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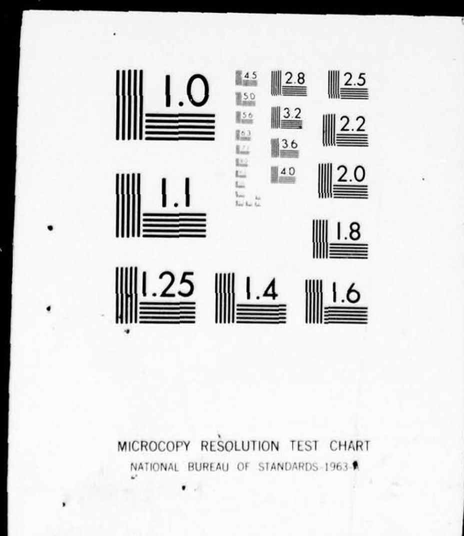

TECHNICAL REPORT C-78-1

PRECAST CONCRETE ELEMENTS FOR STRUCTURES IN SELECTED THEATERS OF OPERATIONS

by

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February 1978

Final Report

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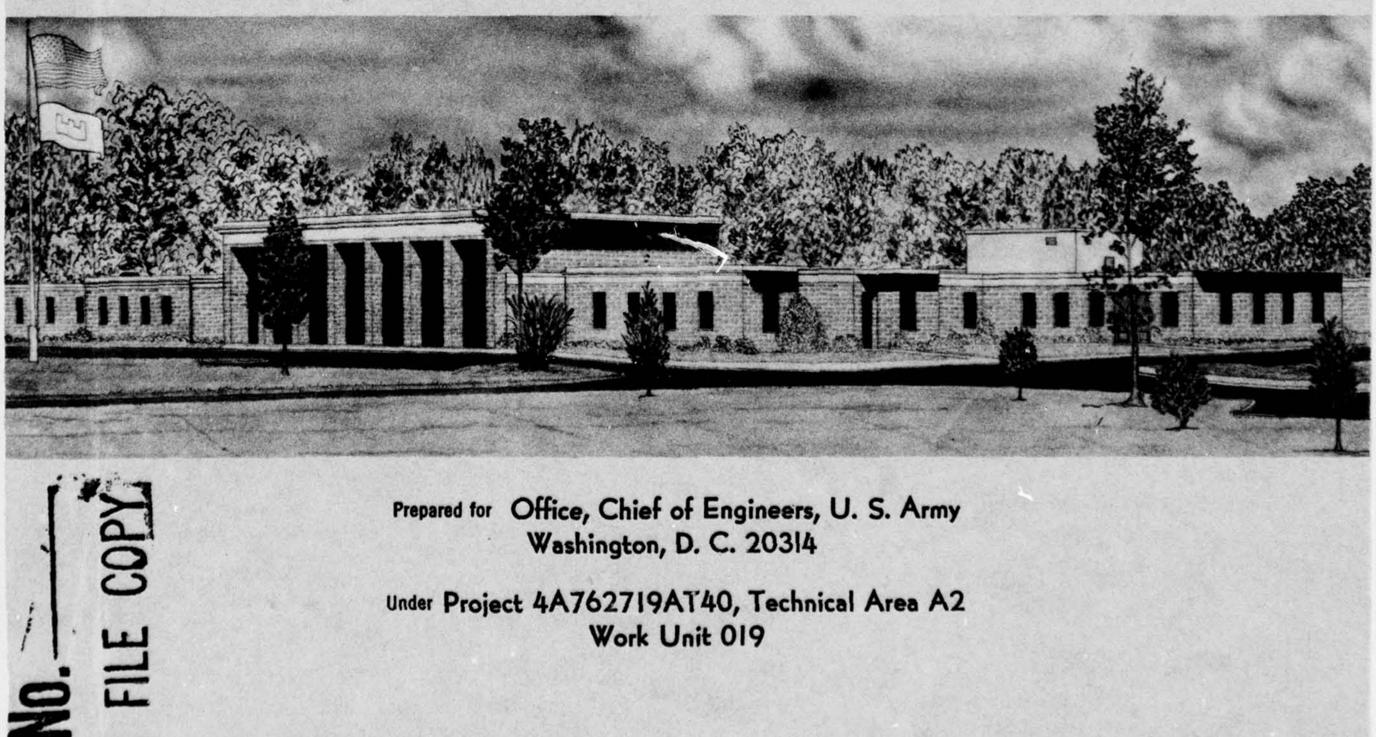

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

The current state of the art of design, fabrication, and erection techniques of various prefabricated elements for concrete structures are reviewed. Included are precast concrete highway bridges, logging bridges, railway bridges, piles, culverts, pipes, floating structures, and field fortifications. The structural properties, advantages, and disadvantages of various elements and systems are discussed. Engineering guidance on the fabrication, handling, → next page

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20. ABSTRACT (Continued).

storage, transportation, connection, and erection of precast concrete structural elements is provided.

Designs for two precast concrete military bridges capable of supporting military Heavy Equipment Transporters (HET's) are developed. These bridges can be easily transported to the construction site by existing military equipment and assembled with a minimum of time, labor, and equipment. A plan for the construction of a concrete precasting facility that will minimize the materials, manpower, and equipment necessary for mass production of the recommended precast concrete military bridges is formulated.

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PREFACE

The study reported herein was conducted by personnel of the Concrete Laboratory (CL) of the U. S. Army Engineer Waterways Experiment Station (WES) under the sponsorship of the Office, Chief of Engineers (OCE), U. S. Army, as a part of Project 4A762719AT40, "Mobility and Weapons Effects Technology"; Technical Area A2, "Lines of Communications and Mobility Engineering"; and Work Unit 019, "Prefabricated Elements for Concrete Structures." The OCE Technical Monitor was Mr. R. H. Barnard.

The study was conducted during the period February 1974 to September 1977 under the general supervision of Messrs. B. Mather, Chief of CL, and J. M. Scanlon, Chief of the Engineering Mechanics Division (EMD), and under the direct supervision of Mr. J. E. McDonald, Chief of the Structures Branch. This report was prepared by Mr. McDonald and Dr. T. C. Liu, EMD.

Directors of the WES during this study and the preparation and publication of this report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENTS

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	25.4	millimetres
feet	0.3048	metres
miles (U. S. statute)	1609.344	metres
square inches	6.4516	square centimetres
square feet	0.09290304	square metres
cubic inches	16.38706	cubic centimetres
cubic yards	0.7645549	cubic metres
pounds (mass)	0.4535924	kilograms
tons (short)	907.1847	kilograms
pounds (mass) per cubic inch	27.6799	grams per cubic centimetre
pounds (force)	4.448222	newtons
kips (force)	4.448222	kilonewtons
pounds (force) per square inch	0.006894757	megapascals
pounds (force) per square foot	47.88026	newtons per square metre
kips (force) per square inch	6.894757	megapascals
foot-pound-force	1.355818	joules
degrees (angle)	0.01745329	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins

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* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

PRECAST CONCRETE ELEMENTS FOR STRUCTURES IN SELECTED THEATERS OF OPERATIONS

PART I: INTRODUCTION

Background

1. Even though tactical concepts and combat techniques have changed over the centuries, the engineer support mission to the combat forces has not. The U. S. Army engineer's job is still to enhance the mobility of friendly forces while deterring the movement of the enemy.[1] How this support has been provided in the past has changed with improved engineering developments. As the technology of warfare advances, the engineer in combat becomes harder pressed to support the deployment, rapid movement, and supply of the Army ground forces. The highly mobile Army needs increased ability for rapidly constructing and maintaining lines of communication (LOC) facilities, such as roads, bridges, airfields, and heliports throughout the theater of operations (TO). The Volunteer Army, a smaller force with reduced engineering resources, will have a significant effect on such construction. This will require improved efficiency, better training, better equipment, and better organized and led troops.

2. Present capabilities in construction of LOC facilities are limited to very basic conventional techniques. In concrete construction, this means building timber forms, mixing, placing, and curing of plain and reinforced concrete, or the use of "stick" construction. These conventional techniques are both time-consuming and require extensive logistic support. The concept of establishing designated engineer units to construct prefabricated structural elements in support of LOC construction has not been generally exploited in modern warfare. In isolated instances, the concept has been given limited trials in support of simple bridge and culvert construction on major road building, or in association with depot construction. The designs employed, however,

have always been locally conceived, quite limited in application, and with a minimum of quality control. Ninety percent of the Engineer Construction Groups and Battalions responding to a questionnaire (Appendix A) indicated that concrete precasting operations have a place in Army Engineer TOE units. However, less than 40 percent indicated any prior experience with either fabrication or erection of precast concrete elements. Obviously, a need exists for a family of prefabricated structural elements to be field fabricated in the TO for use in the rapid construction and/or repair of bridges, culverts, retaining walls, loading docks, berthing and pier facilities, and other related structures and appurtenances for LOC facilities.

