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FINAL REPORT

PRECAST CONCRETE REPLACEMENT SLABS FOR BRIDGE DECKS

by

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Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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SUMMARY

The report illustrates and evaluates the first use in Virginia of precast concrete replacement slabs for bridge decks. It shows that a bridge deck can be replaced with the precast slabs while traffic is maintained in the adjacent traffic lane. The quality of the prototype deck appears to be comparable to that of a conventional site-cast deck and, although a conventional deck could be constructed for slightly less money, the new design offers the advantage of reduced on-site construction time that would be worth the added cost in many situations.

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INTRODUCTION

The repair and the replacement of concrete bridge decks at the national level utilize a significant amount of the money available for the maintenance of transportation facilities. Quite often the level of distress in bridge decks resulting from frost action and from salt contamination, and the resulting corrosion of the reinforcing steel, is sufficient to justify total replacement of the deck rather than localized repairs. With conventional re-decking practice, the time required to replace a deck with site-cast concrete may be considerable and result in prolonged lane or bridge closure times causing considerable inconvenience to the traveling public.

A number of techniques have been developed to expedite the deck replacement process. For example, in many situations precast concrete members such as slabs and box- and tee-shaped members can be placed side by side to provide a rapidly constructed, suitable superstructure. However, many of the decks that must be replaced have been constructed on steel stringers, and typically the condition of the stringers justifies leaving them in service. On these bridges the old concrete decks are usually removed and new site-cast concrete decks are constructed. A considerable amount of time is required to remove the old concrete and steel, to install the formwork, position the reinforcing bar, and place the concrete. Additional time is required for the concrete to achieve the desired strength so that traffic can be permitted on the deck.

The reason for using full-depth concrete deck replacement slabs would be to minimize the need to keep a bridge closed to traffic while the site-cast concrete attains the required strength. An added benefit generally realized is that the deck is of higher quality because the slabs are fabricated at a plant under more controlled conditions than likely are encountered in on-site placement of concrete. The controlled conditions allow the use of concrete mixtures with lower water to cement ratios and provide for more effective consolidation and curing of the concrete. Also, it is believed that deck replacement costs could be reduced since on-site construction time would be less and because, in some instances, it would be possible to mass-produce the deck slabs.

BACKGROUND

The concept of precast concrete replacement slabs for bridge decks was described in detail and promoted in a paper by Biswas et al. that was presented at a Highway Research Board meeting in 1973.[1] The paper summarized the research and development that preceded the construction of a prototype deck on the New York State Thruway. The features desired in the prototype structure included (1) a strength and a durability comparable to those of more conventional alternatives, (2) a more rapid deck replacement and reduced interference to traffic as compared to conventional methods, and (3) the provision of full traffic capacity during peak periods. A number of connection details, both composite and noncomposite, were designed for attaching the slabs to the steel stringers.[1,2]

Subsequent to the research and development effort, seven precast deck replacement slabs were installed on the west lane of an access ramp to the New York Thruway in November 1973, and another seven slabs were installed on the east lane in June 1974.[3] Following this prototype installation, the deck of the Krumkill Road Bridge was replaced with precast slabs in 1977, and the slabs for a third bridge located on an interchange ramp were fabricated and installed in 1979.[4] The details of these and other installations are shown in Table 1.

Precast concrete deck replacement slabs have been used by a number of agencies over the years. The system was first used in 1970 in Bloomington, Indiana, to replace the deck on a truss bridge in a 24-hour period.[5] For this application a neoprene pad was placed in the keyways between the panels and the slabs were post-tensioned in the direction of traffic in groups of five. The California Department of Transportation used the precast deck slabs to replace the outside southbound lane of a 32-span bridge on Rte. 17 in Oakland. The lane under construction was opened to traffic each weekday between 2:00 p.m. and 6:00 p.m.[6] The Atchison, Topeka, and Santa Fe Railway Company has placed more than 5 miles of the slabs as a part of a 32-mile timber deck replacement operation currently under way.[6,7,8] The slabs have also been used by the Canadian Pacific Railroad and by Amtrak.[6] The Pennsylvania Turnpike Authority also replaced a deck in 1979 and 1980.[6,7]

