A New Generation of Precast Prestressed Concrete Slab Bridges for Maryland's Rural Highways

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Discusses the decision making process involved in the use of precast/prestressed concrete slab bridges for the replacement of structurally deficient bridges in the state of Maryland. Presents the costs associated with constructing four such bridges and discusses the economic efficiency of precast and prestressed concrete.

In the 1920s and early 1930s, Maryland undertook an extensive road building program that included the construction of many concrete girder and slab bridges. These bridges have served the citizens of Maryland for more than 70 years with few problems. However, time and deterioration, primarily from road salts, have taken their toll on these bridges. Many of them are now in need of major rehabilitation or complete replacement.

With the approach of the 21st century, Maryland must face the challenge of replacing these bridges with economical, efficient, and low maintenance structures. A wide variety of structure types have been considered for these bridge replacements including concrete box culverts, timber bridges, steel beam with concrete slab bridges and prestressed concrete bridges.

In the investigation to determine the most viable type of bridge for these replacement structures, several factors were considered:

First, most of the existing bridges were for stream crossings with spans ranging from 20 to 40 ft (6.1 to 12.2 m) and were located on rural collector type roads. These roads could often be closed to traffic for several months while the replacement bridge was constructed. Precast concrete construction presented a structural system that could be completed quickly while minimizing traffic disruption.

Second, the precast superstructure elements could be constructed with a high degree of quality at an economical cost.

Finally, past experience with the bridges that were being replaced demonstrated that concrete structures can remain in service for 75 to 100 years with little or no maintenance costs.

After taking these factors into consideration, a system of precast/prestressed concrete slab units 3 or 4 ft (0.91 or 1.22 m) in width placed adjacent to each other and post-tensioned laterally in place was chosen (see Fig. 1). Once the post-tensioning is complete, a cast-in-place concrete riding surface is placed over the slabs

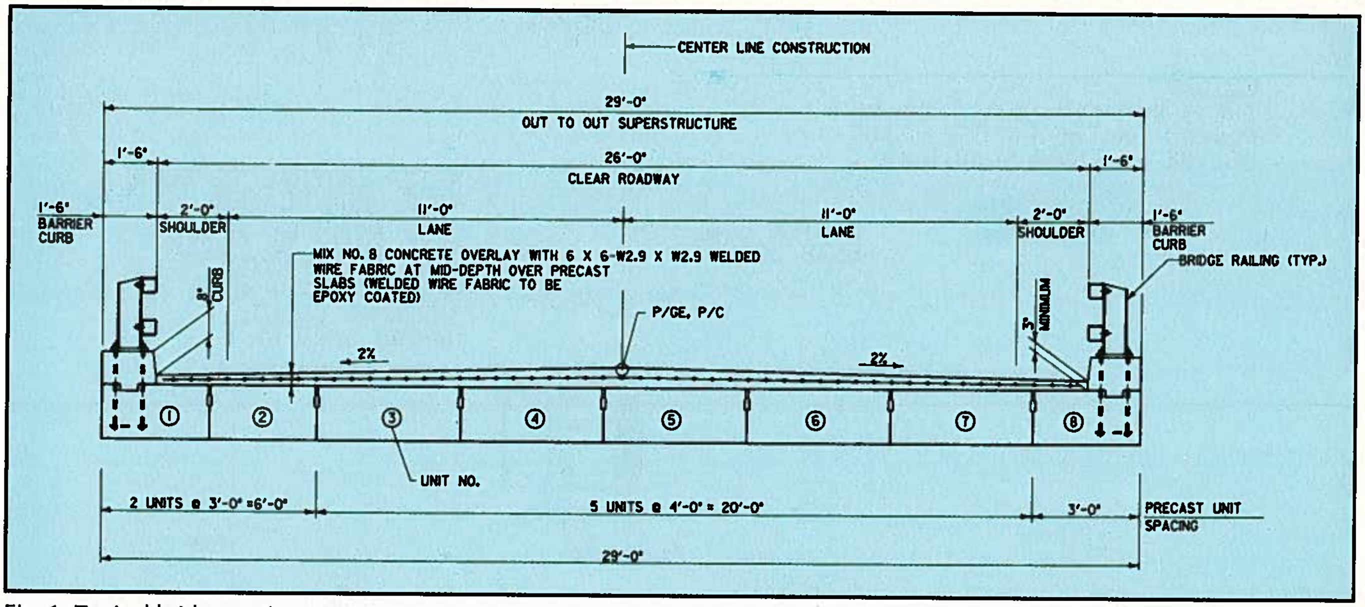

Fig. 1. Typical bridge section.