3. Military bridge construction in a TO is generally limited to structures of a semipermanent type with sufficient capacity to carry divisional loads. Standard fixed bridges, as referred to briefly in TM 5-312,[2] are stock items available for issue from Army supply centers, together with component parts, necessary for erection of the bridge. The term nonstandard is used to identify bridges constructed from raw materials and designed to satisfy the requirements of a particular site. The design, layout, and construction of nonstandard highway and railroad bridges normally constructed in a TO are covered in considerable detail in TM 5-312. However, the majority of the attention is directed to timber and steel as principal construction materials.

4. The physical characteristics and properties of concrete materials, the selection of concrete mixture proportions, the design and construction of forms, and the procedures for the construction of concrete structures are discussed in detail in TM 5-742.[3] Also, the use of reinforced concrete, including precasting, is discussed within the limitations to which this type of construction is considered a responsibility of engineer troops.

5. The primary shortfall for use of troop-constructed, prefabricated concrete elements, either plain, reinforced, or prestressed, is the lack of well-conceived facility designs and construction guidance permitting their employment. The solution to this problem appears to be well within the state of the art for prefabrication and use of precast concrete structural elements.

Objectives

6. The objectives of the program discussed herein were to develop operational guidance, engineering criteria, and specific structural design for the prefabrication and effective use of standardized precast concrete structural elements for use in a wide variety of fixed, deliberate structures associated with TO facilities.

Scope

7. Literature was reviewed and consultations were held with prefabricators and erectors to determine:

a. The state of the art of present prefabricated structural techniques.

b. The structural properties, advantages, and disadvantages of the various systems and elements.

Materials, component configuration, structural efficiency, fabrication facilities, and erection equipment required were considered in this review. Based on this review, a plan is formulated for the construction of a central concrete precasting facility that will minimize the materials, manpower, and equipment necessary for mass production of selected structural elements, which can (a) be easily transported to the construction site by existing military equipment and (b) assembled with a minimum of time, labor, and equipment into a variety of functional structures.

PART II: PRECAST CONCRETE

Definition

8. The term "precast concrete" is used to describe products made of concrete under factory conditions either in a permanent factory or in a temporary casting yard on a construction site and erected on site as finished structural members.

9. The range of precast concrete structural members in common use is very wide, e.g., bridges, piles, culverts, pipes, and floating concrete marine structures. Prestressed concrete is especially well adapted to precasting techniques.

Advantages

10. Compared with on site concrete construction some of the advantages of precast concrete are as follows:[4]

- a. Construction will be more rapid, and the structure is available for use in a shorter space of time.
- b. Generally there will be a reduction in site costs as scaffolding and other temporary supports will not be needed in such quantities (if at all) as for on site concrete work.
- c. There will be considerably less on site concrete work, thus reducing the demand for local site labor and the import of local raw materials.
- d. Casting in precasting factories is usually unimpeded by adverse weather conditions.
- e. Units can be made by mass production methods. Molds can be made to a precision not possible on site, and more intricate work can be carried out. However, since such molds are expensive to make, a considerable amount of repetition in the design is necessary for their use to be economical.
- f. Units can be made to a good, even excellent, standard due to the use of a trained and specialized labor force working under factory conditions; also, units may be cast in the most favorable orientation to simplify shuttering and to obtain improved finishes on the most important faces of the units.

g. Factory sites are usually selected considering the availability of labor, the ready supply of good quality aggregates, and other materials.

h. The finished product can be inspected before it is erected and can be rejected for any substandard work before incorporation in the structure.

i. Certain structures, if required, can be dismantled and re-erected elsewhere.

Disadvantages

11. The disadvantages of precast concrete are summarized as follows:[4]

a. Skill is required to design and detail a joint that can be easily formed on site while at the same time providing the necessary strength.

b. Some additional reinforcement and fittings may be required for handling, transporting, and erection. It has to be appreciated that a precast concrete member must be designed not only to function as part of a total structure but also to withstand the stress conditions pertaining to handling, transport, and erection.

c. If a large number of units are required or if they are large in size, problems can arise concerning storage areas, transportation, and erection costs.

d. Precasting tends to be less suitable for structures with irregular features. To obtain the greatest economy from precision molds, there should be a high degree of repetition.

e. The size and weight of precast concrete units must be restricted as they all have to be lifted and placed in position by some means. The lifting capacity and range of cranes available can govern the size and weight of the units.

PART III: CONCRETE BRIDGE STRUCTURES

12. Precast concrete construction provides a rapid and economical method for erecting new bridges and for repairing or replacing existing structures. This is possible because precast construction eliminates most falsework and shoring at the bridge site and requires only a small erection crew. Precast construction is particularly advantageous in isolated places where labor and materials are not readily available. This is particularly true of those designs that require no cast-in-place concrete.

13. Highway bridges involving varying degrees of precast construction form the majority of those described in this report, just as they form the majority of the bridges being constructed. However, railway and logging bridges and elevated urban highways are also reviewed in a limited manner. An attempt was made to obtain a representative cross section of bridge types; however, considering the large field, many important structures have necessarily been omitted from discussion.

Highway Bridges

14. By far the greatest percentage of highway bridge superstructures encountered in American practice is of simple span, precast, prestressed girder, and cast-in-place deck slab construction (Figure 1). The precast concrete industry produces a variety of precast shapes for bridge construction including I-sections, slabs (solid and hollow), channels, boxes, and tees. These sections may be of reinforced, pretensioned, or posttensioned concrete or combinations of these types. While each section has inherent advantages, availability and local economic factors, as well as span length, often significantly influence the final selection of a particular section. While the majority of bridges discussed herein are of prestressed concrete, some reinforced concrete bridges will be included since they are likely to be more economical for very short spans. Some typical plans for precast concrete highway bridges are given in Appendix G.

15. It is difficult to classify highway bridges according to span

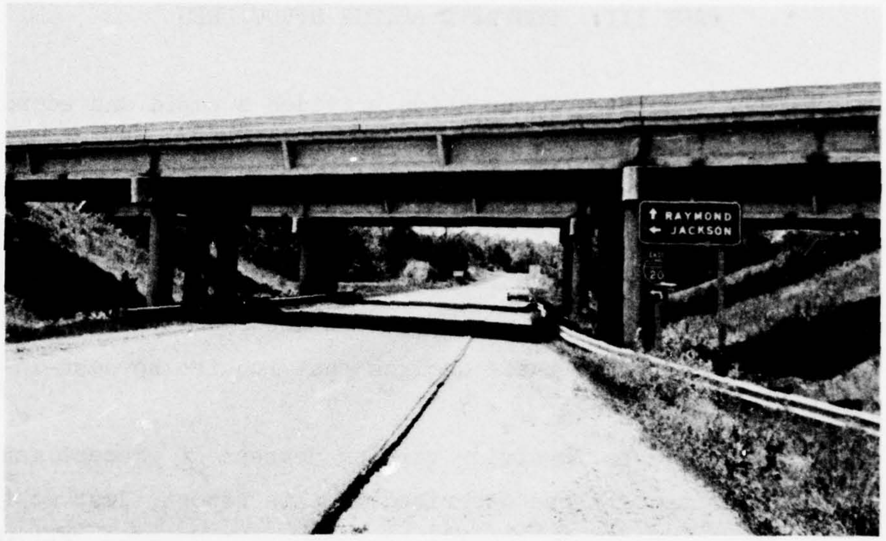

Figure 1. Typical prestressed concrete bridge

lengths since there is no definite line of demarcation between short, moderate, and long spans. For example, Libby[5] arbitrarily assumes short-span bridges to have a maximum span of 45 ft,* whereas Gerwick[6] considers bridge spans up to 140 ft as short spans. Therefore, for the purposes of this discussion, the more common types of bridge structures will be classified according to the type of precast element used.

Precast slab bridges

16. Prestressed solid slab elements are generally economical for use on spans up to about 30 ft. Such pretensioned elements are usually precast 3 to 4 ft wide with shear keys cast in the sides (Figure 2). After erection and grouting of the longitudinal shear keys, the slabs are topped with a wearing surface and leveling course. This topping can be a bituminous material or portland cement concrete.

17. Prestressed hollow-core slabs (Figure 2) are used in bridges with spans approximately 30 to 80 ft. Such slabs generally have either round or square voids. The elements may be precast in any desirable depth and width; however, a depth up to about 30 in. and a width of 3 ft are most common. Similar to solid slabs, grouted shear keys are used,

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is given on page 5.