Table 1. Details of Some Precast Concrete Deck Slab Installations

	Reference	3	3	4	4	5 & 6	7 & 8	6	6	6 & 7	10
	Const. Dates	1973-74		1977	1979		1974 to present			1979 - 1980	1973
Location	State	N. Y.	N. Y.	N. Y.	N. Y.	California	New Mexico	British Columbia	Delaware	Pennsylvania	Alabama
	Agency	Thruway Auth.	Thruway Auth.	Thruway Auth.	Thurway Auth.	Cal. D.O.T.	Atch.Top.San.Fe.R.R.	Canadian Pacific	Amtrack	Turnpike Auth.	Montgomery County
	Route	N. Y. Thruway	N.Y.Thru.@Albany	N.Y. Thruway	N.Y. Thruway	Rt. 17, Oakland	Railroad	Railroad	Railroad	Penns.Turnpike	Old Hayneville Rd.
	Intersection	Amsterdam Interchange	William St.	Krumkill Road	Harriman Interchange	High Street	Near Albuquerque	Revelstoke	Newark		Pintlala Creek
Bridge	Stringers	33WF200 @ 10'-0"	Steel	Steel @ 7'-5"		Steel	Steel	Steel		Steel	Steel at 6'-6"
	Composite	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes - ?	No
	Size	45' x 218'	56' x 143'	123' x 48'		1750'long	5 miles	402'		59' x 1627'	24' x 680'
	No. spans	4 simple	3 continuous	2 simple	3	32	Numerous				5-four span continuous
Slabs	No.	14		36 (18 each)			Many		8		80
	Dimensions	4'-0" x 22'-0"x 8"	6' x 28' x 8½"	5'-2 5/8"x 42'-7/8"x 71/2" 5'-2 5/8"x 21'-2 7/8"x 71/2"	8,990 ft.^{2}		8'-0" x 14'-0" x 8"			7'-6 1/4"x 28'-8" x 6 3/4"	7'-0"x 24'-0" x 7 1/2"
Connections	Type	Bolts or welds to channels	Studs	Studs	Studs	Studs	Steel clips and inserts			Steel clips and inserts	Steel clips and inserts
	Filler	None or epoxy mortar		Epoxy concrete	Epoxy concrete	Calcium alum.grout	None	None	None	None	None
	Composite	Yes	Yes	Yes	Yes	Yes	Yes ?	Yes ?	Yes?	Yes ?	No
	Leveling Material	Metal shims or epoxy mortar	Foam strips	Epoxy mortar	Epoxy mortar		Epoxy grout			Epoxy mortar	None
	Keyways	Epoxy mortar	None	Epoxy mortar	Epoxy mortar		Epoxy grout			Epoxy mortar	18" strips of site-cast concrete
Slab Fab.	Location	Outside near bridge		Precast plant	Precast plant	Outside near br.	Precast plant			Precast plant	Outside near bridge
	Personnel	Maintenance forces		Priv. industry	Priv. industry	Contractor	Priv. industry			Priv. industry	Contractor
	Overlay	Sheet membrane & 4" to 5" of asphalt concrete		3/4" thick mastic membrane & 2 1/2" asphalt conc.	Sheet membrane & asphalt concrete	None	Ballast, ties and track	Ballast, ties and track	Ballast, ties and track	1 1/4" thick layer of latex modified concrete	Asphalt concrete
	Problems	Epoxy used in keyways Took 5 hrs. to set Lot of time required to drill bolt holes in top flange of stringers or to weld channels in position.	Some cracks in sofits. Site cast conc. requirements delayed the opening to traffic.	Some cracks in slabs	Some cracks in slabs						
	Other	Slabs placed on one half of one span 45' x 28'	Patented panel design	Skewed bridge, contractor fabricated and erected slabs and maintenance forces did other work		The lane being replaced had to be open to traffic between 2:00 p.m. and 6:00 p.m. each weekday.	Epoxy mortar bond provides composite action. Slabs are prestressed at plant perpendicular to direction of traffic and cast upside down. Plywood strips serve as form for epoxy grout placed on stringers.			Epoxy mortar bond provides composite action. Slabs are prestressed at site parallel to direction of traffic. Top mat of reinforcing is epoxy coated. Rubber strips serve as forms for epoxy mortar placed on stringers.	New bridge. Top surface of slab slopes so that the thickness is 6" at the curbs.

A nominal amount of longitudinal prestressing was used in the slabs installed in Pennsylvania and the top layer of reinforcing was epoxy coated.

Finally, an alternative design in which the precast replacement slabs are attached to the stringers with steel clips to provide for noncomposite action has been promoted by the steel industry.(9) Believed to be highly economical for deck replacement on secondary roads, the system is thought to have been first used in 1973 for a 20-span bridge in Montgomery, Alabama.(10) The basic difference among the various field installations was in the connection details. Steel shear connectors were used in New York and California to provide composite action between the deck panels and stringers. Epoxy grout or epoxy mortar was used to provide composite action in the railroad applications and on the Pennsylvania Turnpike. The first bridge in Indiana and the bridge in Alabama were noncomposite. The slabs used on the bridge in Indiana and the one in Pennsylvania were posttensioned in the direction of traffic.

