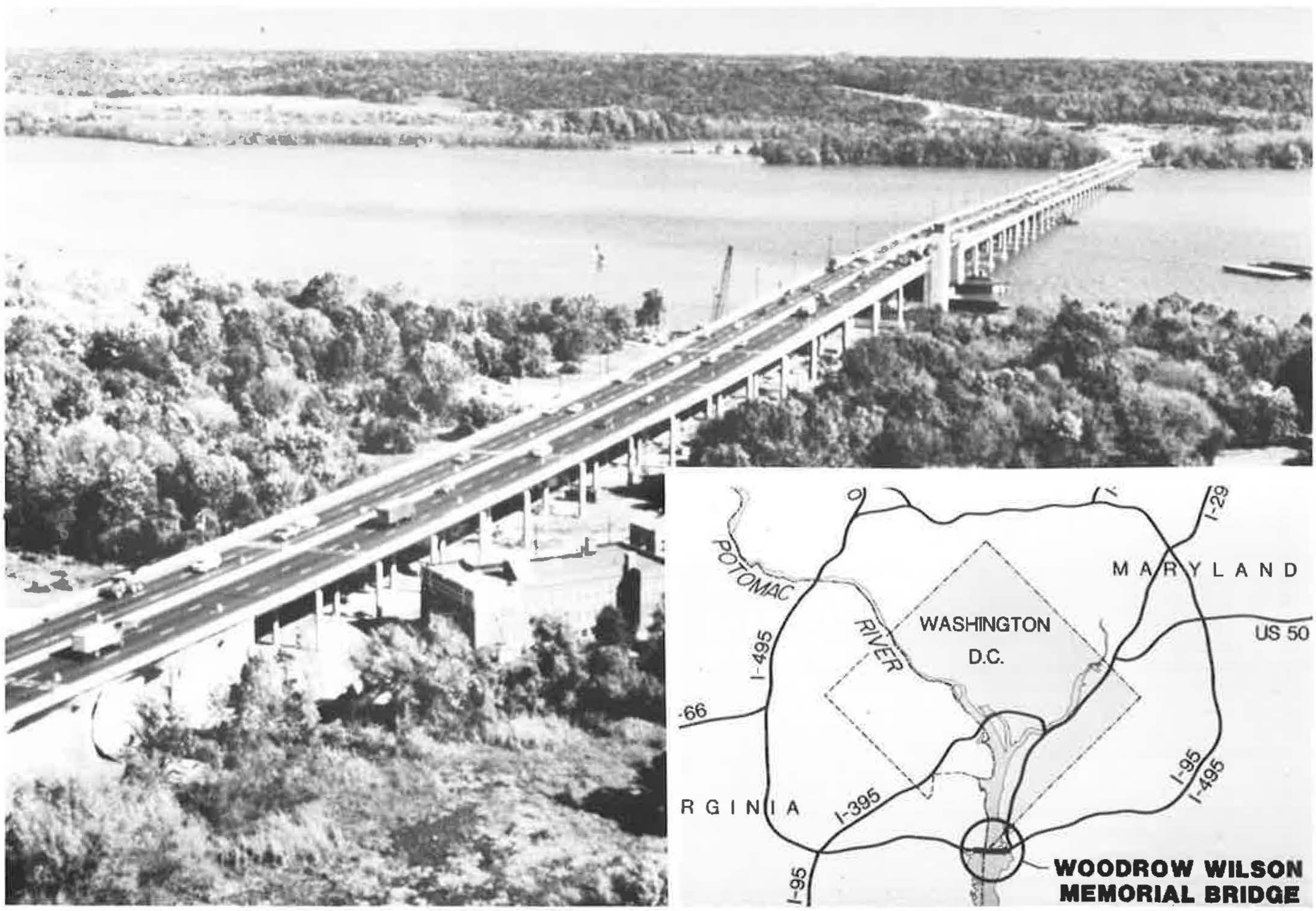
Woodrow Wilson Memorial Bridge, Washington, D.C.: Concrete Deck Reconstruction

The innovative techniques developed to replace and widen the concrete deck of the Woodrow Wilson Bridge may well be applicable to other bridge rehabilitation projects throughout the country

The 5,900-ft Woodrow Wilson Bridge carries major interstate traffic on I-95 across the Potomac River south of Washington, D.C., and is the southern crossing of the Potomac for the Capital Beltway *(below)*.