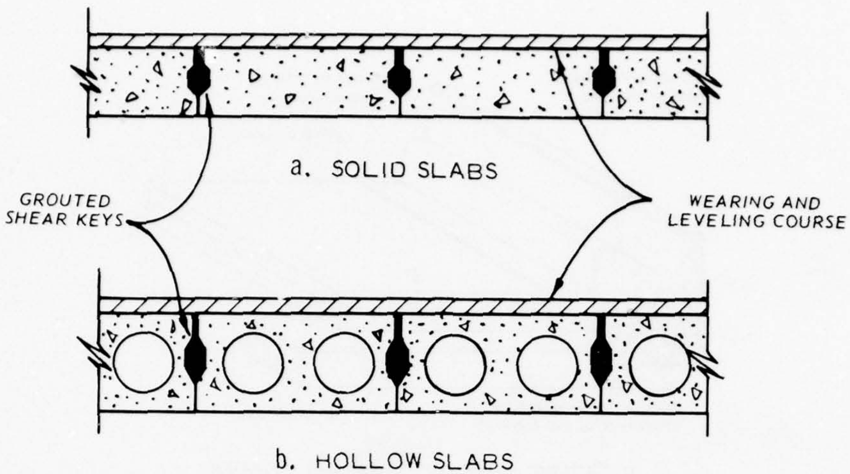


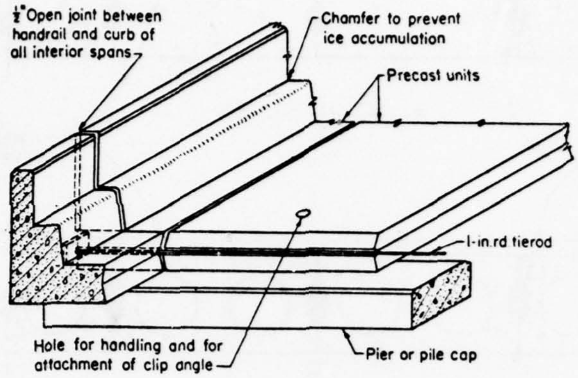
Figure 2. Typical sections of pretensioned slab bridges

and some type of leveling course is normally required.

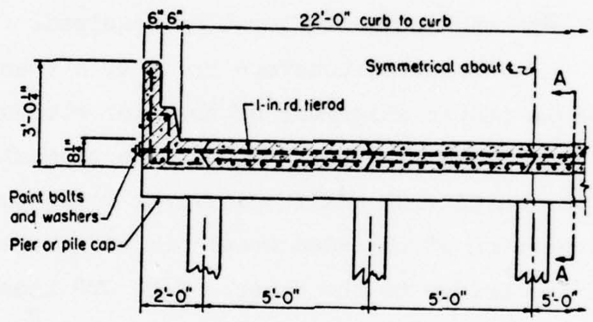
18. As in the reinforced concrete bridges, a transverse tie is required to maintain proper alignment of the slab elements and ensure proper distribution of the live load between the elements. Slab elements are frequently fabricated with small transverse holes through the elements to allow insertion of threaded steel tie bars normally extending from one side of the bridge to the other. Nuts are then placed and tightened at each end of the tie bar. Occasionally, the transverse tie consists of a posttensioning tendon that is placed, stressed, and grouted after the slabs are erected.

19. Construction advantages of slab bridges include very simple details and formwork that are applicable to and favor plant fabrication methods. Precast elements are normally placed by mobile cranes, and since no falsework is required, time and personnel required for field erection are at a minimum.

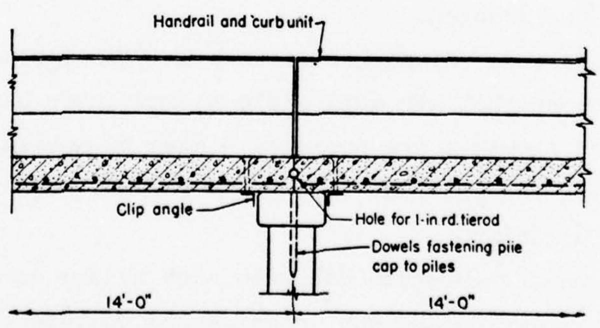
20. A precast reinforced concrete slab bridge developed by the South Carolina Highway Department[7] requires no cast-in-place concrete, an important consideration in some situations. Four 5-ft-wide interior units and two 2-ft-wide exterior curb and handrail units are used to obtain a 22-ft roadway, curb to curb. Spans up to 14 ft have been built with an 8-1/4-in. slab thickness (Figure 3), and for this case, interior



a. Cutaway View of Curb and Interior Sections at Support



b. Transverse Section



c. Section A-A at Support

Figure 3. Precast concrete slab bridge developed by the South Carolina Highway Department (courtesy of Portland Cement Association[7])

and exterior units each weigh 7200 and 6300 lb, respectively. One complete span of the bridge deck is cast at once but is separated for handling purposes into individual units by longitudinal dividing strips of 10-gage sheet metal bent in a <shape. The units are erected at the bridge site in the same relative positions they occupy in the casting yard so that the joints fit closely and provide satisfactory lateral transfer of shear. Obviously, this method of precasting does not provide interchangeability of parts.

21. When all units are in position at a pier, a 1-in. steel rod is inserted through the transverse holes (Figure 3), and the threaded rod ends are tightened to tie the entire roadway together. This figure also shows that the slab units are connected to precast concrete pile caps with dowels.

22. Figure 4 illustrates a design developed by the Nebraska State Highway Department in which the individual slabs are formed with hollow cores to provide a reduction in weight. Each unit has two cylindrical hollow cores that extend through its entire length and cause approximate reductions of 35 percent in the cross-sectional area but only 10 percent in the moment of inertia of the concrete section.[7] The 16-ft span, precast reinforced concrete bridge design is based on American Association of State Highway Officials (AASHO)[8] H15-44 loading (Appendix B). The deck consists of seven precast units, each 1 ft 6-1/2 in. deep. Outside units are 3 ft 3 in. wide; interior units are 3 ft wide with each weighing approximately 7300 lb.

23. Shear keys and transverse tie rods are provided for lateral distribution of superimposed loads. One tie rod is located at midspan, and the other two are approximately 6 ft either side of midspans. Slab units are connected to concrete pile caps through welding of the reinforcement and use of cast-in-place concrete (Figure 4).

<u>Precast channel bridges</u>

24. Precast units of channel-shaped sections have been used extensively for short-span bridges to obtain greater strength with a minimum of dead weight.[7] Channel girders (Figure 5), both reinforced and prestressed, are being widely used in various parts of the country,

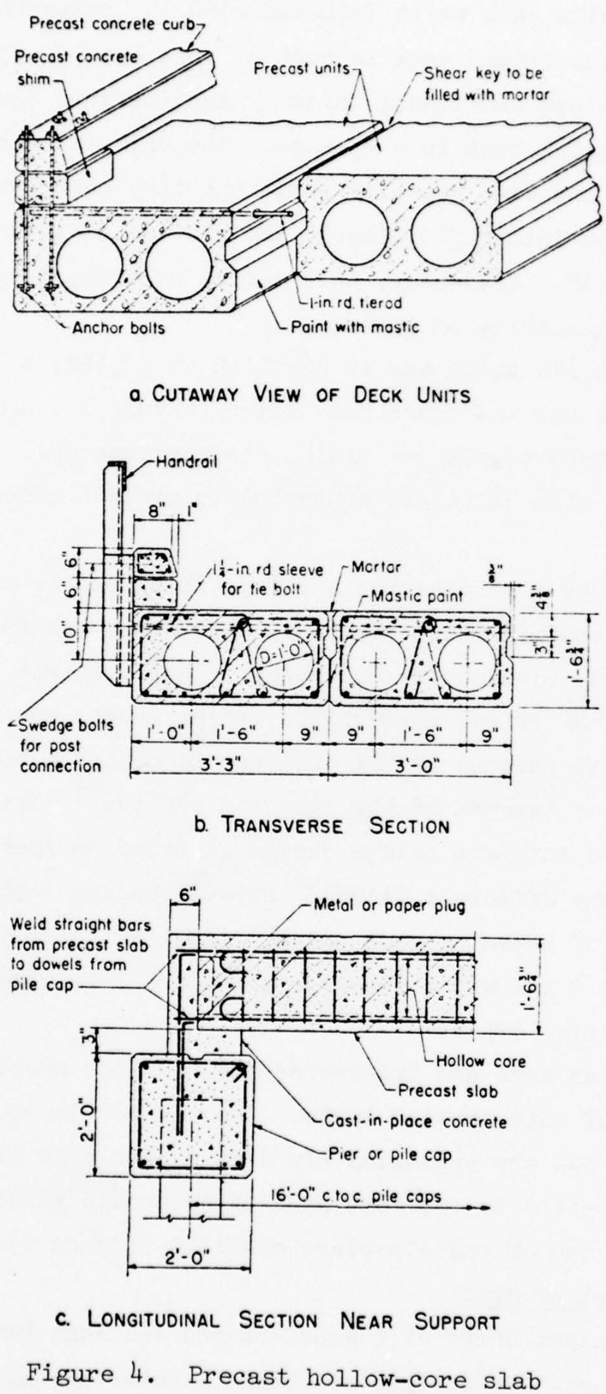


Figure 4. Precast hollow-core slab bridge developed by the Nebraska Highway Department (courtesy of Portland Cement Association[7])