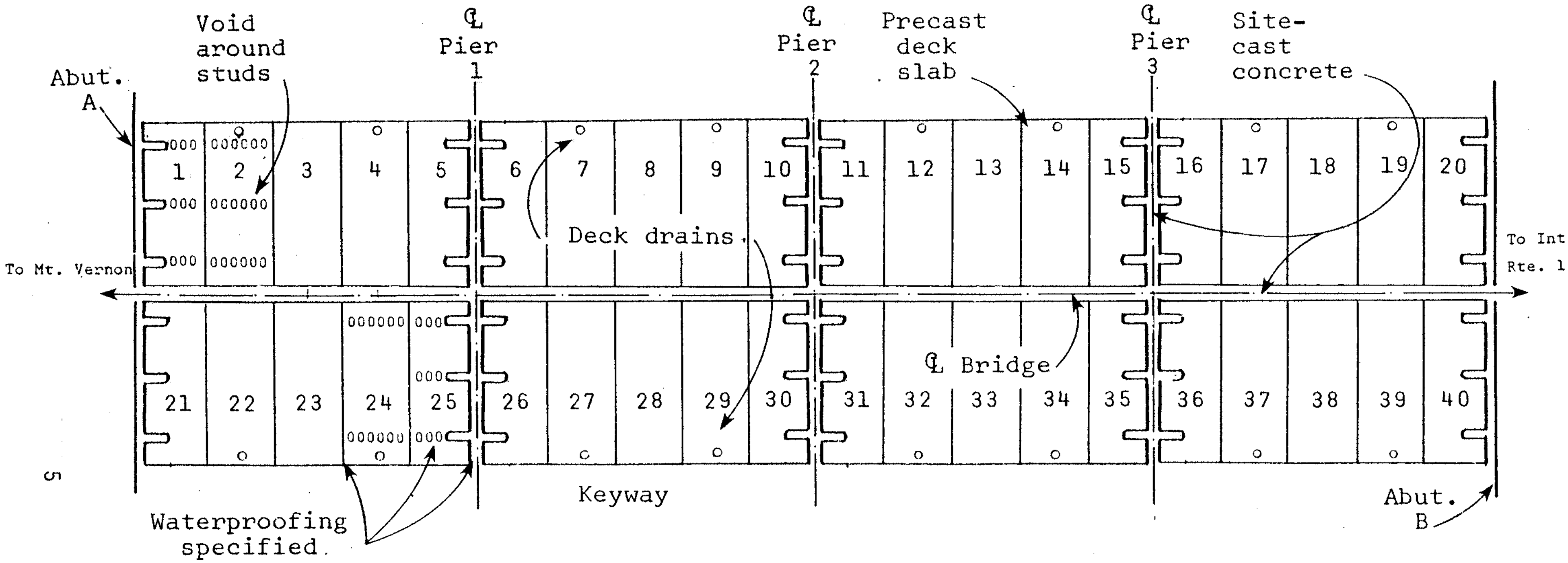
Efforts to promote the concept in Virginia were initiated by the Research Council in 1973. Although the concept was promoted by the Research Advisory Committee for Industrialized Construction and later the Bridge Research Advisory Committee, a final design for a prototype structure did not surface until February 1981, when the plans for replacing the deck of a 4-span bridge on Rte. 235 near Mount Vernon in the Culpeper District were approved for advertisement.(11) It was anticipated that this prototype deck replacement project would provide the much needed insight into the suitability of using precast replacement slabs. The fabrication and installation of these slabs are covered in the following sections of this report.

FABRICATION OF SLABS

A plan view of the slab layout for the bridge on Rte. 235 is shown in Figure 1. Two basic types of slabs were specified, but minor differences required the production of four types; namely end slabs, left and right, and interior slabs with and without drains. The large voids in the end slabs were required to satisfy the AASHTO shear stud spacing requirements.

Valley Blox of Harrisonburg fabricated the forty slabs. The precaster constructed two concrete casting pads and fabricated two sets of side forms specifically for the project so that one set of forms could be used for each of the two basic types of slabs.

The daily production routine involved stripping forms in the morning, assemblying the formwork and steel at midday, casting the concrete in the afternoon, and applying accelerated curing with steam at night. Typically two slabs were produced each day. The fabrication of the slabs is illustrated in Figures 2 and 3.



Left end slab - 5,10,15,20,21,26,31,36.
Right end slab - 1,6,11,16,25,30,35,40.
Interior slab (with drain)- 2,4,7,9,12,14,17,19,22,
24,27,29,32,34,37,39.
Interior slab (w/o drain) - 3,8,13,18,23,28,33,38.

Figure 1. Precast slab layout. (From reference 12.)

