

FINAL REPORT
AN INDUSTRIALIZED CONSTRUCTION APPROACH TO CONCRETE
SUPERSTRUCTURES FOR BRIDGES

by

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(A Cooperative Organization Sponsored Jointly by the Virginia
Department of Highways and the University of Virginia)

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SUMMARY

The objective of this study was to develop drawings for a specific site or sites that incorporated the best concepts of industrialized bridge superstructure construction, that is, great emphasis was placed upon the use of modular design and assembly line techniques in the prefabrication and assembly of the superstructure.

The final design featured a 3-span bridge (each span approximately 60 feet long) of eight foot wide or less prestressed box beams. Other experimental features included a totally precast concrete parapet, longitudinal glued joints (transverse posttensioning was available if glued joints failed), the absence of a field placed wearing surface (provisions were available to apply one later if necessary) and longitudinal posttensioning for continuity.

The bridge was advertised for bids in the fall of 1972, but it failed to receive an earnest bid.

A new study, with similar objectives and with the active participation of the Virginia Prestressed Concrete Association, is presently under way and showing considerable promise of achieving the stated objectives.

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INTRODUCTION

In the United States today there is much discussion of the concept called "systems building". This interest is due to the need for vast quantities of quickly constructed and economical urban housing and the belief of housing authorities that this need can be satisfied only through a systems building approach.

In the building construction concept, a systems building, systems approach, and industrialized construction are practically synonymous terms. A frequently used definition of systems building in the construction industry is that it is the "coordination of design, manufacture, site operations and overall financial and managerial administration into a disciplined method of building." In our industrialized society this means that the systems building approach to construction makes full use of modular design and assembly line techniques in the prefabrication and assembly of a structure. It also means extensive preplanning, engineering, and coordination of tasks. The systems building approach to construction means that vast amounts of time for making detailed decisions are invested once in the hope of recovering dividends through duplication on many individual projects.

In the work reported herein, the term "industrialized construction" has been used in lieu of the other mentioned terms to describe the work undertaken. It is felt that "industrialized construction" better describes the scope of the work reported, since the financial and managerial aspects of bridge superstructures are not included.

PURPOSE

The principal objective of this study was to develop drawings for a specific site or sites that incorporated the best concepts of industrialized bridge superstructure construction. Subordinate objectives of the study were as follows:

1. To develop a design to be prepared by an engineering consultant using a minimum number of components for the greatest amount of adaptability.
2. To limit this project to concrete superstructures; however, pier caps and abutment seats may possibly be included, depending upon the design developed. The remaining parts of the bridge would be conventionally built.
3. To develop a design that eliminates the need for cast-in-place concrete or a separately applied wearing surface.
4. To develop a design that incorporates a low first cost, a low maintenance cost, and a pleasing appearance.

BENEFITS

The potential advantages of using industrialized construction concepts in the bridge industry are essentially the same as those in the commercial building markets.

1. The usage of less skilled manpower is greater in plant manufacturing. The reasons for this are that the work is more repetitive and much of the skill needed for on-site construction is replaced in plants by machines.
2. The cost of construction is frequently reduced when the fabrication of components is industrialized into plant and machine production.
3. There is an increase in product quality as a result of more in-house fabrication, because quality control is better.
4. There will be a move in the direction of year-round construction since most on-site work would be of an erection and connection nature as opposed to handling, placing, and forming fresh concrete.
5. There would be a decrease in the time-consuming and costly decisions that are frequently necessary in site construction of bridges.

LITERATURE SURVEY

A number of agencies have sought means by which the on-site construction time of bridge building could be reduced. These efforts have ranged from precasting a particular item to almost total prefabrication of the structure.

The Bridge Division of the Texas Highway Department (1964) developed and is using precast prestressed panels to span between prestressed girders to serve both as a form for cast-in-place (CIP) concrete and as bottom reinforcing for the bridge deck. The CIP concrete bonds to the prestressed panel and beam to form a unitized deck. Structures incorporating these panels are reported to be performing well.

Salmons (1970) reported on the use of the prestressed concrete channels with an interior void used in conjunction with a monolithic top slab of CIP concrete. The configuration of this void is such that it performs as a two-hinged arch and it can be formed from corrugated metal, plywood or similar materials. Proposed for use on primary and secondary roadways, the design was found to perform structurally as concrete theory predicted, to be more economical than comparison structures, and to be most feasible in the thirty feet to eighty feet span range.

