# Precast Concrete Deck Modules for Bridge Deck Reconstruction

CHARLES SLAVIS

**Replacement of deteriorated and obsolete bridge decks is requiring increased attention from design and construction engineers. The need to shorten the time the bridge is closed to traffic has led to the use of precast concrete deck systems. Their value is demonstrated on bridges that must carry traffic for some portion of every 24-h period. Precast deck modules have been used on such diverse projects as expressway bridges in Pennsylvania and California and railroad bridges in British Columbia and Delaware. The Santa Fe Railroad has begun a multiyear program to replace timber decks with precast concrete on its 32 miles of bridges that have timber-deck and steel-girder designs. The precast deck modules used on these projects were produced at the site or produced at multipurpose plants and shipped to the bridge site. Placement was made with combinations of welded, epoxy, and cement-grouted connections. This paper reports on the state of the art of precast concrete deck replacements, their application in reconstruction, and their influence on deck design in new construction.**

The deterioration of bridge decks, which is accelerated by the extensive use of salt for snow and ice control, has required the bridge engineer to address the question of repair versus replacement. Both options must consider the maintenance of traffic during construction and how this consideration affects cost. Where extensive repair is necessary and traffic maintenance is difficult as well as critical, the replacement option of using precast deck modules may prove very practical. This has been the case where a section of deck has been removed, a replacement section added, and traffic allowed to use the bridge during some portion of every 24-h period. In the case of highway bridges, the time allotment is controlled by peak traffic demand. In the case of railroad bridges, the time allotment is controlled by systemwide demand and scheduling.

Precast deck modules have also been used on long bridges to ensure that deck replacement was completed during a single construction season. This has even proved to be the most economical deck-construction method for some new bridges. The highway departments of Indiana and New York and the New York Thruway Authority were among the first agencies to use precast modules in field experiments with new bridges or deck replacement.

Precast deck modules share some common considerations, regardless of their application. The most important of these are design considerations: where the modules will be cast, how they will be transported, and what construction procedures will be used. These factors, along with structural requirements and any restrictions on time availability (either per 24-h period or per construction season), must be considered by the design engineer. A close look at several individual projects illustrates how these factors vary from project to project.

## PENNSYLVANIA TURNPIKE

The Pennsylvania Turnpike had a 1627-ft-long bridge on its northeast extension in need of deck replacement. The distance between the bridge and the ground below reached a maximum of 140 ft (Figure 1). The existing bridge consisted of a concrete deck on steel girders. The design engineers concluded that precast deck modules were the best alternative. The modules allowed minimum personnel at the bridge site, where there was danger of construction at 140 ft aboveground. They also provided rapid erection to ensure completion of each parallel half of the bridge in a single construction season.

The modules were cast off site in a plant where production conditions allowed the use of a lower water-cement ratio concrete mix, more precise vibration, and a more controlled curing operation. The 7-ft 6.25-in by 28-ft 8-in by 6.75-in slabs, each weighing 18 000 lb, were trucked to the site as needed (Figure 2) and lifted directly into place (Figure 3). No on-site storage was necessary.

Because traffic was being maintained on one-half of the bridge for the length of the construction season, the removal of the old deck could proceed well in advance of the redecking operation. This made the task of preparing the girders to receive the precast modules much less complicated. The contractor placed slabs at the rate of 6 modules/day and completed slab placement in less than two months (Figure 4). Connection of the module was made by using epoxy mortar spread over the top flange of the

Figure 1. Pennsylvania Turnpike bridge.

Figure 2. Precast modules are trucked to placement site on operating half of bridge.

Figure 3. Modules are lifted from truck and placed directly on prepared girders.

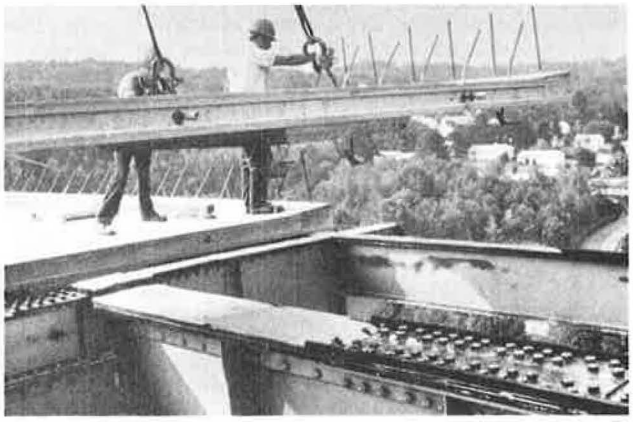


Figure 4. Placed modules were finished with cast-in-place parapet and latex-modified concrete wearing surface.

girder and supplemented by bolted spring clips located near the edge of each module. The final wearing surface on the bridge consisted of 1.25-in latex-modified concrete.