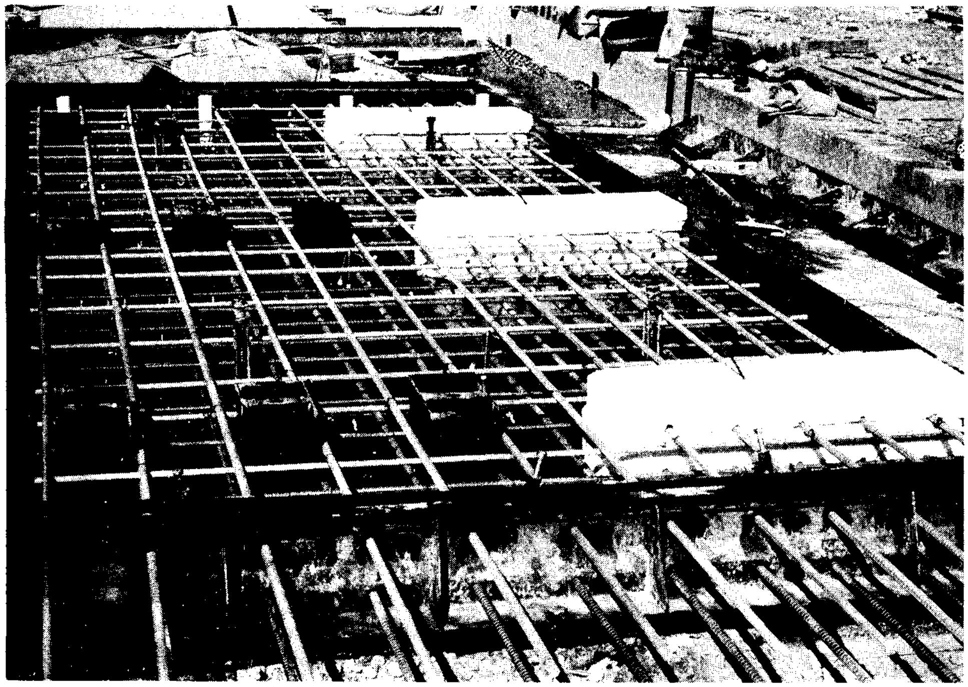


Figure 2. Forms are prepared for the casting of an end slab.

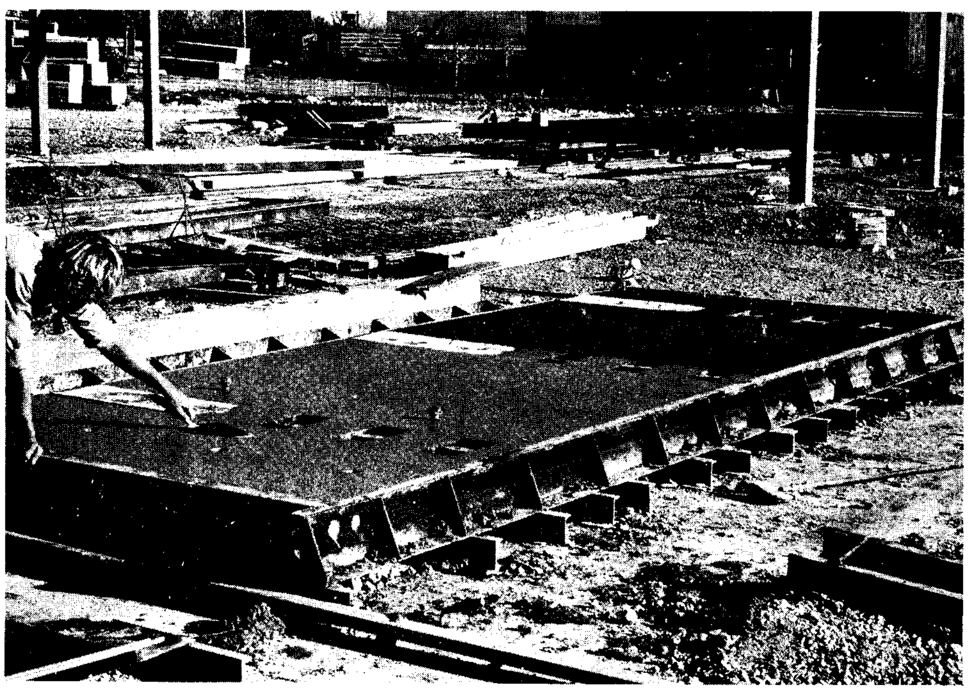


Figure 3. Finish is placed on an end slab.

The slabs were removed from the casting bed with a crane and stored in the yard. For handling purposes, four inserts were cast into each slab at approximately the quarter points. During storage and transport the slabs were supported by three timbers positioned so as to provide the same support that would be provided by the steel stringers once the slabs were installed on the bridge.

A tractor and trailer or flatbed truck was used to transport the slabs, in groups of two or three, the approximately 140 miles to the bridge site, where they were unloaded and installed on the bridge.

INSTALLATION OF SLABS

Information on the installation of the replacement slabs is summarized in Table 2. Before the slabs were placed, steel stud shear connectors were welded to the flanges of the stringers at the locations specified on the plans. While the trucks loaded with slabs waited at the bridge site, an epoxy mortar was prepared and placed on the top flange of the stringers to be covered by the slabs (see Figure 4). The epoxy mortar consisted of an approved two-component epoxy and dry silica sand. The ingredients were mixed with a paddle propelled by a drill. While the epoxy was plastic, the slabs were moved one at a time from the trailer and lowered into position on the stringers (see Figures 5, 6, and 7). Once the slabs were positioned a trowel was used to strike off the excess epoxy along the edges of the top flanges under the slabs. Typically five slabs, enough for one lane and one span, were placed each day, although at least twice as many could have been placed.

To allow the placement of the slabs on the two middle spans the crane was supported on the slabs that had been placed on the end spans (see Figures 5 and 7). Timbers were placed across the joints that separated two spans to allow the crane to move from one span to the next without cracking the end panels (see Figures 5, 7, and 8). The crane supports were positioned directly above the stringers.