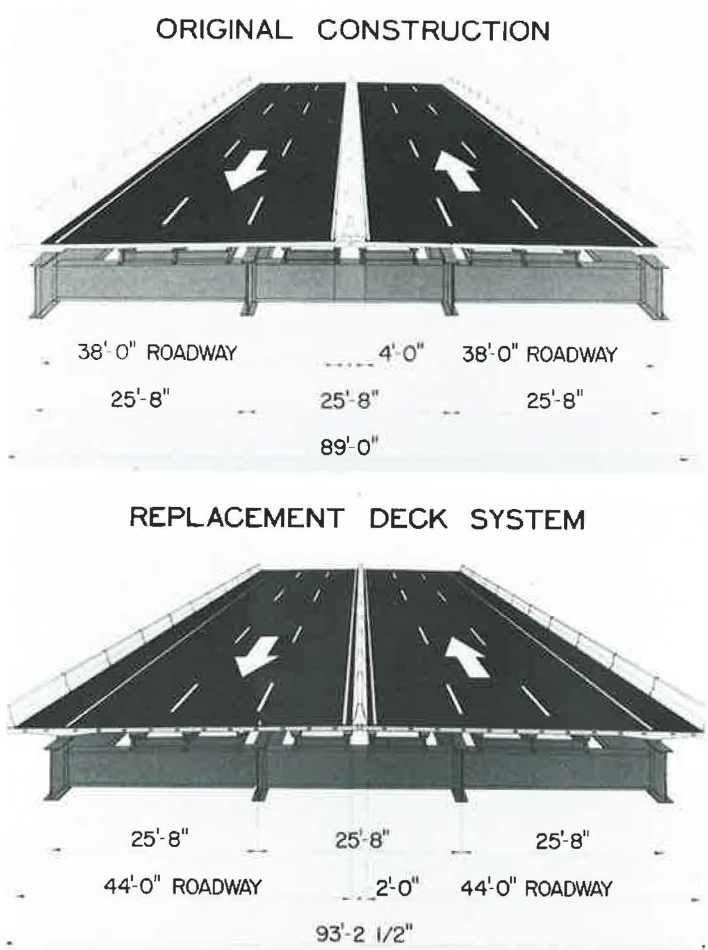


Figure 1. The replacement deck system provides 44-ft roadways constructed of full-roadway-width, precast, transversely post-tensioned, lightweight concrete panels. The system permits space for disabled vehicles, which perviously had caused commuter traffic delays.

After 20 years of heavy traffic and exposure to deicing chemicals, the Woodrow Wilson Memorial Bridge, which spans the Potomac River south of Washington, D.C., was in such poor condition that motorists were reluctant to drive on the bridge. The deck obviously had to be replaced; however, about 125,000 vehicles cross the bridge each day and closing it to traffic, even for a short time, was an impossible solution.

The project to replace the deck of this six-lane, 5,900-ft, steel girder bridge with precast, post-tensioned, lightweight concrete panels was completed during a period of 12 months with minimum disruption to traffic. The application of innovative construction techniques and new materials based on research findings and recent test results enabled the bridge to remain open to traffic during construction while the contractor completed the project at reduced cost more than 3 months ahead of schedule. The bridge was also widened by 4 ft 2½ in., and the median was narrowed and the safety walk removed to provide shoulders on each side for disabled vehicles (Figure 1).

The structure, with its 212-ft bascule, was constructed between 1959 and 1962 by the Federal Highway Administration (FHWA), and is jointly operated and maintained by the District of Columbia, Maryland, and Virginia. By 1977 peak daily traffic totals on the bridge had exceeded 110,000 vehicles, with hourly directional totals as high as 5,000 vehicles during morning and evening rush hours. Not only were breakdowns and accidents causing delays, but also serious deterioration of the reinforced concrete deck was evident and maintenance and repairs were compounding the delay problem.