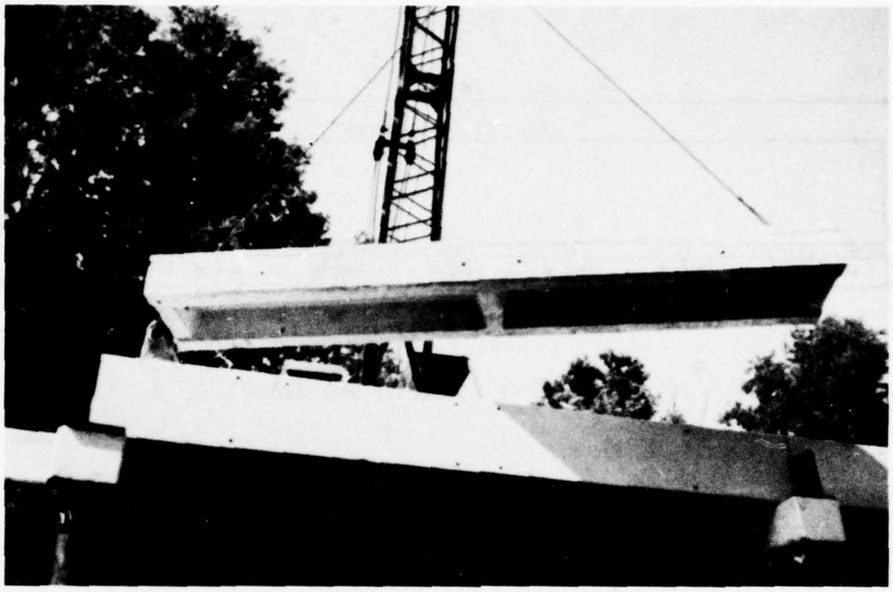
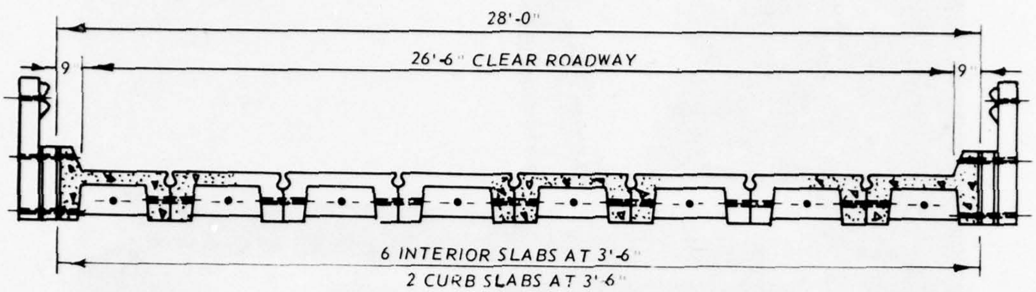


Figure 5. Precast channel girder

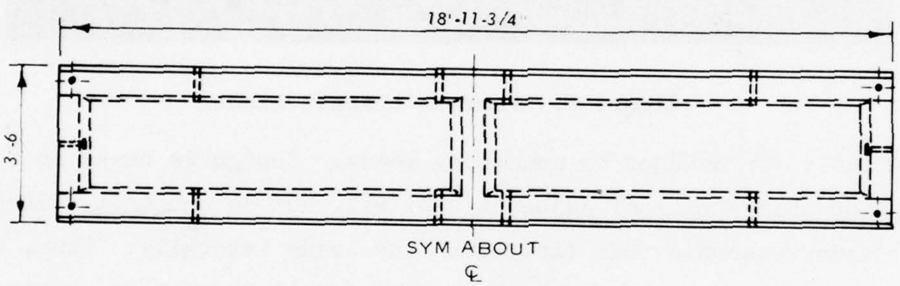
particularly for bridges on secondary roads. Design is based on the assumption that a pair of adjacent ribs will act as one unit. Shear keys and/or transverse tie rods distribute the loads laterally. Thus, the load carried by each element is less than a full wheel load, making possible an economical design with no sacrifice of rigidity.

25. The State Aid Division of the Mississippi State Highway Department (MSHD) makes extensive use of precast reinforced concrete channel girders for a 19-ft span bridge. This reinforced concrete bridge is designed for AASHO[8] loading H15-44 with a 26-ft 6-in. clear roadway (Figures 6-8). This superstructure is designed for use with timber or steel piling, and not only the channels but also all elements of the superstructure are precast.

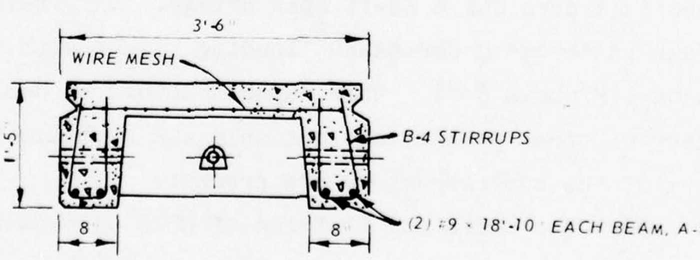
26. The State Aid Division of MSHD also uses a similar channel section of precast, prestressed concrete designed according to AASHO loading H15-44 for a 31-ft span (Figures 9-11). Two 1-in. stressteel tendons in each leg of the channel are used for prestressing. After the concrete has reached a minimum strength of 3,000 psi, a prestressing force of 60,000 lb is applied to the two top tendons only for handling