Once the twenty slabs required for the upstream lane of the bridge were placed, the areas (see Figures 1, 8, and 9) around the stud shear connectors were filled with high early strength concrete containing a shrinkage-compensating additive, Intraplast N. Next, the site-cast concrete required at the ends of the spans was placed, and then the grout containing a shrinkage-compensating additive was placed in the keyways between the slabs (see Figure 1). All the site-cast concrete and grout was covered with an epoxy mortar to provide waterproofing.

Table 2. Summary Data on Labor, Equipment, and Materials for Deck Replacement

Activity	Total No. of Days	Average No. of Men	Total Man-Hours	Total Man-Hours per $ft.^2$	Equipment	Materials
Welding studs	4	1	26	0.005	Miller portable welder, pickup truck	Steel studs
Placing precast deck slabs	10	5	250	.044	Clark crane, pickup truck, epoxy mixer, hand tools, generator	Precast deck slabs, epoxy, sand
Filling voids around studs	3	8	112	.020	2 pickup trucks, generator, vibrator, wheelbarrow, hand tools	Epoxy bonding compound, A4 H.E.S. concrete with non-shrink additive
Forming and placing concrete in deck at ends of spans	4	7	280	.049	2 pickup trucks, generator, air compressor, vibrator, hand tools	Formwork, epoxy bonding compound, A4 H.E.S. concrete with nonshrink additive
Filling keyways between precast slabs	4	7	84	.015	2 pickup trucks, generator, air compressor, vibrator, hand tools	Portland cement mortar with non-shrink additive
Placing class I waterproofing on site-cast concrete	2	7	91	.016	Pickup truck, epoxy mixer, hand tools, generator	Epoxy, sand
Placing grout and setting precast parapets	2	8	160	.028	Clark crane, pickup truck, hand tools	Precast parapets, portland cement grout with nonshrink additive
Forming and placing steel and concrete in site-cast center strip	5	5	162	.029	Pickup truck, generator, hand tools, vibrator	Reinforcing steel, formwork, epoxy bonding compound, A4 H.E.S. concrete with nonshrink additive
TOTALS	34	-	1,165	0.205	—	—

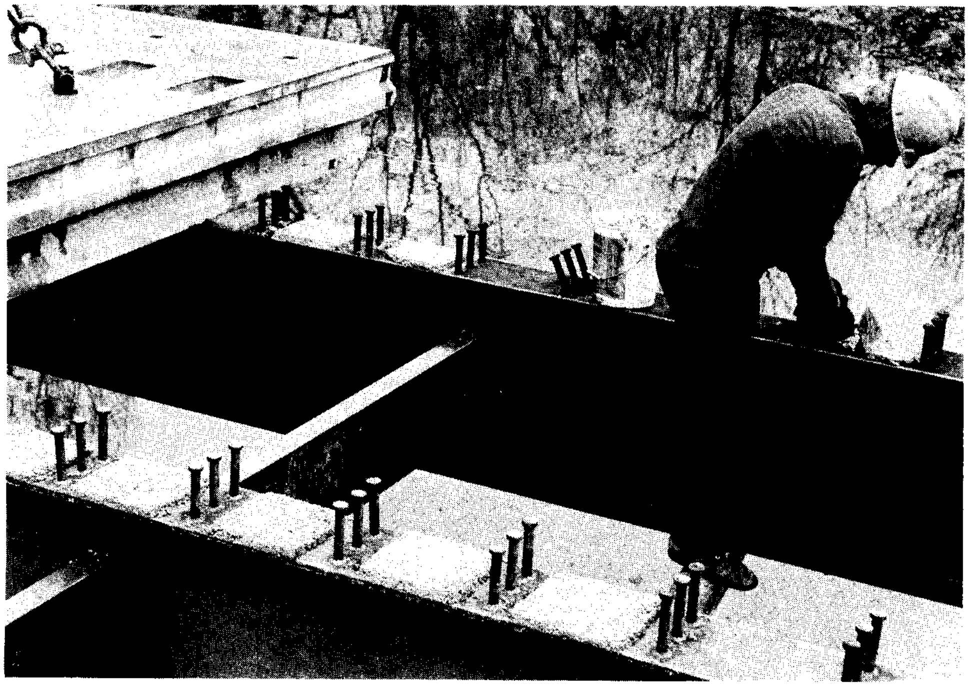


Figure 4. Epoxy mortar is placed on top flanges of stringers prior to setting the slabs.

Figure 5. Slab is lifted from trailer prior to being placed.