A study conducted at Purdue University (1968) used prestressed concrete panels four feet by six inches in cross section and, depending on the width of roadway, of any reasonable length. These panels were placed across steel beams and were posttensioned longitudinally. A sealing material was placed in the joints between the panels for sealing purposes and to reduce stress concentrations at the joint. The panels were fastened to the steel beams with steel clips bolted into an insert in a manner similar to that used in fastening rails to prestressed concrete ties. Field installations using these concepts are presently under study.

The United States Steel Corporation (1973) presents a design for short span bridges using steel stringers with precast concrete deck units placed in a transverse or longitudinal direction. Eighteen-inch gaps between the units are filled with CIP concrete. Using the transversely placed units, a bridge, reported to be very economical, has been built in Montgomery County, Alabama.

Mississippi and several other southern states are using a bridge designed and produced by the Choctaw Corporation of Memphis, Tennessee. Except for the pier stems, which are steel or sometimes timber, the components are all formed from precast or prestressed concrete. The precast deck sections are longitudinally placed channel members. These deck members, used without a wearing surface, rest on precast pier caps. Abutment wing walls are also of precast concrete. Spans normally used are 19, 31, or 45 feet, which permit a two or three span structure to be in use one week after the start of construction.

PROCEDURES

This study was originated under a working plan dated November 1970. There was a request in this working plan that the proposed project be funded by HPR funds, but this request was never granted by the FHWA and so the project was financed with state funds.

One of the first steps taken to initiate this project was that of forming an ad hoc advisory committee (this group later became a formal Council Research Advisory Committee). This ad hoc committee was composed of representatives from the Highway Department, the Research Council, the highway industry and a fabricator's group. A nationally recognized structural engineer, who was later engaged to develop conceptual designs, was also a member of this committee (see Appendix 1 for Committee Roster). The fabricator's group was composed of representatives from prestressing firms doing business in Virginia (see Appendix 2 for Group Roster). William M. Woody served as the fabricator's representative to the ad hoc advisory committee. The twofold purpose of the fabricator's group was to bring together the thinking of the prestressing industry on design features and to critique the designs that originated from the project. Two unusual features of the ad hoc advisory committee were that it contained members from industry and that through their representation their ideas and contributions were received at the earliest stages of planning.

The procedure used in arriving at a design for the first prototype superstructure was as follows. A number of superstructure designs used by other states, those solicited from the fabrication group and the Department's Bridge Division, and those developed at the Research Council were evaluated by each member of the advisory committee. Each member rated a group of selected factors by a numerical system in which the ratings ranged from outstanding (+3) to bad (-1). Considered were such features as structural safety, adaptability for different sites, cost of components, speed of construction, appearance, and transportability. The individual ratings were totaled and the design receiving the largest numerical total was judged to be the best (see Appendix 3 for the Rating System). Using the ratings as guides, the consulting engineer (Thomas A. Hanson & Associates) then prepared a report entitled "Systems Bridges - Phase I: Superstructure," April 1971. This report dealt with such factors as structural design, geometric features and safety, and included three alternate preliminary designs in incorporating the features considered by the committee to be desirable. The report, which fulfilled the consultant's contract, was received by the committee and the three alternate preliminary designs were rated by the committee. The design receiving the highest rating was adopted as the one to be fabricated for field installation. The preliminary details of this design are shown as Appendixes 4 and 5.

A site in Augusta County, Rt. 664 over the South River, was selected for the field installation. The experimental bridge was to replace a 2-span pony truss bridge built in 1914 (see Appendix 6). Negotiations with Hayes, Seay, Mattern & Mattern, consulting engineers of Roanoke, were then initiated for the preparation of the final design for the particular site. The final design, completed in August 1972, featured a 3-span bridge (each span approximately 60 feet long) of eight foot wide or less prestressed box beams. Other experimental features included a totally precast

concrete parapet, longitudinal glued joints (transverse posttensioning was available if glued joints failed), the absence of a field placed wearing surface (provisions were available to apply one later if necessary) and longitudinal posttensioning for continuity.