a. CROSS SECTION OF ROADWAY



b. PLAN INTERIOR UNIT



c. INTERIOR UNIT CROSS SECTION

Figure 6. Precast reinforced concrete channel girders for 19-ft span

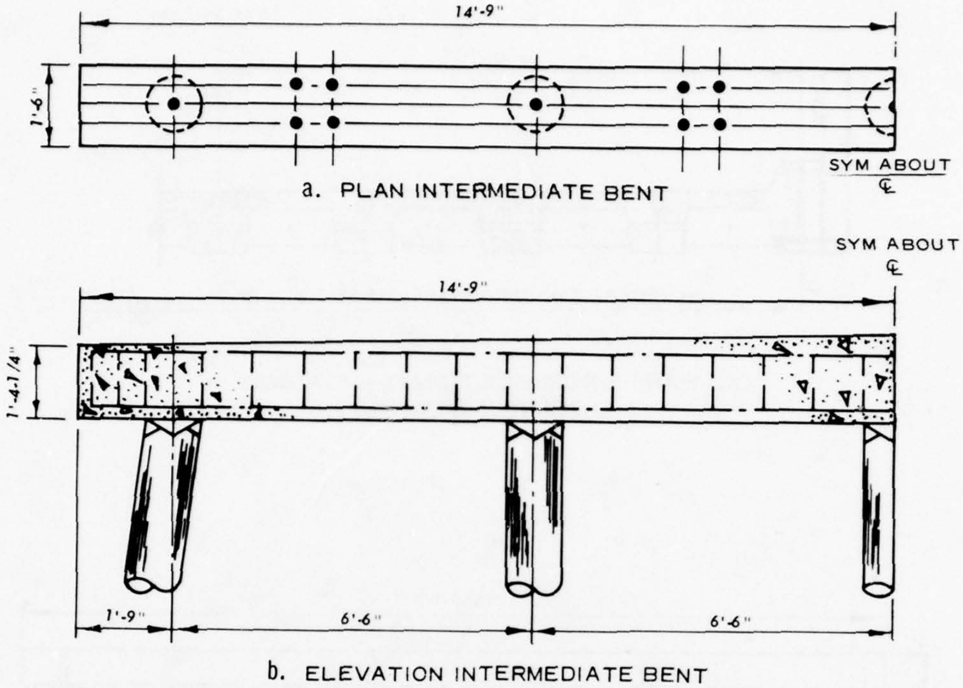


Figure 7. Precast pile cap for 19-ft span of reinforced concrete

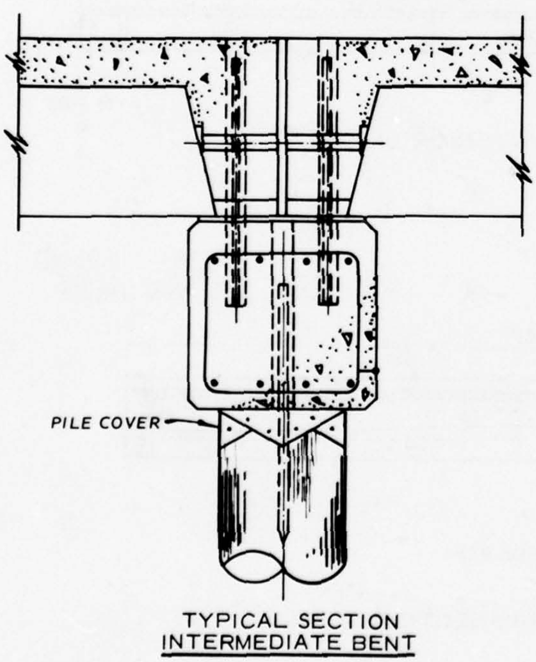
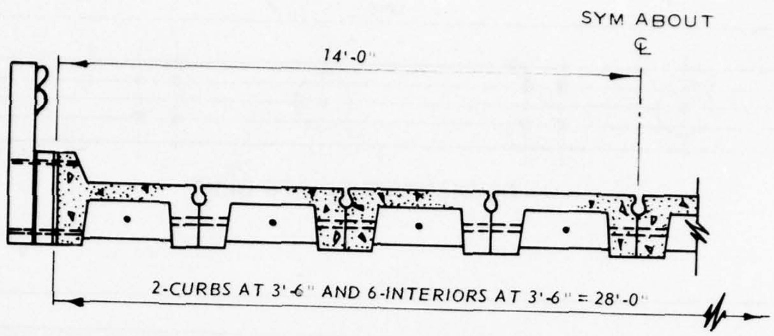
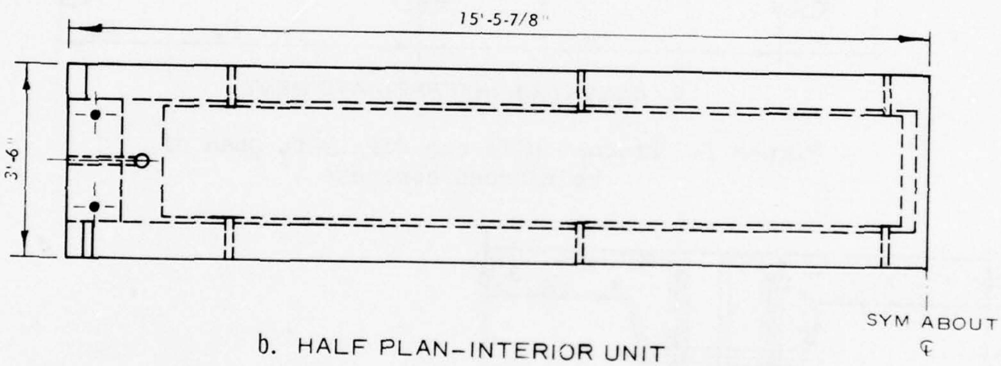


Figure 8. Connection details for 19-ft span of precast reinforced concrete



a. PART CROSS SECTION OF ROADWAY
SHOWING ASSEMBLY



b. HALF PLAN–INTERIOR UNIT

c. LONGITUDINAL SECTION

Figure 9. Precast, prestressed concrete girders for 31-ft span

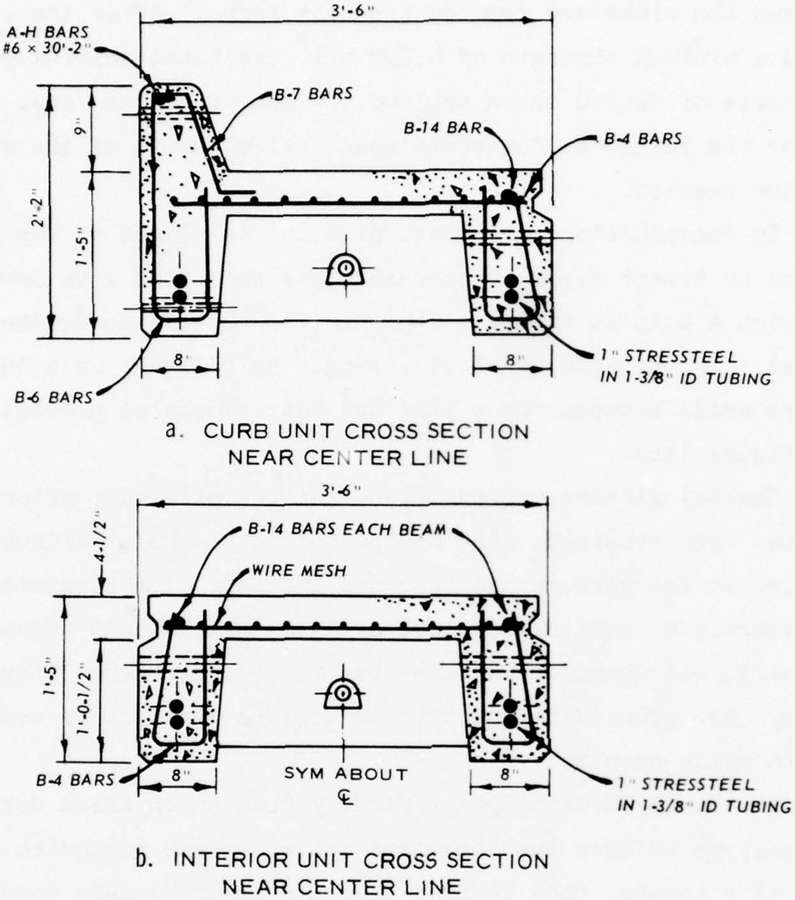


Figure 10. Girder details for 31-ft span

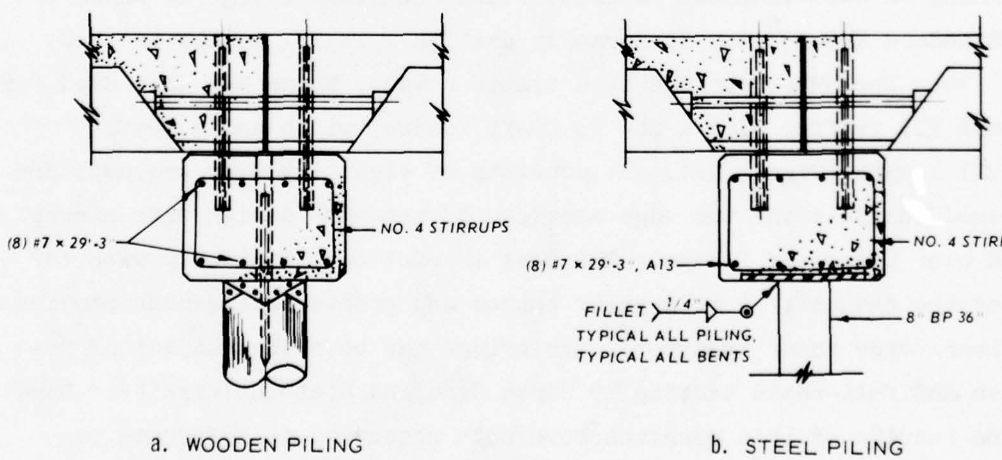


Figure 11. Connection details for 31-ft span of precast, prestressed concrete

purposes, and the slabs are removed from the forms. After the concrete has reached a minimum strength of 4,200 psi, the total initial prestressing force of 90,700 lb is applied to each of the tendons. As was the case for the reinforced concrete span, all elements of the superstructure are precast.