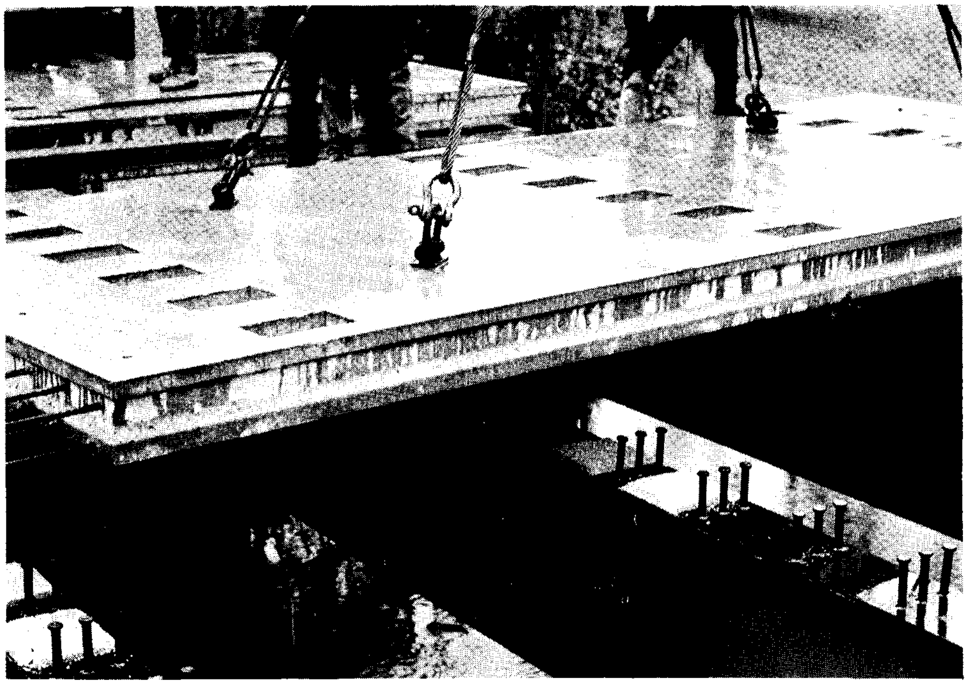


Figure 6. Slab is lowered onto stringers which are covered with epoxy mortar.

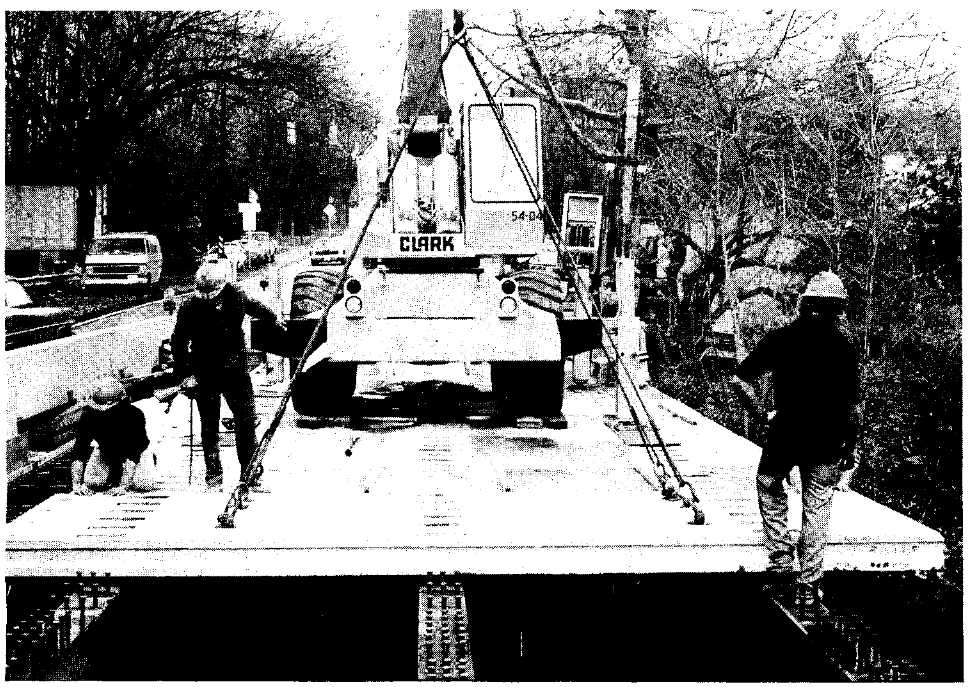


Figure 7. Slab is lowered to final position on stringers.