The beams rested on single-stem piers and featured a pier-cap beam connection whereby the tops of the pier caps and beams were of the same elevation such that the top surface of the cap was also a part of the deck riding surface. An elevation view of the bridge is shown in Figure 1 and a cross-sectional view of the superstructure is shown in Figure 2. The estimated cost of the experimental structure was about \$185,000. A breakdown of cost items is shown in Appendix 7.

It was roughly estimated that a more conventional type structure incorporating four foot wide prestressed box beams would cost about \$115,000. Of course, as is generally the case in developmental work, the fabrication of the original prototype is more costly than that of subsequent structures.

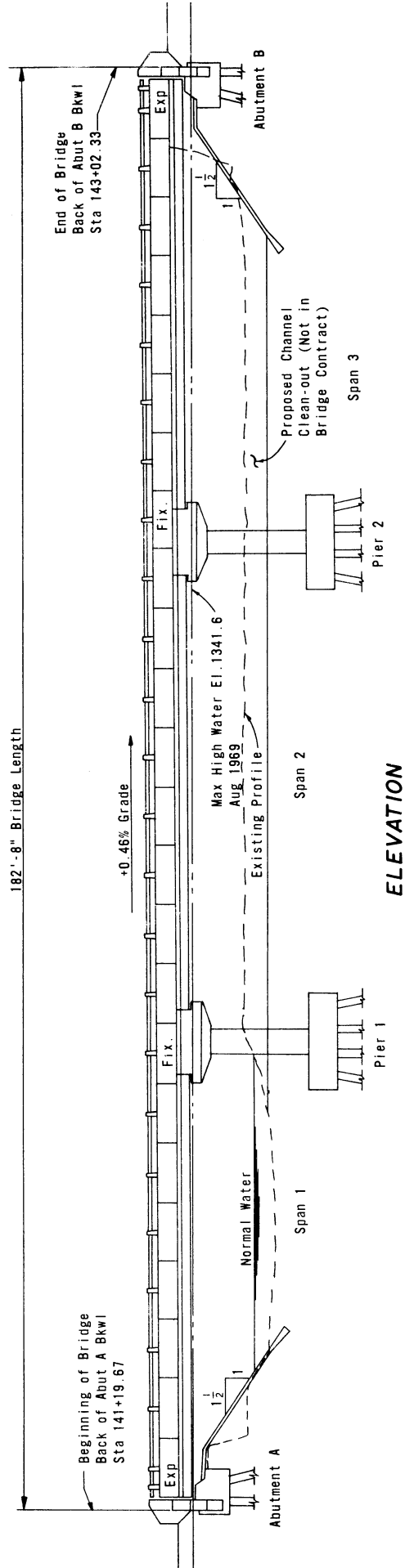
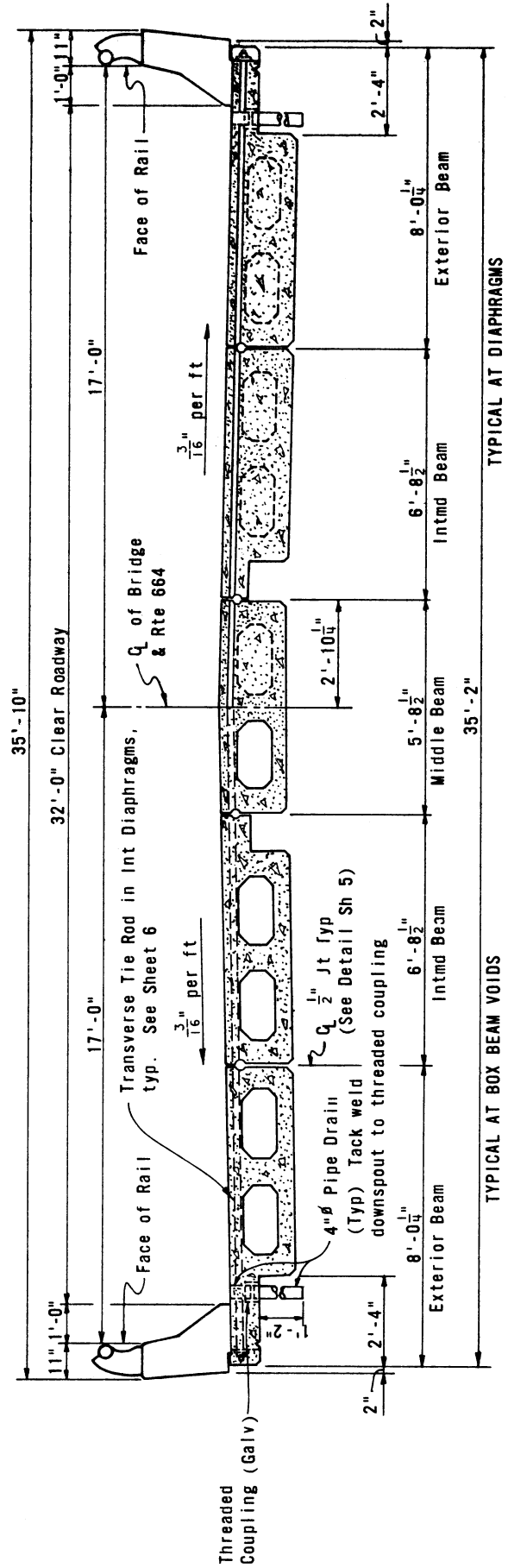