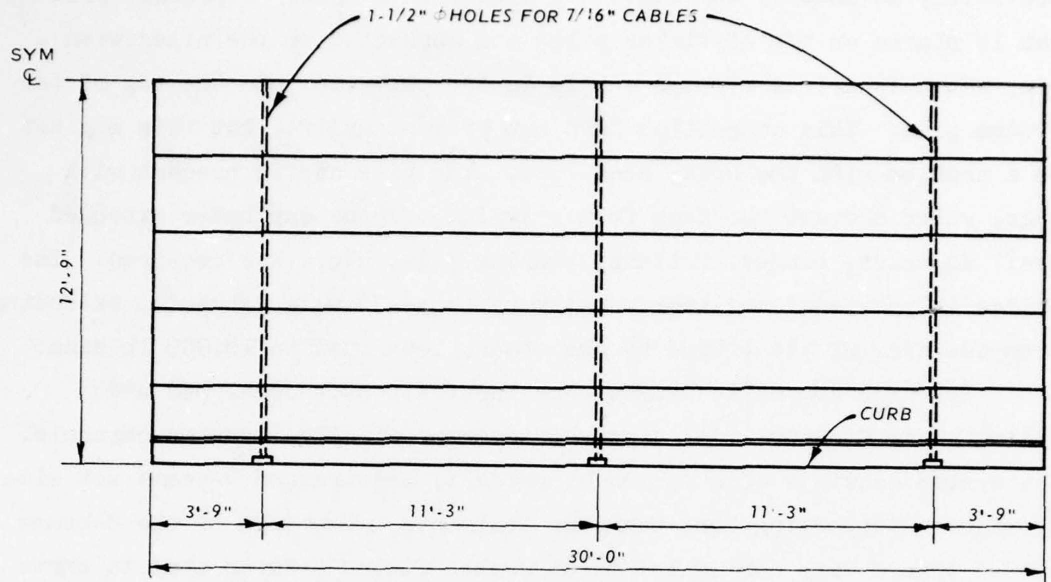
27. In construction, a precast pile cap is placed on top of either steel or timber piles and connected to the piles with dowel pins driven through a hole in the pile cap into the top of the wooden piling (Figure 11a). In the case of steel piling, the pile cap is connected using fillet welds between the piling and bearing plates precast in the pile cap (Figure 11b).

28. Channel girders are positioned on the pile cap; after proper alignment has been obtained, pins are placed in the holes (Figure 11), and all holes in the girders and caps are grouted. The elements are tied transversely by bolting the legs of adjacent channels together. Longitudinally, all channel ends are also bolted together. After bolting, all keys are grouted before traffic use; no leveling or wearing course is normally required.

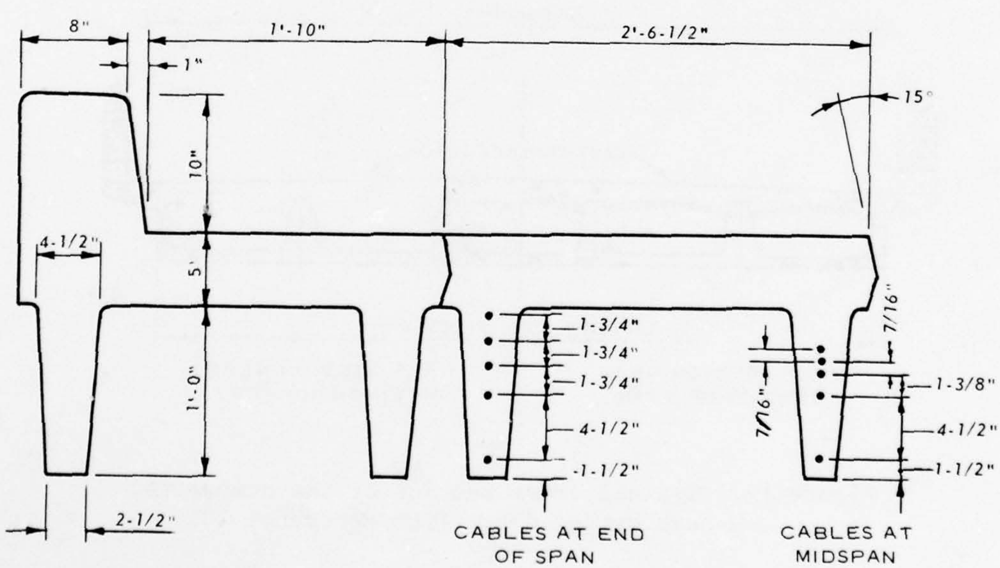
29. The North Carolina State Highway Commission tried several precast channel type bridges that required cast-in-place composite concrete. After several attempts, they decided that for their "county road" bridge, they needed a type of bridge that could be installed anywhere without depending on cast-in-place concrete. The resultant bridge is known as the Standard BMD-13[9] and is normally cast on a 14-in. double-tee bed.

30. The BMD-13 bridge is a simple bridge, which has been used for H10 and H15 traffic with a 24- to 29-ft roadway width and a 30-ft overall length (Figure 12). It consists of eight interior precast, prestressed channels and two edge sections of the same design with a curb added over the outer flange. The deck is cast monolithically with the web of the channel. A triangular tongue and groove arrangement provides for transverse shear transfer. The bridge has been the subject of research and full-scale testing by North Carolina State University. Some of the results of this research have been presented in Reference 9.

31. Connection details are less sophisticated than those shown



a. Plan



b. Partial section

Figure 12. North Carolina channel girder bridge

previously as used by the State Aid Division of MSHD. A precast pile cap is placed on top of timber piles and connected to the piles with a pin, which is driven through a hole in the pile cap into the top of the wooden pile. This connection does not prevent uplift, but this may not be a problem with the heavy dead load. The pile cap is precast with lugs, which prevent the deck from crawling off the cap under extended use. No welds, hinges, rollers, bearing pads, etc., are required. The bridge is posttensioned transversely by three 7/16-in. strands, extending from one side of the bridge to the other, tensioned to 18,900 lb each.

32. The composite U-beam construction system developed and evaluated in Missouri[10,11] uses what are essentially inverted channels. The system consists of a series of precast, prestressed U-beams set side by side on supporting bent beams or abutments. The legs of the U-beams extend upward with corrugated metal arches fitted between them to serve as stay-in-place forms for the cast-in-place top slab. The resulting bridge deck is very similar to a multicell box superstructure. Figure 13 presents a typical cross section of the composite U-beam bridge

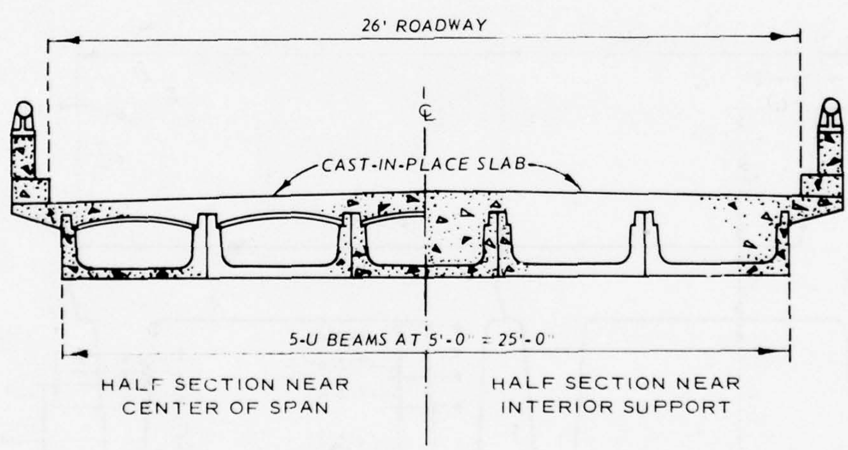
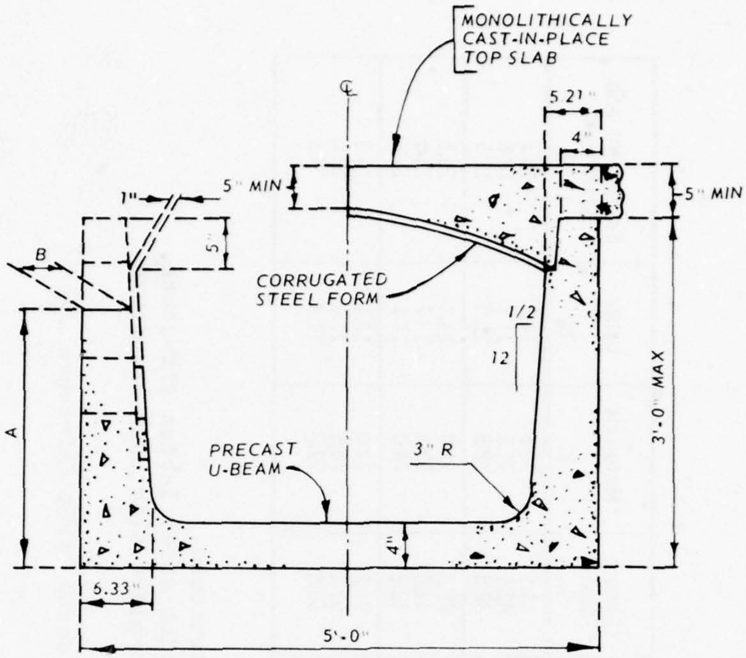


Figure 13. Typical cross section of the composite U-beam bridge deck (from Reference 10)

deck. The variation in beam depth (Figure 14) will accommodate AASHO HS20-44 loading over a span range of approximately 30 to 80 ft depending upon the thickness of the cast-in-place top slab.