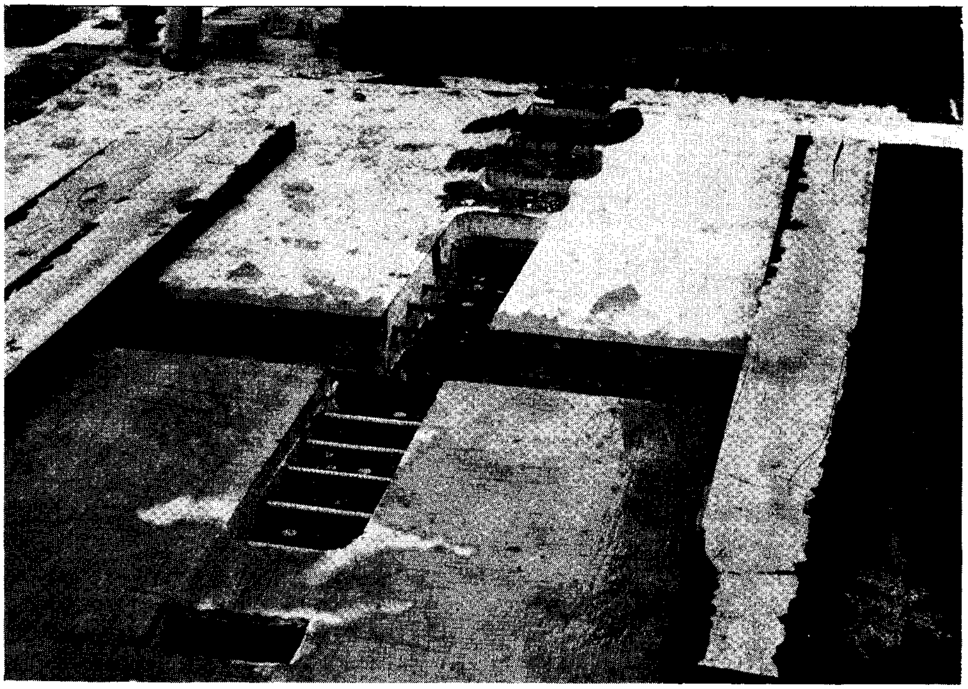


Figure 8. Timbers were used to prevent cracking of the end slabs as the crane was moved from one span to the next.

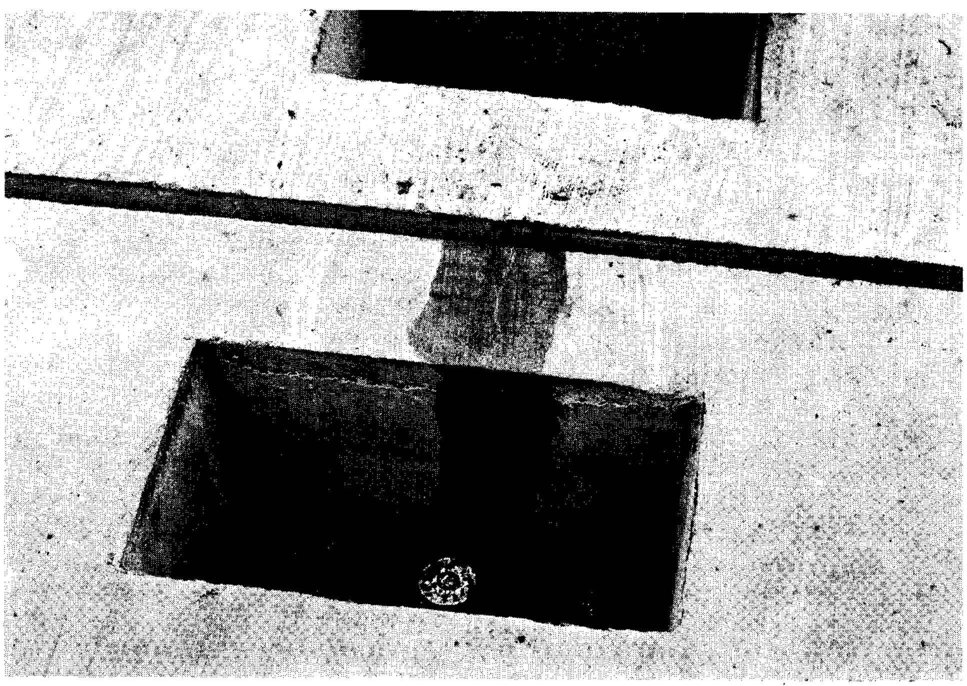


Figure 9. Hairline cracks found in some slabs were repaired with epoxy.

Following the installation of the precast parapets, the construction of the terminal walls, and the installation of the guardrail, traffic was turned onto the completed lane. The deck concrete on the downstream lane was removed and the twenty precast slabs were installed in the same way as the slabs on the upstream lane. The placing of the concrete in the 2 ft. wide center strip connected the slabs in the two traffic lanes. A bituminous concrete course 5 in. thick along the centerline and tapering to 1 in. thickness along the parapets was placed to provide drainage and to serve as a wearing surface.

COST

The chief engineer for Moore Brothers, Inc., the contractor, submitted a value engineering proposal in which he indicated he would construct the deck with conventional site-cast concrete for $57,000 as compared to the bid price of $68,193.50 for the experimental precast slab construction and thereby save the Department 16.4% of the bid price for the latter type construction.(13) However, the Department reviewed the proposal and estimated that the savings would be only 5.7% if the conventional construction was used.(14) The Department felt that the opportunity to evaluate the new type construction was worth the additional $3,913.50.