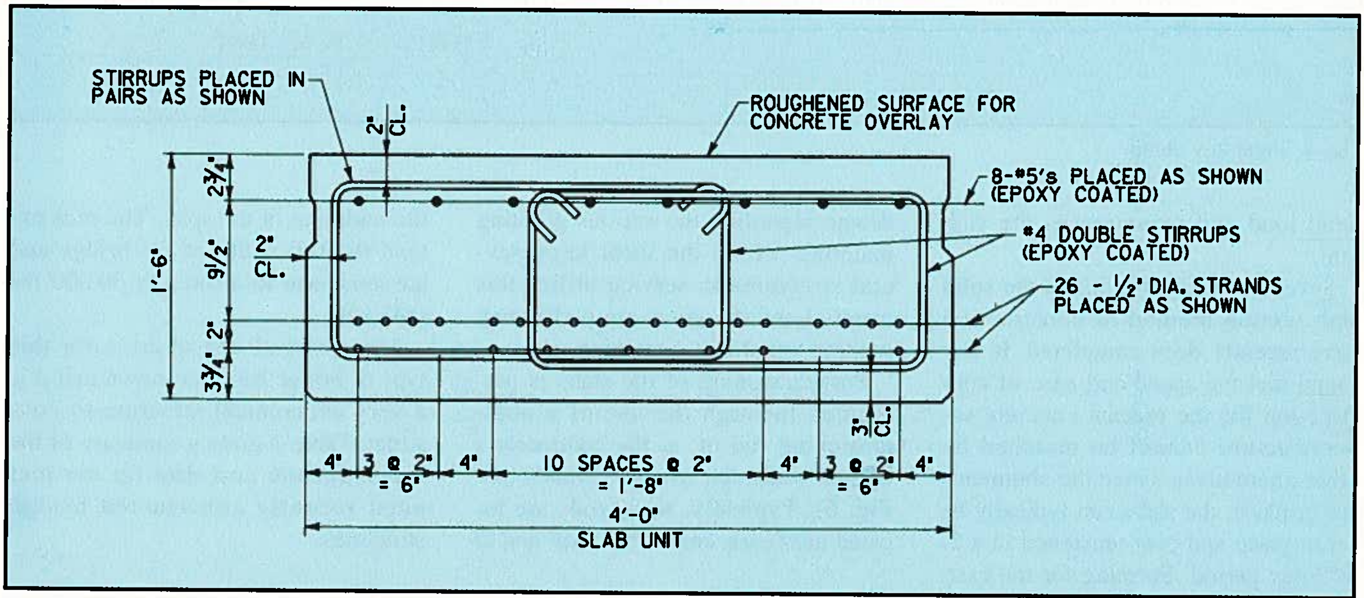

Fig. 2. Typical solid slab unit.

and a safety curb and steel railing are added to complete the structure.

Unlike typical slab design, Maryland uses solid slab sections (see Fig. 2) instead of conventional voided slab sections. While the solid section may be less efficient from a structural design standpoint, it was chosen for durability. Past experience with voided slabs revealed that they deteriorated quickly in the area of the voids due to salt chloride penetration (see Fig. 3). Many of these slabs experienced punctures in the top portion of the slab and filled with water. This condition not only presents a freezing problem but it significantly increases the structure