The Maryland State Highway Administration (MSHA), under agreement with the FHWA, contracted with consulting engineers Modjeski and Masters to prepare a feasibility report on the redecking. In 1979 the MHSA contracted with Greiner Engineering Sciences, Inc., to conduct additional investigations, perform designs, and prepare contract documents for the redecking. After further intensive study by Greiner and consultation with the MSHA and the FHWA, a replacement deck system that met the mandatory conditions for the project was designed and subsequently constructed. In September 1982 the construction contract was awarded to the Cianbro Corporation of Pittsfield, Maine.

Construction to replace and widen the original concrete deck of the Woodrow Wilson Memorial Bridge while maintaining traffic was begun in November 1982 and completed in October 1983. The contract required completion of the deck work in 575 calendar days; the work was completed with a bonus payment within 350 calendar days.

DESIGN INNOVATIONS

The design of this project is in the forefront of the technology for the rehabilitation of bridge decks. The innovative design features that contributed to the success of the project include the maintenance-of-traffic program; precast, post-tensioned, lightweight concrete panels; protection systems for reinforcement and strand; the use of methyl

---

This article is based on a paper presented at the 62nd TRB Annual Meeting by James G. Lutz, Projects Director, Greiner Engineering Sciences, Inc., Baltimore, Maryland. Lutz was the Project Manager for the renovation of the Woodrow Wilson Memorial Bridge.

TMAs Protect Construction Crews

Because approximately 125,000 vehicles cross the Woodrow Wilson Bridge daily, the rehabilitation of the bridge had to be completed quickly, with little disruption in the traffic flow and as little danger as possible to the traveling public and the construction workers. Therefore, much of the work was done at night, when there is less traffic on the bridge. The nighttime traffic-control plan required that several pieces of equipment be moved onto the bridge after 8 p.m. and off again before 6 a.m., a process that took 4 hours.

To protect the workers and the public from the inherent dangers in working at night, the contractor, Cianbro Corporation, utilized Hex-Foam Truck-Mounted Attenuators (TMAs) manufactured by Energy Absorption Systems, Inc. The Hex-Foam TMAs are portable crash cushions that are attached to the rear end of maintenance trucks to provide an impact-absorbing barrier between errant vehicles and work crews. Hex-Foam is designed to crush on impact, dissipating collision energy while bringing the impacting vehicle to a safe stop. The TMAs have been shown to protect stationary maintenance vehicles from an impacting vehicle traveling up to 45 mph.

By using three TMAs as a protective barrier between equipment and motorists, the time required for the equipment-moving procedure was reduced to 45 minutes. Once the equipment was in place, all traffic was rerouted onto two lanes of the six-lane bridge while decking and painting work continued. During daytime pothole-patching operations, two TMAs were set up to form a shield protecting workers at the end of the work zone.

On five separate occasions, a TMA was hit severely enough to cause damage to the unit, but motorists and workmen were protected from potentially serious injuries.

methacrylate polymer concrete; and the overall practicality of the system given the limiting criteria for the project.

To meet the requirement that the bridge remain open to traffic during replacement of the deck, a comprehensive maintenance-of-traffic program was developed. During the night work periods, when the major work was completed, traffic was maintained in two lanes, allowing the contractor access along the roadway being replaced. During the daytime peak hours, all six lanes were kept open to traffic, with closure of one lane in each direction in the daytime off-peak hours to allow such operations as median relocation and other miscellaneous work (Figure 2).

The replacement deck system provides for 44-ft roadways constructed of full-roadway-width, precast, transversely post-tensioned, lightweight concrete panels. The typical lightweight panel was 46 ft 6¼ in. wide, 10 to 12 ft long, and 8 in. thick with a 5-in. haunch at the exterior girder. A total of 1,026 panels were required for the two roadways. Sufficient reinforcing steel was provided for fabrication, handling, edge beam capacity before longitudinal post-tensioning, distribution, and temperature. All embedded steel has 2 in. of cover and, with the exception of stressing strands. is epoxied. All stressing strands are sheathed in plastic. Ducts for longitudinal post-tensioning, pour holes, holes for hold-down bolts, and other necessary apertures were formed when the panels were cast.