RAILROAD BRIDGES

The Santa Fe Railroad has undertaken a program of bridge deck replacement that has a different set of criteria but results in an operation very similar to the Pennsylvania Turnpike bridge. The deck to be replaced on the Santa Fe was not a single deck but a deck type that consisted of timber decking on steel-girder bridges. There is a total of 32 miles of this type of deck spread out over the more than 12 000 miles of the system. The basic deck module selected was 8 ft by 14 ft by 8 in and weighed about 6 tons. It was designed for a Cooper's E80 loading and was cast at a commercial prestressing plant in Albuquerque, New Mexico. The location of the plant on the Santa Fe line allowed transportation throughout the system, while maintaining the quality control that results from a plant-cast operation.

The Santa Fe redecking has some variations, depending on whether the deck to be replaced can be taken out of service for only several hours at a time (as in single-track territory) or for several days (as in double-track territory). The field operation is basically the same, but only a short section of the bridge is done at a time in single-track territory. The required steps consist of removing the rail, ballast, and timber deck; preparing the girders; placing the precast deck modules; and replacing the track (Figures 5-7). The use of an epoxy mortar spread on the girder was the only connection provided between the modules and the girder.

Although the total deck-replacement operation is easily defined with a single-track bridge, thorough planning must be combined with knowledgeable and efficient construction to ensure that the track is available for service within the 4- to 6-h time allotment.

The Santa Fe is not the only railroad to make use of precast concrete in replacing bridge decks. Ca-

Figure 5. After cleaning, girders were coated with epoxy grout to bond modules to girders.

Figure 6. Precast modules are cleaned prior to placement to ensure that epoxy grout will bond.

nadian Pacific replaced the deck on a 402-ft-long bridge near Revelstoke, British Columbia, while interrupting traffic for two separate, preassigned 12-h periods. The National Railroad Passenger Corporation (Amtrak) also used eight precast deck modules, complete with monolithic ballast curbs, to replace a deteriorated concrete deck on a single-track bridge near Newark, Delaware.

Figure 7. Final operation is addition of wood curbs and replacement of ties, ballast, and track.

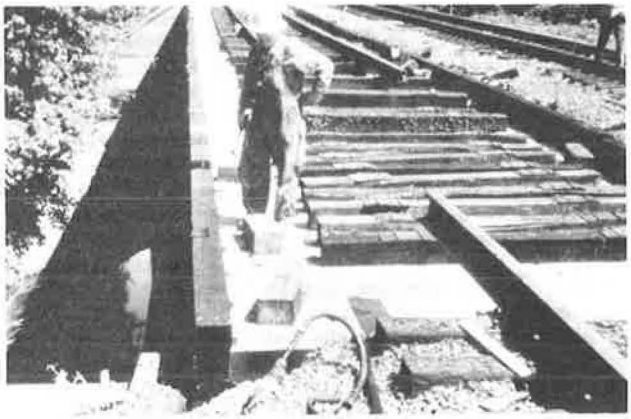


Figure 8. Casting bed was set up adjacent to bridge site.

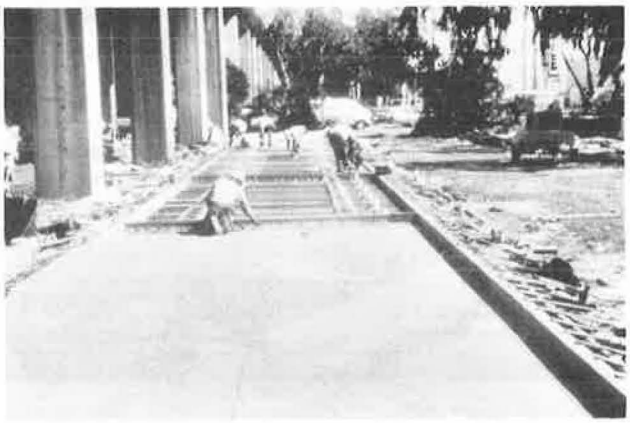
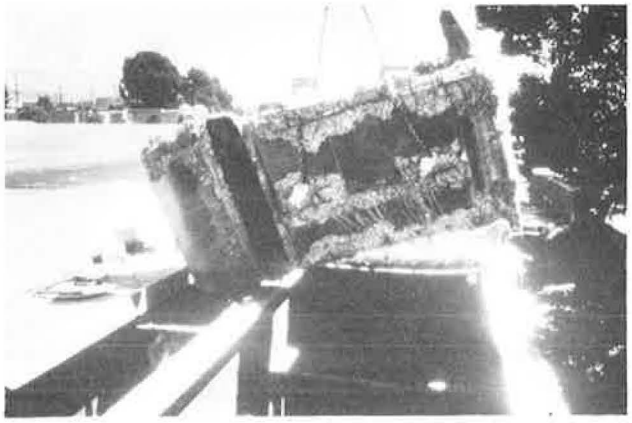


Figure 9. Existing deck is removed as part of each day's operation.



HIGH STREET OVERHEAD

The phasing of deck replacement within a prescribed time slot out of each 24-h period is not limited to the railroad industry. Repair work on modern urban freeways often takes place with all lanes operating at full capacity during peak hours. An excellent example of bridge deck replacement under such conditions was the High Street Overhead, which is a 1750-ft structure on CA-17 within the City of Oakland.