A	20"	24"	28"	32"	36"
B	4.67"	4.50"	4.33"	4.16"	4.00"

Figure 14. U-beam dimensions and details (from Reference 10)

33. Estimated costs of the U-beam system were compared with actual costs of three typical bridge structures selected to give a representative range of span length and to consider the most common types of bridge superstructures used for shorter spans in the Missouri highway system. From the prices listed in Figure 15, it can be seen that for the shorter span bridges, A-2141 and A-2039, the cost of the original superstructures exceeds the average estimated cost of the U-beam system by 10 and 13 percent, respectively. However, the estimated average cost of the U-beam system for bridge A-2416 is about 21 percent less than the actual cost of the original voided slab superstructure. Therefore, the U-beam system would appear to have an economic advantage for medium-span ranges.

Bridge		Cost of superstructure			Savings	U-beam cost	Materials	Labor	Equipment and overhead
		Proposed system		Actual bridge					
		Total	$/sq.ft.	$/sq.ft.	$/sq.ft.	%	%	%	%
A-2141	High	$19,882.40	6.83	7.38	.55	41.8	70.6	14.3	15.1
	Average	19,284.23	6.63	7.38	.75	42.1	71.5	14.7	13.8
	Low	18,760.58	6.45	7.38	.93	42.5	72.5	15.0	12.5
A-2039	High	24,820.91	7.44	8.22	.78	41.5	71.6	13.3	15.1
	Average	23,956.68	7.18	8.22	1.04	41.8	72.8	13.7	13.5
	Low	23,156.60	6.94	8.22	1.28	42.2	74.0	14.1	11.9
A-2416	High	58,756.60	8.74	10.33	1.59	51.2	74.0	10.7	15.3
	Average	54,376.58	8.12	10.33	2.21	52.1	76.6	11.0	12.4
	Low	50,088.78	7.51	10.33	2.82	52.8	79.2	11.3	9.5

A-2141: Three equal spans (34 ft) of precast slab structure.
A-2039: Three span (35, 43, 35 ft) continuous composite steel I-beam structure.
A-2416: Four span (43, 70, 70, 43 ft) voided cast-in-place slab deck structure.

Figure 15. Summary of superstructure costs (from Reference 10)

34. Channel stringers with a depth of 3 ft 5 in. were effectively used to span 95 ft on the Ardrossan[12] grade separation structure in Alberta, Canada. The 38-ft-wide bridge is designed to carry HS20 loading across spans of 103 ft. The center support (Figure 16) is a two-leg

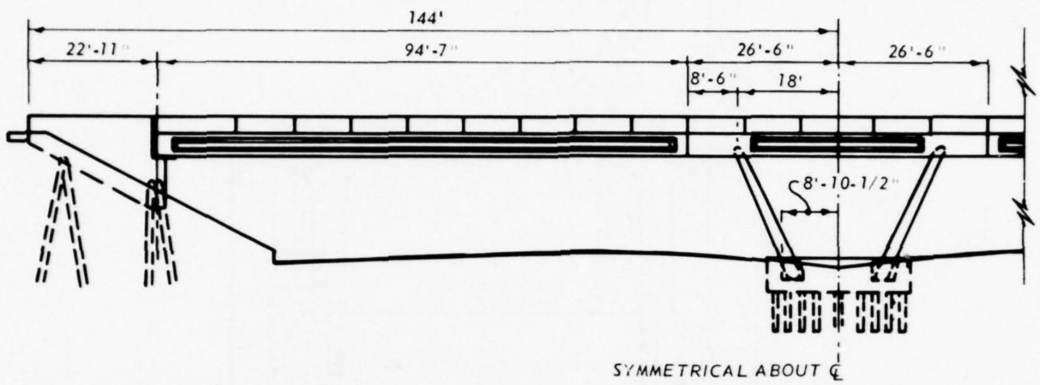


Figure 16. Ardrossan grade separation structure (from Reference 12)

frame that carries a 53-ft section. Legs taper from 18 ft apart in a common footing to 36 ft at stringers, which cantilever 8 ft 6 in. each way. The precast, conventionally reinforced pier legs were set in prepared pockets (Figure 17) and supported by cables while the center section stringers were placed and adjusted. The pockets were then filled with grout. The channel stringers (Figure 18) were set on neoprene pads on the cast-in-place fixed abutments and attached to the cantilevered ends of the center stringers by Cazaly hangers. The concrete of the stringers forms the deck of the bridge and is topped with 2 in. of asphalt wearing surface.

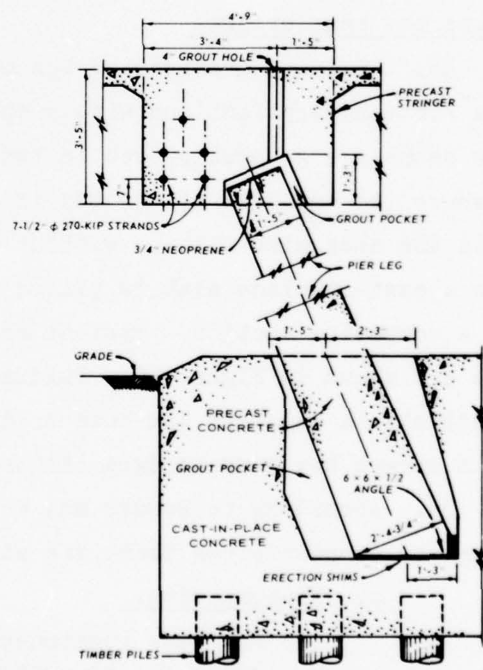


Figure 17. Center pier details (from Reference 12)

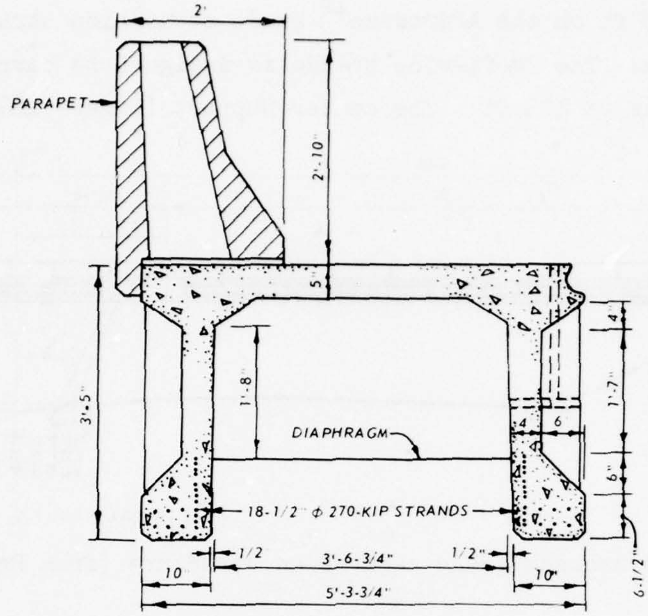


Figure 18. Channel stringer details (from Reference 12)

Precast box beam bridges

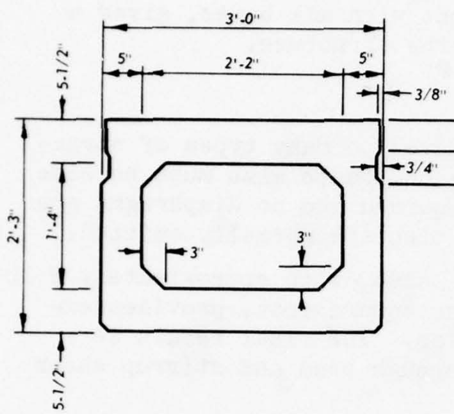
35. Precast, prestressed box beams have been accepted by engineers for many applications with a span range of 20 to 120 ft.[13,14] These beams are generally used in two basic types of highway structures, one where the top slab at the box is designed to carry full wheel loads and is the deck slab with or without a wearing surface, and the other where a cast-in-place slab is placed integrally with the beams to provide a composite section. Typical cross sections for the two types of beams are shown in Figure 19. Initially, box beams were used almost exclusively in adjacent box beam bridges; however, they have also found use in spread box beam bridges (Figure 20).

36. According to Bender and Kriesel[13] the advantages of noncomposite and composite box beams are as follows:

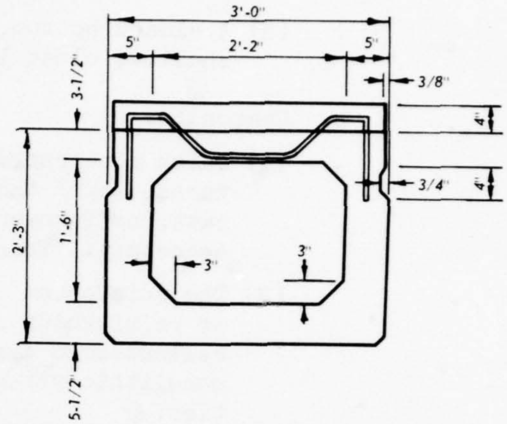
a. Noncomposite.