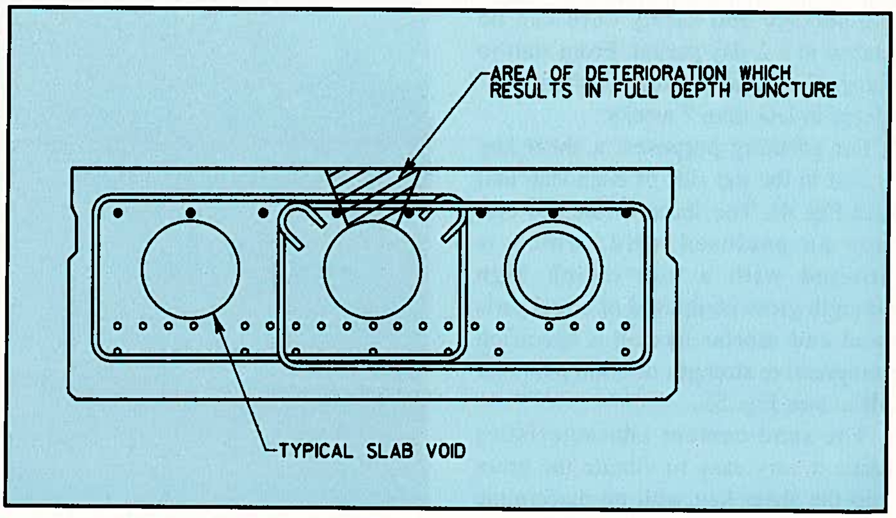

Fig. 3. Conventional voided slab unit.