The High Street Overhead is a 32-span structure and has individual spans that range in length from 30 to 75 ft. The California Department of Transportation undertook a detailed study that resulted in the deck replacement of the outside southbound lane. Critical factors in the decision to use precast deck modules included average daily traffic in excess of 170 000 vehicles, heavy congestion during peak evening commute hours, and the lack of a practical means to provide a detour to accommodate the lost capacity resulting from the required lane closures.

The actual contract for the High Street bridge deck replacement required the contractor to have the outside southbound lane available for peak-hour traffic between 2:00 and 6:00 p.m. each weekday. There were also lane-closure restrictions on some weekends. The resulting schedule gave the contractor 20 h each weekday plus some weekends.

In addition to the severe time restrictions, there were several elements that distinguished the High Street deck replacement from other construction jobs. The contractor selected to set up a casting operation on the site, which was adjacent to the bridge (Figure 8). This eliminated any size restrictions on the modules necessitated by the need to transport them from a plant. The finished size of the modules was then dictated by the requirements of the structure and also by the ability and lifting capacity of the contractor's crew and equipment (Figures 9 and 10). Connection was provided with shear connectors welded to the girders and grouted into holes in the modules. Another element that required special attention was the deck surface. Unlike railroad bridges, which are covered with ballast, or total bridge projects, which conclude with paving the entire deck, the 20-h limitation required that tolerances on the deck modules ensure a finished surface capable of handling traffic at the commencement of each day's peak traffic period (Figure 11). The success of the High Street deck re-

Figure 10. Precast deck modules, complete with safety shape parapet, are lifted into place.

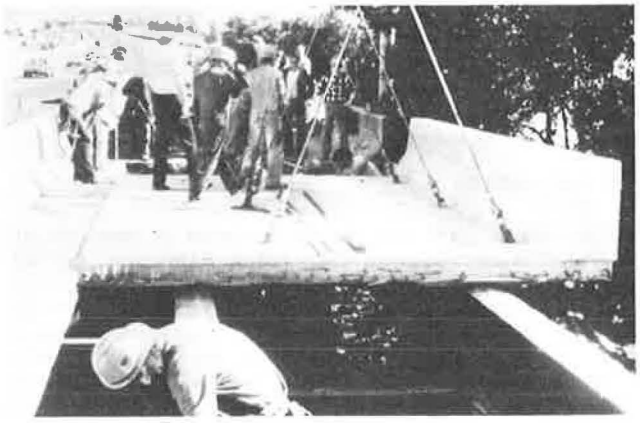


Figure 11. New deck is reopened to traffic during weekday peak period.

placement shows how advanced planning, engineering, project management, and quality control combine to result in a thoroughly successful project.

## BENEFITS

Before discussing current research and anticipated future uses, a review of the established benefits of precast deck modules is in order. The most recognized benefit is erection time, which is more limited by economics than by any physical constraint of current technology. On-site casting and heavy lift equipment make projects even more impressive than High Street feasible when time restraints provide the necessary economic justification. If the engineer recognizes the prospective contractor's capabilities and designs the bridge accordingly, more economical designs will result. Further savings may be obtained if provision is made to allow contractor-proposed changes. This can be accomplished by including a value-engineering clause in the contract documents. The ability to cast modules to tolerances that can be used without need of further surfacing is another benefit that is available if economically justified. The benefits associated with quality control of precasting should also be considered.

## FURTHER RESEARCH

The total number of bridges that have been redecked by using precast concrete deck modules is relatively small. The advantages of precast modules will not be fully realized until bridge engineers' concerns about the fatigue behavior and durability of the connections are answered. To this end, the Federal Highway Administration (FHWA) has sponsored research on connections, which supplements research and experiments associated with some early precast deck and modular deck installations. Although it is too early to report on the FHWA study, some of the earlier experimental decks were installed in 1973 and 1974, and the various deck-to-girder connectors are still performing as designed. Some problems have occurred in preventing moisture leakage between adjacent slabs where dry joints were used in early installations, but the use of a sand and cement grout or epoxy mortar in the joints seems to prevent this problem. The long-term durability of grout or mortar must still be determined.

The use of precast modules has been limited to steel-girder bridges in redecking applications, as bridges with prestressed concrete girders have not existed in large numbers until recent years. In anticipation of increased use of precast modules for deck replacement on this bridge design, the FHWA study includes connectors for modules to concrete girders.

## CONCLUSION

The development of precast modules for deck replacement has both influenced and been influenced by the development of precast deck components for use in new construction. The use of prestressed concrete stay-in-place forms showed the advantages of both speed and safety in using precast components in bridge deck construction. The outcome of this is the development of the precast segmental box-girder bridge that has an integral wearing surface included in the precast segments. This cross-influence of precast bridge components can also be seen in the Florida Department of Transportation's current experiments with deck modules for short-span bridges. The Florida modules are full-span panels that are connected laterally to form a bridge deck. They are used without girders and, in effect, are a precast-slab-type bridge. These experimental modules have included integral decks or have had the deck cast in place once the modules are erected.

Precast, prestressed concrete is and will continue to be useful to the bridge engineer in designing for both new construction and reconstruction.

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