The contractor had bid the forty deck panels and the 13.3 $yd.^3$ of high early strength concrete required for the deck at a total cost of $62,583.50,(15) which is equivalent to $11.01 per $ft.^2$ of deck. For comparison, costs for alternative types of construction are shown in Table 3.(14,15,16,17) Obviously many factors must be considered when comparing the costs for the various types of decks. Factors which can have a major impact on the square foot costs for the deck are inflation, on-site construction time, total cost of project, variations in costs between counties, and the effect of the type of deck on the cost of the other components of the bridge. For example, a bituminous concrete overlay was specified for the bridge with precast deck slabs, whereas no overlay is used with conventional site-cast construction. However, there is little additional cost that can be attributed to the overlay since a premium price must be paid for the small amount of bituminous material that must be used on the approach spans of a conventional deck.(14) Similarly, when considering the relatively low cost of the SS6 timber deck construction reflected in Table 3, it must be remembered that the deck is not of the same quality as the other types. Furthermore, the costs of structural steel are approximately 50% greater (depending on span length) for the SS6 construction than for the other types and if the stringers must be purchased, their cost can more than offset the saving attributed to the use of the timber deck. Finally, personnel involved with the construction of the Rte. 235 bridge estimated that the bridge could be constructed in half as much time using the precast slabs as compared to conventional site-cast concrete. The data in Table 3 indicate that on-site construction time for the deck is longer than for glulam deck construction but shorter than for more conventional types such as site-cast concrete and timber plank deck construction.

Table 3

Installed Cost and Construction Time for Different Types of Bridge Decks

Type Deck	County	Route	Type Labor	Year	Total Deck Cost	Deck Cost/ft.^{2}	On-site Construction Time, man-hours/ft.^{2}
Precast concrete	Fairfax	235	Contract	1981	$62,583.50	$11.01	0.18
Site-cast concrete	Fairfax	235	Contract	1981	57,000.00*	10.03	—
Site-cast concrete	Northampton	603	Contract	1978	47,924.00	14.79	—
Site-cast concrete	Suffolk	13	State Force	1976	3,723.62	10.13	0.95
Site-cast concrete	Albemarle	231	State Force	1976	2,107.08	10.64	0.79
Glulam	Fairfax	641	Contract	1978	44,024.00	20.38	0.11
Glulam	Patrick	645	State Force	1978	18,570.17	12.75	0.15
Glulam	Henry	687	State Force	1978	15,704.53	13.13	0.16
SS6	Pittsylvania	686	State Force	1976	3,278.93	3.08	0.29
SS6	Nelson	662	State Force	1976	2,727.65	3.83	0.24

*Based on value engineering proposal submitted by contractor.

The cost of the inconvenience to the public due to prolonged on-site construction time should be considered when making decisions concerning deck replacement. Clearly, the information in Table 3 indicates that the use of precast concrete slabs for deck replacement is reasonably competitive with other alternatives.

PROBLEMS

Two problems were encountered during the construction of the bridge on Rte. 235 that were attributed to the use of the precast slabs. One consisted of cracks developing in the narrow area adjacent to the voids provided for the stud shear connectors in several of the end slabs (see Figure 9). The cracks were bad enough in two of the slabs that the units were rejected and in two others the cracked areas adjacent to the ends of the span were removed and new concrete was cast at the bridge site. Hairline cracks were repaired with epoxy.

The cracks formed during the handling of the slabs, and it is believed that the design of the slabs contributed to their tendency to crack. There was little concrete cover between the longitudinal reinforcing bars and the sides of the voids. Also the small concrete section in the vicinity of the voids could probably not withstand the tensile stress caused by transporting and handling the slabs. It is believed that the incidence of cracking could be reduced or eliminated by providing more cover over the longitudinal rebars and by changing the design of the end slabs so that they are identical to the interior slabs.

The second problem was only indirectly related to the use of the precast slabs. Most of the high early strength concrete used to fill the voids around the studs did not satisfy the strength requirements. The low strength was attributed to the addition of the Intraplast-N, an expanding grout aid, to the concrete. When added at the recommended dosage of 1% by weight of cement the 3-day strength was 1,900 psi and the 28-day strength was less than 4,000 psi. When used at a dosage of 0.5% by weight of cement the 7-day strength was 3,700 psi. The Virginia Department of Highways and Transportation's specifications for the project required the use of a shrinkage-compensating additive while achieving a 4,000 psi concrete strength in 3 days to expedite construction of the bridge.

The problem was caused by the incorrect use of the admixture, which is designed to be used in concrete that is to be confined. The concrete placed in the voids was not confined and therefore, was able to rise above the surface of the deck. The high void content concrete which was created was obviously low in strength.

It is believed that for future applications a cover could be placed over the void to confine the concrete and thereby maintain satisfactory strength while providing compensation for shrinkage.

Despite these two minor problems that can be alleviated in the future, the bridge has a pleasing appearance and excellent ride quality, and it is believed that it will perform as well as a conventional site-cast concrete deck. Similar precast concrete slabs will be used to replace the deck on the Woodrow Wilson Bridge in the near future. The experience in Virginia and elsewhere[3,4,5,6,7,8,10,18] suggests that for deck replacement the use of precast concrete slabs is an acceptable alternative to conventional site-cast concrete construction. Furthermore, it is believed that in some situations state forces could purchase or precast their own slabs and use them instead of timber for redecking operations on secondary roads.

CONCLUSION

Precast replacement slabs for bridge decks are a viable alternative to conventional site-cast concrete deck construction when full-depth deck replacement with a minimum of lane closure time is required.

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