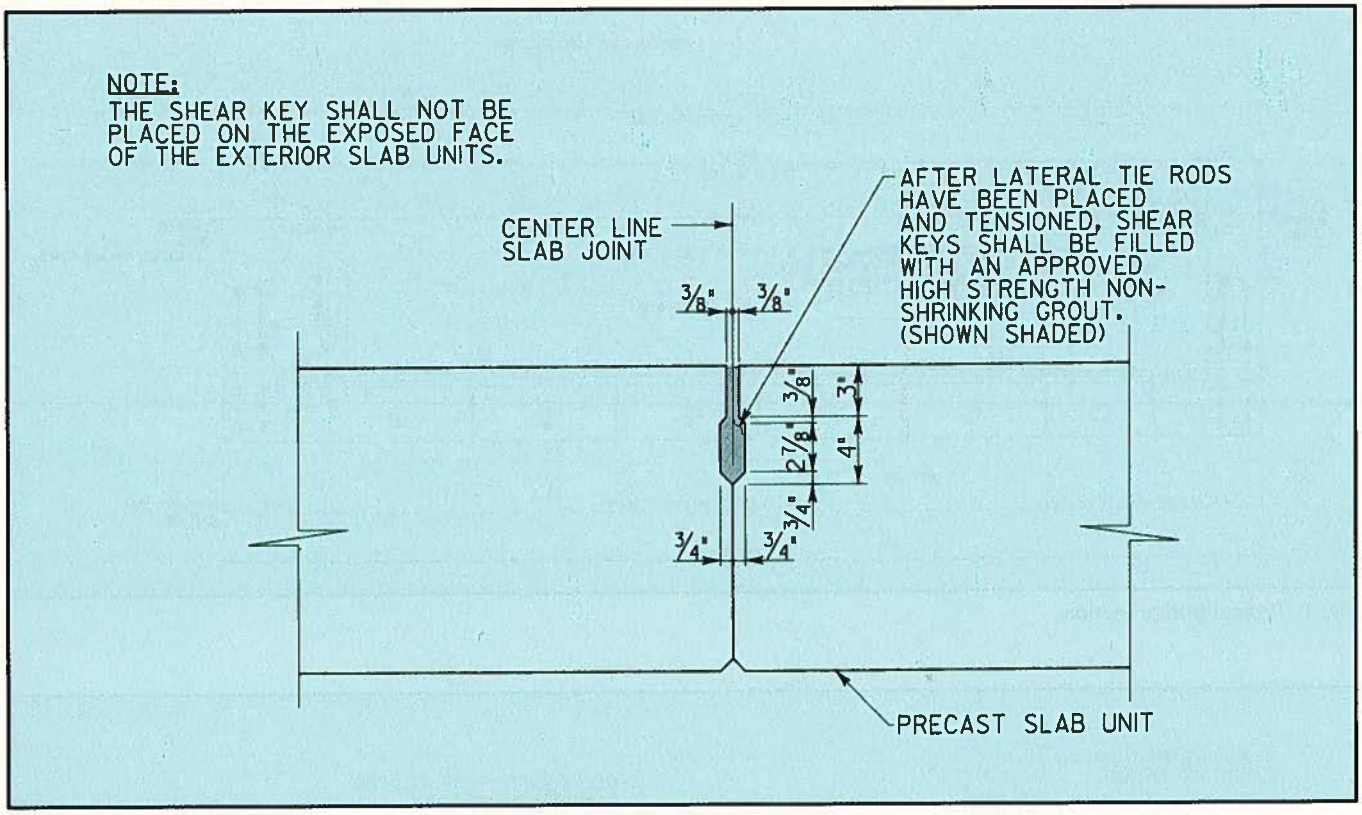

Fig. 4. Shear key detail.

dead load and overstresses the slab unit.

Several structures utilizing the solid slab section method of construction have recently been completed. It was found that the speed and ease of construction for the precast concrete superstructure cannot be matched by other alternatives. Once the abutments are in place, the slabs can typically be set in place and post-tensioned in a 2- to 3-day period. Forming for the cast-in-place riding surface and safety curb will take 4 to 5 days. Grouting of the shear keys will take 1 day and the riding surface and safety curb can be placed in a 2-day period. From start to finish, the superstructure is often completed in less than 2 weeks.

For grouting purposes, a shear key is cast in the top side of each slab unit (see Fig. 4). The shape of the key creates an enclosed void, which is grouted with a non-shrink high strength grout composed of equal parts sand and mortar having a specified compressive strength of 5000 psi (34.5 MPa) (see Fig. 5).

The sand-cement characteristics make it very easy to vibrate the grout into the shear key with no discernible voids. Although there has been some debate regarding the various grouting materials within the shear keys, several structures in service utilize this material and the joints are performing without longitudinal cracking.

Post-tensioning of the slabs is performed through the use of a post-tensioning rod or, at the contractor's option, with high strength strands (see Fig. 6). Typically, these rods are located near each end of the span and at the midpoint of the span. The rods extend the full width of the bridge and are tensioned to a force of 30,000 lbs (133 kN).

The speed of construction for this type of bridge has also shown that it is a very economical structure to construct. Table 1 gives a summary of the superstructure cost data for the four most recently constructed bridge structures.

Fig. 5. Grouting of slab joints prior to overlay placement.