The transverse ½-in.-diameter strands are in pairs in the planes of the top and bottom reinforcing. At both edges of the panels, these strands transition to mid-depth of the slab for anchorage. Post-tensioning was performed in the yard during curing. The transverse post-tensioning is a primary component of the structural design of the panels, whereas the principal function of the longitudinal post-tensioning is the elimination of transverse joints, thereby sealing out water and eliminating reflective cracking in the wearing surface. The longitudinal post-tensioning was performed in place through an average of 17 panels. The transverse joints between the panels were filled with methyl methacrylate polymer concrete immediately before longitudinal post-tensioning.

Perhaps the key element of the entire deck system was the development of the bearings on the stringers and the exterior girder, consisting of a sliding steel bearing plate on the flange, keyed to poured-in-place polymer concrete by welded studs (Figure 3). The sliding plates prevent the introduction of stresses in the structural steel due to shrinkage, creep, and foreshortening during post-tensioning of the deck. To provide for this system throughout the length of approaches, and for the deepened slab at the exterior girder, the grade of the finished deck was raised 4½ in. Three bearings were provided on each of five stringers, and three or four bearings on the girder under each panel.

Methyl methacrylate polymer concrete and mortar were used for the bearing pads, the transverse joints, the closure pours, and the wearing surface at roadway joints. The use of polymer concrete was approved only after extensive testing by the MSHA and the FHWA confirmed published claims concerning structural properties, placement characteristics, and rapid set time over a wide temperature range.

CONSTRUCTION INNOVATIONS

The construction contract was awarded to Cianbro Corporation, the lowest of 15 bidders. The precast, lightweight concrete panels and parapet sections were fabricated for Cianbro by Shockey Brothers, Inc., of Winchester, Virginia.

At the precasting plant, extensive planning was the key to success with the timely production of more than 1,400 accepted shop drawings, daily production of six to nine panels and parapet sections, and expeditious completion of the finishing details.

On site, early completion was

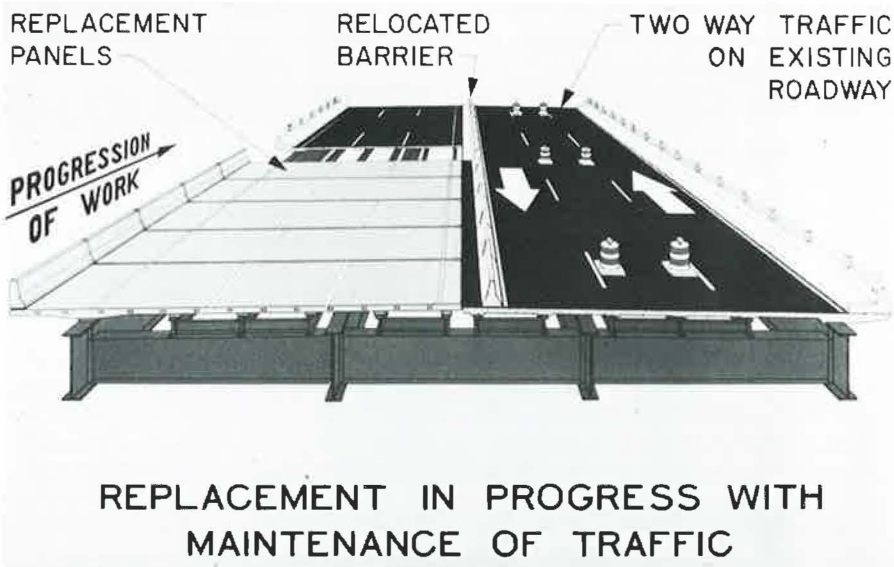


Figure 2. During nighttime construction periods, single-lane two-way traffic was maintained on one roadway for the full length of the bridge. The old deck was removed and the spaces were covered with grating to carry the daytime peak-hour traffic when all six lanes were open.

View of the bridge with construction in progress on the westbound lanes.