Figure 1. Elevation view of experimental bridge.



TYPICAL TRANSVERSE SECTION

Figure 2. Typical transverse section of experimental bridge.

RESULTS

The experimental bridge was advertised for bid in the fall of 1972. It was included in Project 0664-007-165, C501, B633, which contained road work and other incidentals. Only one bid was received on the project, and it considerably exceeded the Department's estimate. The bridge was the principal factor in the high bid. A check with the prestressing industry revealed that they had not presented an earnest quote to any general contractor for the superstructure elements. Thus, the contractor submitting the bid did not have well calculated costs for the bridge elements. The project, of course, was not awarded.

Two months later, in December 1972, a meeting with a number of prestressers revealed that they were wary of the deck units and failed to provide serious estimates because of their weight (approximately 65,000 to 67,000 pounds) and because of the prestresser's inability to accurately estimate the costs of experimental units under the strict enforcement of the Department's specifications. No special provisions were available for the units.

In February 1972, the Research Advisory Committee for Industrialized Construction (RACIC), formerly the ad hoc advisory committee, recommended that the Augusta County road project be relinquished as a site for an experimental bridge. The recommendation was accepted by the Secondary Roads Division and this thereby permitted the road project to become active again and to include a bridge of conventional design.

ESTABLISHMENT OF NEW STUDY

At the request of the Virginia Prestressed Concrete Association (VPCA), in the late spring of 1973 the RACIC met with their representatives to determine if the ideology of this study should be salvaged and, if so, to see if it could be developed around selected products common to the prestressing industry. It was decided that the objectives were worthy and a new study was then promptly undertaken by the VPCA and a report was presented to the RACIC in August of 1973. This report, entitled "New Approaches in Prestressed, Precast Concrete for Bridge Superstructure Construction in Virginia", was carefully studied by the RACIC and action was subsequently taken by the committee to field test one superstructure system (four alternatives were offered) on five bridges located in the Bristol and Salem Districts. These bridges are scheduled for advertisement in the fall of 1974. All matters pertaining to these bridges will be covered by a new study and file number.

REFERENCES

1. "Test of Precast Prestressed Concrete Bridge Deck Panels", Bridge Division, Texas Highway Department, 1964.
2. Salmons, J.R., "Study of a Proposed Precast-Prestressed Composite Bridge System", Missouri Cooperative Highway Research Program Report 69-2, May 1970.
3. Gutzwiller, M.J., R.H. Lee, and C.F. Scholer, 1968 Use of Precast, Prestressed Concrete for Bridge Decks (Feasibility Report—Phase I), Joint Highway Research Board Project, Engineering Experiment Station, Purdue University, Lafayette, Indiana.
4. United States Steel Corporation, Short Span Steel Bridges, September 1973.

