could continue to run two lanes of traffic in each direction while construction progressed. The portions of the deck replaced in each of the five stages are described (7):

- Stage 1: The deck in the two southbound lanes – 24 feet (7.3 meter) wide
- Stage 2: The deck in 1.5 lanes starting from the end of stage 1 construction to the centerline of the bridge – 18 feet (5.48 meter) wide
- Stage 3: The deck beginning from the bridge centerline and 1.5 lanes into the northbound lanes – 18 feet (5.48 meter) wide
- Stage 4: The deck in the two lanes to the north – 24 feet (7.3 meter) wide
- Stage 5: Seal joints into steel extrusions

Between the different stages of construction, in order to make the structure continuous and provide good load transfer between the deck panels cast, threaded couplers were utilized. After all deck installations were completed, the entire deck was diamond ground and overlaid with a 0.75-inch (19 mm) layer of epoxy concrete. A picture of nighttime construction at the Tappan Zee Bridge is shown in Figure 26. Figure 27 shows a typical installation of an *Exodermic*^{TM} unit in a bridge deck.

Figure 26. Nighttime construction on the Tappan Zee Bridge.

Figure 27. View of an *Exodermic*™ bridge deck unit (looking from underneath the bridge).

The *Exodermic*™ deck units used at the Tappan Zee Bridge project were 7.5 inches (190 mm) in overall thickness with a 4.5-inch (114 mm) thick deck. The concrete used in the deck was the NYSDOT's high-performance concrete mix design with small maximum size aggregate. The mix design used 725 lb/cubic yard (430 kg/cubic meter) of cementitious material, including 20% fly ash and 6% micro silica. The water/cement ratio was limited to 0.40. Although the design 28-day strength was 5,000 psi (34.5 MPa), strengths as high as 10,000 psi (69 MPa) were achieved because of the inclusion of water-reducing agents in the concrete mix. Deck panels used in stages 1 and 4 were 24 feet x 12 feet (7.3 meter x 3.65 meter) in dimension and weighed 18,000 pounds (8165 kilogram), while those used in stages 2 and 3 were 18 feet x 12 feet (5.48 meter x 3.65 meter) in dimension and weighed 13,000 pounds (5897 kilogram).

The efficiency of construction was largely dependent on the size of the crew. With two crews working simultaneously, 3,000 to 3,400 square feet (280 to 315 square meter) of deck was replaced during one night. The NYSTA also improved the efficiency by bringing in additional barrier moving equipment. The typical time taken to move the barrier by 12 feet (3.65 meter) is 2 hours, and in a construction operation of this nature where time is a critical factor, reducing the time spent on moving lanes (or barriers) can be very useful. In this specific case, arrangement of the seven lanes in a 5/2 or 4/3 configuration offered a lot of flexibility to the contractor in planning for Maintenance and Protection of Traffic (MPT). Some of the above information presented in this report was collected from personal communication with NYSTA (8).

<u>Performance of the ExodermicTM Deck System:</u>

The *Exodermic*™ bridge deck panels have performed very well in the Tappan Zee Bridge since their installation in 1998. They have shown no signs of deterioration. They have been used in several other projects requiring rapid construction in New York and other States in the country. However, it is important to note that the details presented in this section are only relevant to the Tappan Zee Bridge, and the success of this project was largely due to the care exercised in the project planning stages and the careful execution of the construction. The *Exodermic*™ deck units have also been verified in the lab, and they were found to perform well under fatigue and static loads (9).

Lessons Learned from the Tappan Zee Bridge Deck Replacement Projects

Several factors have played into the success of the deck replacement project at the Tappan Zee Bridge, many of which are very specific to this project. The previous sections have provided an overview of the deck replacement procedure adopted in the Tappan Zee Bridge. The installation procedure of the deck has been discussed in as much detail as required to acquire a broad idea of the extent of the project. Several other details are, in most cases, very specific to this project and designed for this application. The choice of a precast deck type is case-specific. However, the lessons learned from the successful execution of this project are of great value to agencies that might consider similar projects. The following issues would be, in general, very important consideration for all projects of this nature:

Primary Considerations

- Careful planning: A detailed and careful planning of several issues – traffic management, contractibility issues, crane capacity, contractor's technical and construction skills, time management, and staging construction – is the key to success in such projects.
- Attention to details: It is important to give attention to all details, however trivial they may seem, right from the beginning. Small lapses can have serious repercussions in projects of this nature. Since almost all events of the construction phasing fall on a the critical path, which is often a short 10-12 hour window, no detail can be left to chance or left for being solved on the field.
- Traffic control: The need for controlling traffic in an efficient manner cannot be overstated. Although the traffic management operations implemented at the Tappan Zee Bridge were specific to the project, it demonstrated the importance of this aspect in rapid construction projects.
- Brainstorming as a group: It is important to involve all individuals involved at all stages of the project. In projects of this nature, each individual plays an important role in the teamwork. For smooth execution of the project, it is necessary that the role of each team member is defined, and the feasibility of the operation ascertained.
- Think future: During the planning stage, future rehabilitation options are to be considered in choosing the deck panel type.
- Backup: It is extremely critical to have backup construction equipment and trained personnel that can be accessed quickly during such an operation. Equipment failures can be very expensive if no alternative is readily available.
- Trial: A dry run of the construction operation will help the crew involved get acquainted with the installation procedure and iron-out small inconsistencies and doubts. It is also worthwhile to execute the deck replacement project on a small area of a bridge and keep the scale of operation small before increasing the crew size and the size of the operation.
- Verify design: The design has to be verified well ahead of time. Reinforcing details and design flaws can cost a lot of time in the project timeline.
- Field verification: The contractor should verify all field elevations with the plans to avoid last-minute delays.