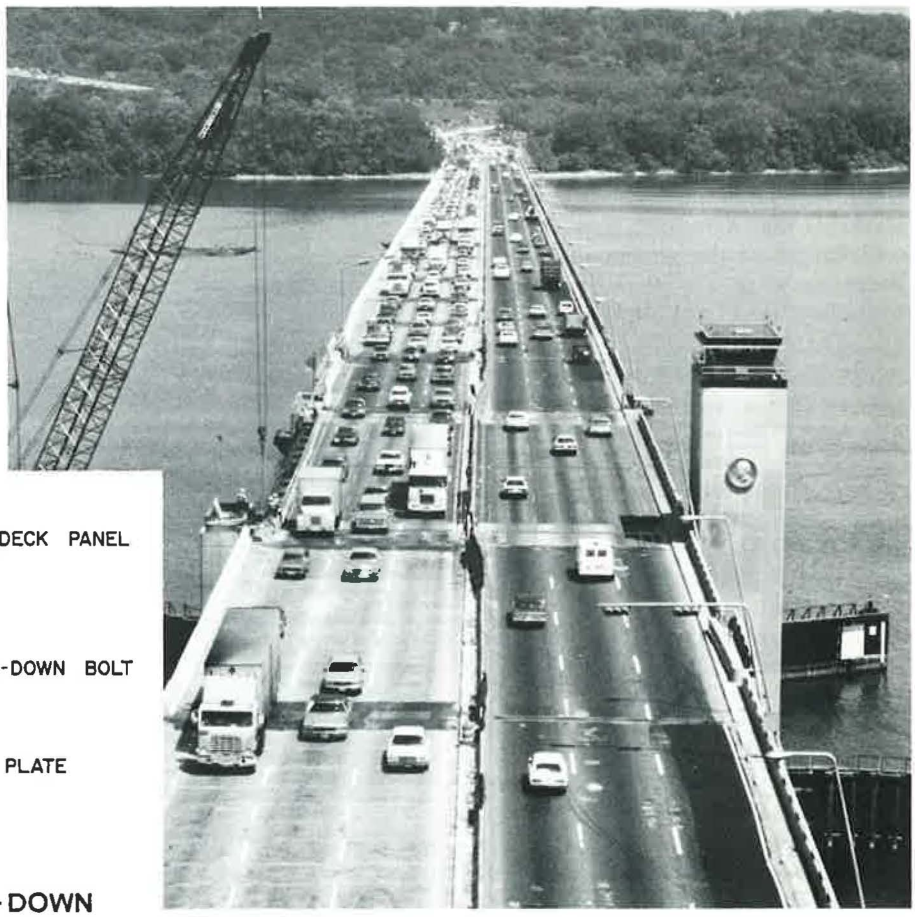
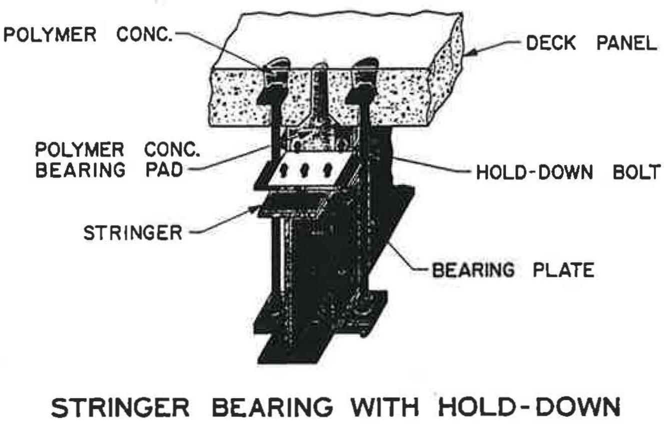


Figure 3. Diagram of the polymer concrete bearings on the stringers and the exterior girder.



Polymer Concrete Pedestals: FHWA Research Led to Innovations

Researchers at the Turner-Fairbank Highway Research Center of the Federal Highway Administration worked closely with the Maryland State Highway Administration and Greiner Engineering Sciences, Inc., to design the pedestals and the polymer-concrete formulations for supporting the precast slabs installed on the Woodrow Wilson Bridge. The final design included a steel plate at the bottom to break bond with the girder, or stringer, so that the slabs could be post-tensioned in the longitudinal direction. Nelson studs project upward from the plates to provide a shear connection to the polymer concrete that was used to cast the pedestals.