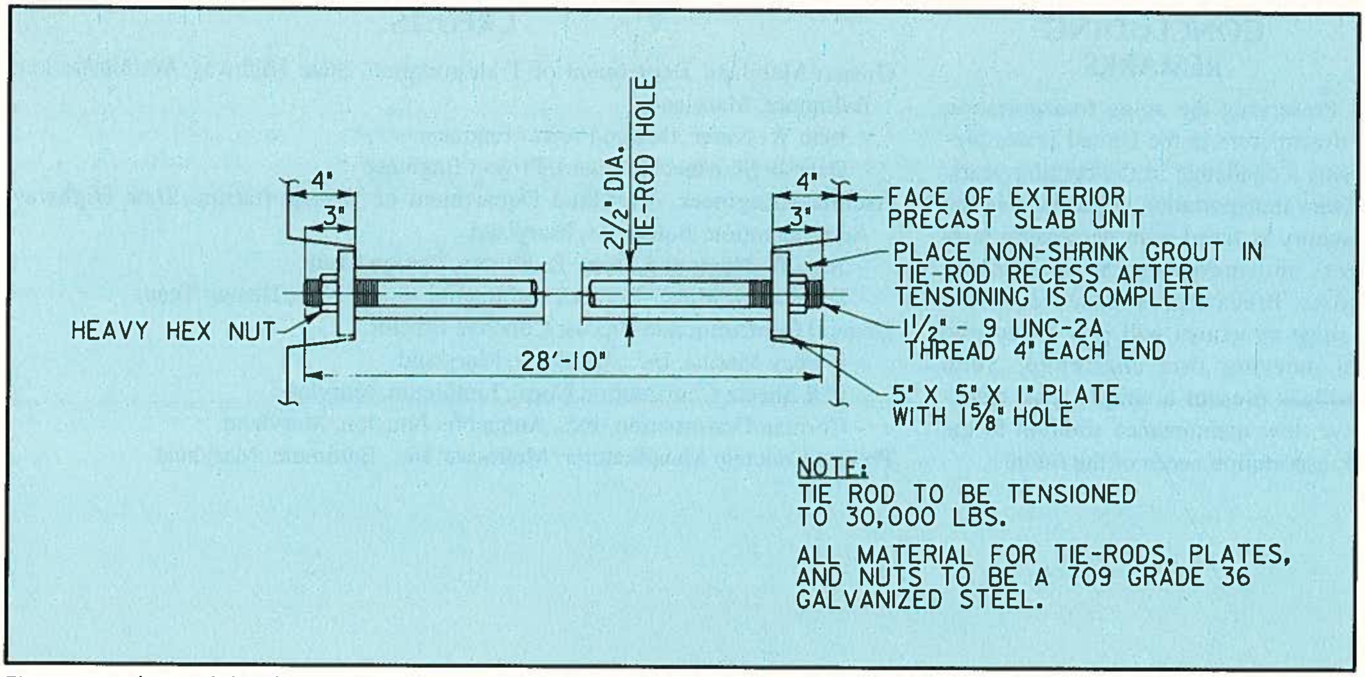

Fig. 6. Lateral tie rod detail.

These figures cover the complete cost of the new superstructure including precast concrete elements, cast-in-place riding surface and the bridge safety rail or parapets. In the past 5 to 10 years, these structures have averaged approximately $65.00 per sq ft ($700/m²) in the Maryland area. These costs may seem high compared to other areas of the United States because Maryland has predominately used steel structures until recently. It is expected that as the use of concrete superstructures increases, the costs will decrease.

A key factor in the decision making process was the low maintenance costs associated with the concrete bridge structure. The high cost of painting bridges instigated the re-evaluation of steel superstructures for bridges of this type. It is believed that precast/prestressed concrete bridges will be virtually maintenance free for the next 50 to 75 years (see Fig. 7).

The old concrete bridges that are being replaced bear testimony to this prediction. The use of epoxy-coated reinforcing steel and other modern materials should help to prolong the life of these bridges. In addition, these bridges have been constructed without joints, which will further preserve the substructure by not allowing roadway drainage to flow onto the abutments.

Table 1. Summary of superstructure cost data for four recently constructed bridges.

Maryland Route 404 over Norwich Creek	
Length = 36 ft (10.97 m)	Width = 29 ft (8.84 m)
Superstructure cost = $70,802	Cost = $67.82 per sq ft ($730/m²)
Maryland Route 425 over Branch of Hilltop Fork	
Length = 52 ft (15.85 m)	Width = 33 ft (10.06 m)
Superstructure cost = $116,000	Cost = $67.59 per sq ft ($728/m²)
Maryland Route 300 over Andover Branch	
Length = 46 ft (14.02 m)	Width = 40 ft (12.19 m)
Superstructure cost = $105,600	Cost = $57.39 per sq ft ($618/m²)
Maryland Route 300 over Tributary of Andover Branch	
Length = 37 ft (11.28 m)	Width = 40 ft (12.19 m)
Superstructure cost = $85,000	Cost = $57.97 per sq ft ($624/m²)

Fig. 7. Completed structure on Maryland Route 404 over Norwich Creek.

CONCLUDING REMARKS

Preserving the aging transportation infrastructure in the United States presents a challenge in the coming years. Every transportation department in the country is faced with decreasing budgets and increasing infrastructure costs. Precast/prestressed concrete bridge structures will play a key role in meeting this challenge. Such bridges present a simple, cost effective, low maintenance solution to the transportation needs of the future.

CREDITS

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DISCUSSION NOTE