MEMBERSHIP OF THE AD HOC ADVISORY COMMITTEE FOR INDUSTRIALIZED
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APPENDIX 2

FABRICATOR'S GROUP

Myers Van Buren
Bayshore Concrete Products, Inc.
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Alvin Schulze
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Richmond, Virginia

William W. Ross
Old Hickory Pipe Company
Bristol, Tennessee

R. D. Minnix
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Winchester, Virginia

Albert E. Rollins
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APPENDIX 3
PROPOSED DECISION CRITERIA FOR EVALUATION OF ALTERNATE CONCRETE SUPERSTRUCTURE DESIGNS

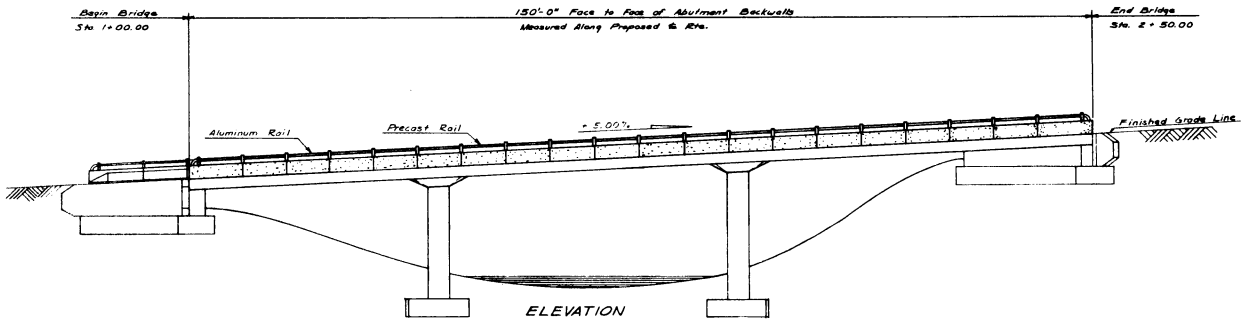
Factor	Value Modifier (VM)	Value Rating (VR)				Weighted Minimum Point Requirements (f)		
		Bad (-1)		Good (+2)			Outstanding (+3)	
		Bridge A	Bridge B	Bridge C	Bridge D			
Structural Safety (a)	5					10		
Adaptability for different sites and situations (b)	4					8		
Low cost of premade components (c)	3					6		
Low cost of on-site assembly of components	3					6		
Low cost of other on-site construction (including foundations)	3					6		
Low routine maintenance cost	3					3		
Speed of construction	2					2		
Appearance	2					2		
Quality of riding surface	2					2		
Minimal cost of forms required (d)	2					2		
Minimal number of different components	1					2		
Minimum special erection equipment required	1					2		
Transportability of components, forms, and erection equipment	1					2		
Ease of repair in case of damage	1					2		
Other unusual features (good or bad) (e)	1					2		
TOTAL WEIGHTED POINTS								

FOOTNOTES

- (a) Deck, rails, etc., safe under all standard loading conditions (including impact, flood, etc.)
- (b) As different spans, skews, widths, etc.
- (c) Based on fabrication of 30 similar bridges (not including cost of forms)
- (d) Based on reuse of forms 30 times
- (e) Limited to three such features
- (f) Weighted Points = VM x VR