A major problem encountered was the shrinkage and gravity flow of the polymer concrete downward from the underside of the precast slab. Spaces as great as 1/8 in. over 50 percent of pedestal cross section formed between the precast slab and the pedestal. Various schemes of form venting, vibration, forming, and physically keying the slab to the pedestals were tried. The plan finally accepted was to create an inverted cone of polymer concrete, increasing from the 2½-in.-diameter fill hole to a 6-in.-diameter base at the bottom of the slab interface with the pedestal. Three-hundred-pound concrete "sandwiches" were made of the component materials and taken to the National Bureau of Standards Laboratory in Gaithersburg, Maryland, for testing in double shear in the 12-million-pound Universal testing machine. A concrete "sandwich" consisted of two test specimens (section of precast slab, pedestal, and base plate) with the base plates fastened together.

Over 30 mixture designs were performed to formulate an adequate mixture based on a methyl methacrylate monomer containing dimethyl-p-toluidine as promoter and powder aggregate containing benzoylperoxide as initiator. The ingredients were varied slightly to form a cold- and a hot-weather formulation. The specifications called for less than 0.10 percent shrinkage. Material with a 15-min worktime had typical compressive strengths that often approached 6,000 psi at 1 hr.

Polymer concrete was also used to seat the expansion joints and to fill the joints between slabs during the longitudinal post-tensioning of the system.

The work is part of a broader program of using modern materials in special applications where the cost benefits are great because of the special properties of these materials. Research reports are available on patching, bridge overlays, pile fabrication, and other applications.

achieved also through detailed planning along with such innovations as work platforms that were hung from the bottom flanges of the girders and moved ahead daily as the work progressed; temporary steel grid decks that were placed after each night's work to carry traffic through the day until the beginning of the next night's work when they were removed; and the sequencing of work. The preparatory work was performed during the day to allow the major work, which consisted of the removal of the existing deck and the placement of the precast deck sections, to proceed rapidly at night. This sequencing of work enabled the contractor to set 1,026 panels during a work period of 129 nights.

The contract for the entire project was awarded for $23,726,000. Of this amount, approximately $21,000,000 was deck-related, producing a unit cost of approximately $41 per square foot for the removal and the replacement of the deck and the maintenance of traffic.

Precast deck panel is lowered into place during nighttime construction work. Ovals are ducts for longitudinal post-tensioning.

Maryland State Highway Administration Procedures

It is the policy of the Maryland State Highway Administration that once a major involvement with a bridge structure begins, every effort is made to address all of the needs of the structure during the construction period. In addition to the unique deck replacement procedure, other procedures of interest that were performed during the rehabilitation of the Woodrow Wilson Bridge are described below.

An in-depth inspection of all of the girder details, especially in welded areas, was performed; and retrofitting procedures and construction items for repairing known or suspected problem areas were included in the original contract. Some of the techniques used were developed in recent years through research at Lehigh University under NCHRP Project 12-15, "Detection and Repair of Fatigue Cracking in Highway Bridges."

By means of the work platform that simplified access to all parts of every girder, an inspection team, using ultrasonic inspection techniques, was able to carefully review all of the elements of the structural units. When cracks were verified in the suspected areas, additional retrofitting details were provided for all similar areas of the bridge. These procedures ranged from the simple, such as drilling holes, to the more detailed, such as welding stiffeners to flanges or adding bracing.

Because of the failure of the hinge pin on the Mianus River Bridge in Connecticut, during the construction of the Woodrow Wilson Bridge replacement deck, an extra work order was initiated that provided for state and private inspection teams to evaluate in depth all pin connections. A fully documented report was prepared. Fortunately, no problem areas were discovered.

During the deck-panel replacement, every effort was made to safeguard not only the public but also the workmen. The use of crash attenuators attached to the rear end of vehicles allowed for easy placement and maneuvering ability and provided an impact-absorbing barrier between motorists and work crews on many occasions. Additionally, during the work period the contractor was required to place screening along the center of the bridge in order to block the view of the traveling public from the work area, thereby eliminating slowdowns and accidents usually caused by "rubbernecking."

Before construction, complete sounding information was obtained in the areas of all of the substructure units to relate the present river bottom to that existing when the bridge was first constructed. Scour areas were discovered and corrected.