Other Considerations

- Choose optimum: Efficiency has to be maximized by choosing an optimum size of operation, size of crew, area of deck replacement, etc. For example, the use of an additional barrier system, although more expensive, pays off as savings in time and replacing larger areas of the deck in the limited timeframe.
- Preparation hours: The operations in the preparation hours are as critical as those done during the actual construction time. Care should be taken to ensure that any work that can be done more easily in the daytime is not performed at night, when the time is an important issue.
- Weather pattern: The contractor needs to factor in the weather patterns during the construction days. Poor weather conditions can hamper an efficient construction operation, and it might be worth not working a night instead of working inefficiently. Also, poor weather conditions (such as a bad winter day), although not suitable for an on-site job, might not hamper preparatory work.

- Inspectors: Inspectors at the construction site and at the precast plant have a very critical role to play in the success of the project.
- Calendar dates for completion: The calendar dates for shutdown have to be specified explicitly. This has a big impact on traffic control and construction stage planning.
- Concrete material:
  - Using coarse and fine aggregate in the rapid-setting material is recommended. Concrete is a preferred material over grout, especially for its better shrinkage characteristics.
  - The use of a mobile mixer (such as those manufactured and sold by Zimm) can provide better consistency in the material because they can be calibrated precisely. A consistent material provides more reliable long-term performance. The mobile mixers are also capable of supplying material as and when desired by the contractor. This is very important given the very fast set time of these materials.
  - Follow the manufacturer's recommendations for mix design. Excess rapid-setting cement in the mix can mean higher shrinkage and the possibility of shrinkage cracks.
  - Good curing is very important for controlling shrinkage cracks, especially in rapid-setting concrete with high heat of hydration. Wet burlap should be applied immediately after the closure pours are made.
- Surface texture: Skid resistance and surface texture requirements of the project have to be well defined ahead of time. These issues can be incorporated into the precasting operations or accounted for in the construction stage.
- Organization: A well-coordinated and organized method of working will make the operation smooth.
- Good partnering: The agency has to be open to suggestions from the contractor. Good partnering and healthy teamwork go a long way in the success of such challenging projects.

To date, very few such projects have been undertaken, and a few that have had remarkable success have not received the deserved publicity. With the growing popularity of rapid nighttime construction, more projects of this nature will demonstrate the feasibility of precast construction in deck replacement.

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Acknowledgement

Details of the deck replacement projects at the Tappan Zee Bridge were provided by Mr. Peter R. Stapf, P.E., Director, Structural Design, NYSTA. Product information on the *Inverset*™ and *Exodermic*™ systems was given by Mr. Peter J. Smith, P.E., from Fort Miller Co., Inc., and Robert A. Bettigole, P.E., from Exodermic Bridge Deck, Inc., respectively. The support from these individuals was useful in the preparation of this report and it is greatly appreciated.

APPENDIX A

CONSTRUCTION SEQUENCE FOR REPLACEMENT OF MALL LANE CONCRETE DECK AND STEEL STRINGERS WITH PRE-FABRICATED INVERSET UNITS FROM PIER 1 TO PIER 81

Night 1: Preparation

1. Close two lanes
2. Bring equipment to the bridge
3. Close third lane
4. Saw cut transverse joint at fixed pier
5. Remove Jeene joint at expansion joint
6. Cut top splice plate at fixed bearing locations
7. Drill lifting holes
8. Clean up and remove equipment
9. Pick up MPT
10. All lanes open by 6 AM

Night 2: Erection (Span A)

1. Close two lanes
2. Bring equipment to the bridge
3. Saw cut longitudinal joints including the concrete headers at the expansion joints
4. Chip out concrete at saw cuts
5. Drive straddle crane on the bridge
6. Close third lane
7. Remove first panel
8. Remove existing fixed bearings
9. Install new elastomeric fixed bearings
10. Install longitudinal support beam
11. Install first unit on existing expansion bearings and on new fixed bearings
12. Complete all diaphragm connections
13. Weld unit to bearings
14. Grout the longitudinal join
15. Install pre-fabricated overlay panels
16. Remove straddle crane from the bridge
17. General clean up
18. Lay down temporary stripes
19. Paint temporary barrier guidance line
20. Pick up MPT
21. Open all lanes

Night 3: Erection (Span B)

1. Close two lanes
2. Bring equipment to the bridge
3. Saw cut longitudinal joints including the concrete headers at the expansion joints
4. Chip out concrete at saw cuts

5. Drive straddle crane on the bridge
6. Close third lane
7. Remove first panel
8. Remove existing fixed bearings
9. Install new elastomeric fixed bearings
10. Install longitudinal support beam
11. Install first unit on existing expansion bearings and on new fixed bearings
12. Complete all diaphragm connections
13. Weld unit to bearings
14. Grout the longitudinal join
15. Install pre-fabricated overlay panels
16. Remove straddle crane from the bridge
17. General clean up
18. Lay down temporary stripes
19. Paint temporary barrier guidance line
20. Pick up MPT
21. Open all lanes

Night 4: Joint Closures

1. Close two lanes
2. Remove the pre-fabricated overlay panels
3. Grout transverse joint at fixed pier with elastomeric concrete
4. Install Jeene joint
5. Install waterproofing membrane
6. Install asphalt overlay
7. Pick up MPT
8. Open all lanes at 6 AM

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