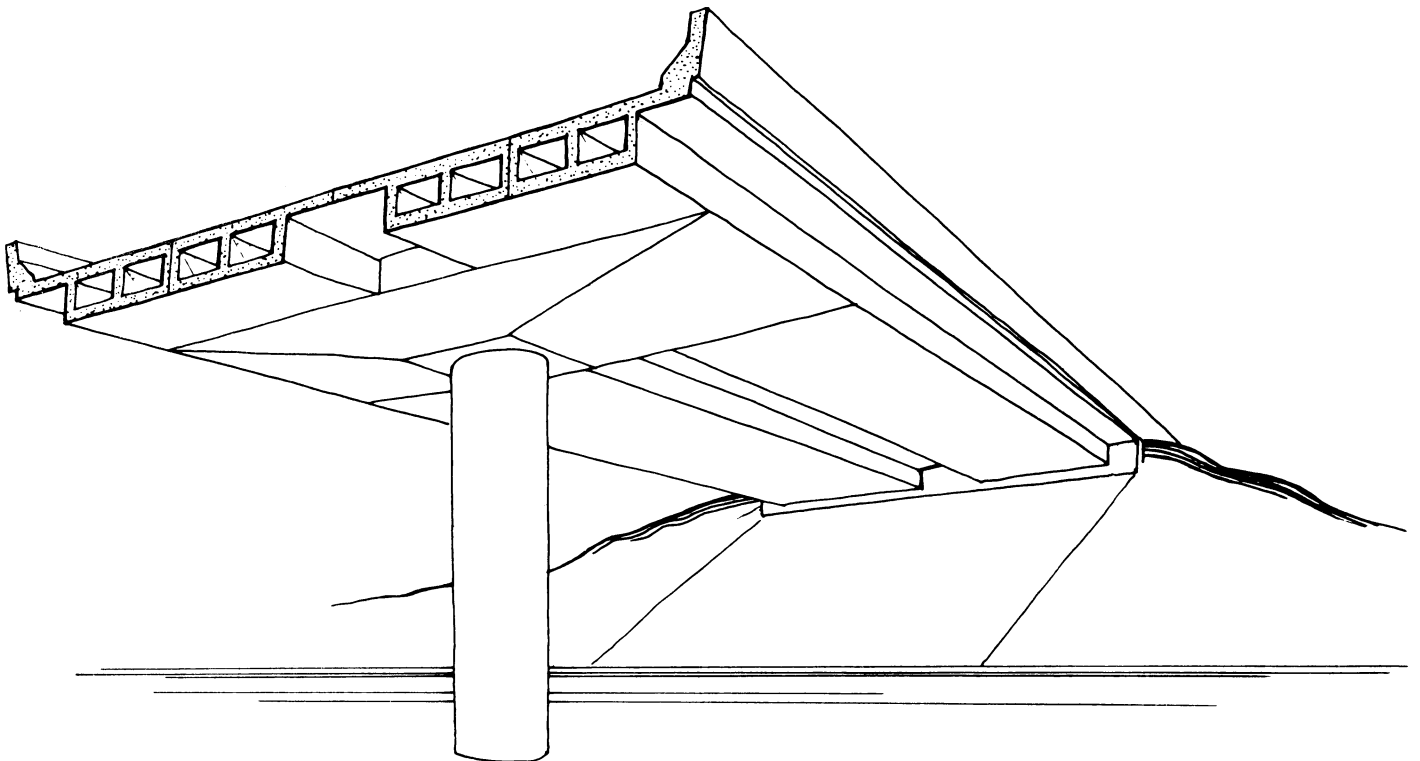
APPENDIX 4

ELEVATION VIEW OF PRELIMINARY BRIDGE DESIGN



APPENDIX 5

CROSS SECTION VIEW OF PRELIMINARY BRIDGE DESIGN



APPENDIX 6
SITE FOR EXPERIMENTAL BRIDGE



2385

APPENDIX 7

HAYES, SEAY, MATTERN & MATTERN
ARCHITECTS & ENGINEERS

QUANTITY & COST
ESTIMATE

PROJECT 0664-007-165, B633 COMM. NO. 3746
Route 664 over South River SHEET NO. 1 of 1
 LOCATION Augusta County DATE 26 July 1972
 SUMMARY BY RWF PRICES BY RWF CHECKED BY CAJ

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	UNIT COST	TOTAL
	Superstructure :				
	Precast Prestressed Concrete Box Beams:				
	Exterior Beams	Ea.	6	\$8,678.00	\$52,068.00
	Intermediate Beams	Ea.	6	7,261.00	43,566.00
	Middle Beams	Ea.	3	6,179.00	18,537.00
	Post-tensioned Prestressing	L.S.	1		11,000.00
	Precast Concrete Parapet	L.F.	360	15.00	5,400.00
	Bridge Railing	L.F.	360	9.00	3,240.00
	Superstructure Total				\$133,811.00
	Substructure :				
	Concrete, Class A4	C.Y.	84.2	130.00	\$10,946.00
	Concrete, Class A3	C.Y.	134.6	104.00	13,998.40
	Reinforcing Steel	lbs.	37,820	0.20	7,564.00
	Structure Excavation	C.Y.	447	12.00	5,364.00
	Steel Piles - HP10x42	L.F.	1,822	9.00	16,398.00
	Concrete Slab Riprap	S.Y.	439	15.00	6,585.00
	Substructure Total				\$60,855.40
	Total for Structure B633				\$194,666.40*
	Removal of Existing Structure	L.S.	1		\$20,000.00
	Total				\$214,666.40
	* Note: This figure is in error - it should read approximately \$185,000.00				