(1) Far less construction time is required; therefore, roads can be opened to traffic quickly.

(2) Less field labor, supervision, and inspection are required.

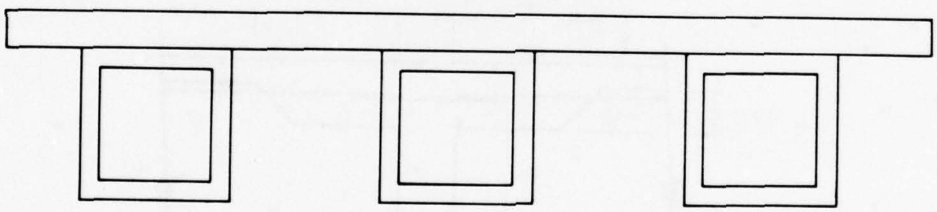


a. Noncomposite box beam

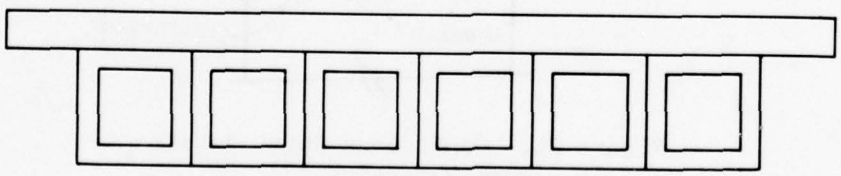


b. Composite box beam

Figure 19. Typical cross sections for box beams (from Reference 13)



a. Spread box



b. Adjacent box

Figure 20. Box beam bridge configuration

(3) An excellent depth-to-span ratio provides more clearance or more waterway opening than most other bridge types.

(4) Good load distribution is achieved through the grouted keyways.

(5) A closed bottom, inherent with all boxes, gives a shallow, clean look to the structure.

b. Composite.

(1) Quick construction compared to many types of structures. Even though the composite slab must be site cast, no formwork is required and no diaphragms are necessary. Transverse ties are normally omitted.

(2) The reinforced concrete slab, with approximately 2 lb of reinforcing steel per square foot, provides excellent load distribution. The final result is a monolithic structure through bond and stirrup shear ties.

(3) Continuity can be achieved, as illustrated in Figure 21, often resulting in further depth reduction, and always providing a closed joint over piers.

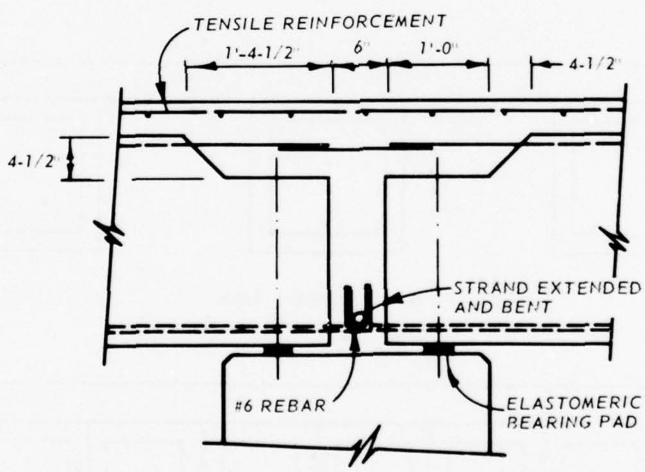


Figure 21. Continuous joint detail (from Reference 13)

37. The alignment of a portion of Interstate Highway 87 through Connecticut traverses a swamp containing very soft peat and organic silts approximately 60 ft in depth and 3000 ft in length.[15] Normal construction procedures, such as removal and replacement of the unsuitable

material or use of sand drains, were not considered practical. Therefore, it was proposed that the swamp be crossed on a low-level, modular structure, which could be assembled rapidly and also serve as a work platform for pile driving and erection equipment while it was being built. Precast piles, pile caps, abutments, and prestressed concrete box beams overlain with a 4-in. mesh reinforced concrete wearing surface (Figure 22) were selected for preliminary design. Span lengths of 50 ft

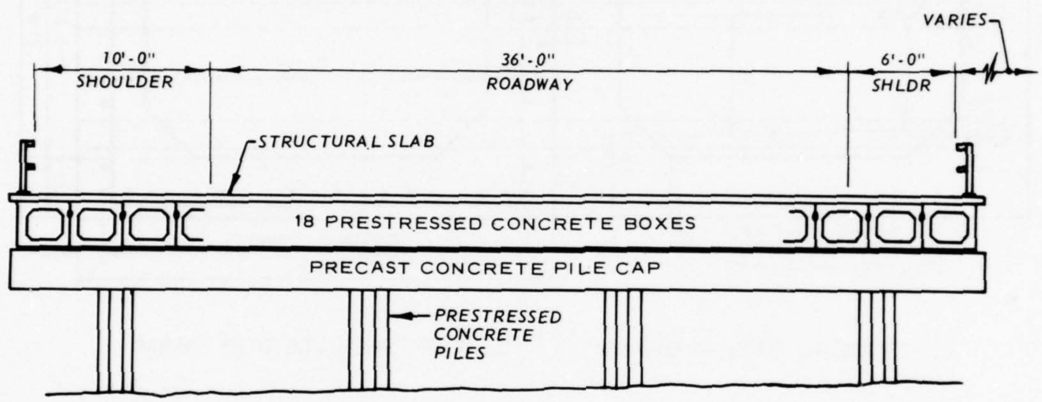


Figure 22. Typical section of I-87 roadway looking south
(from Reference 15)

were determined by using the loading diagram for a crane, which weighed 434,000 lb with an 80-ft beam. Proceeding with a normal design for HS20 loading (Figure 23) indicated the need for a deeper box section or a composite section. Since a 4-in. concrete wearing surface was already planned, the addition of reinforcing steel made it a structural slab. The composite action between the box girders and slab was achieved by using an epoxy-polysulfide bonding compound.

38. Increased unsupported pile lengths that were encountered during construction made it necessary to distribute the horizontal forces over five bents by making the superstructure continuous over four spans. Continuity was achieved through cast-in-place concrete diaphragms at the fixed piers (Figure 24) and with the addition of steel bars in the structural slabs of each fixed pier.

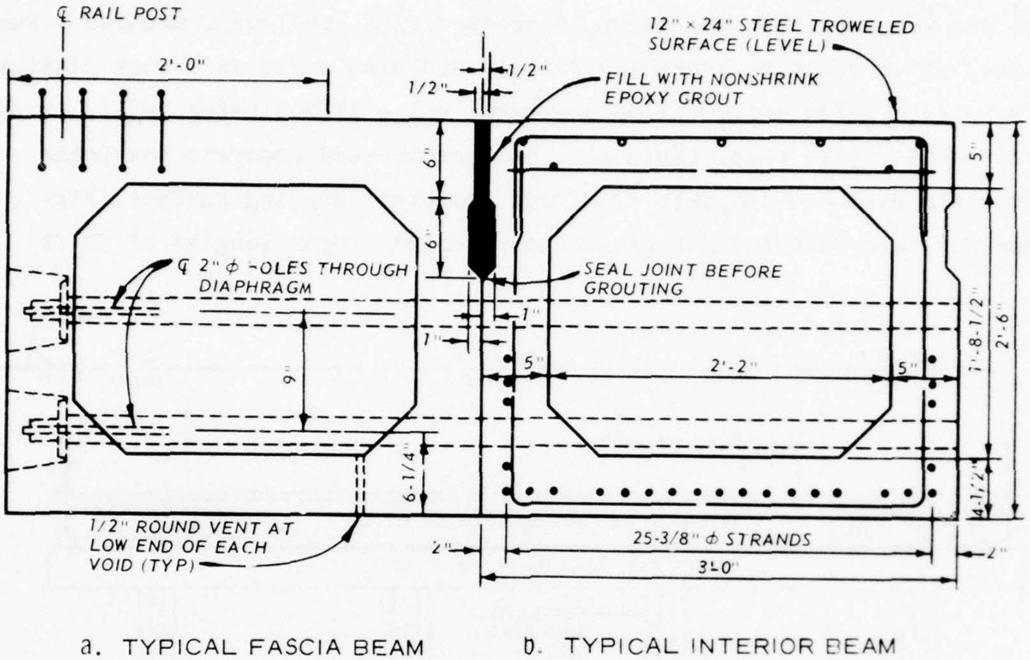


Figure 23. Prestressed box girder sections (from Reference 15)

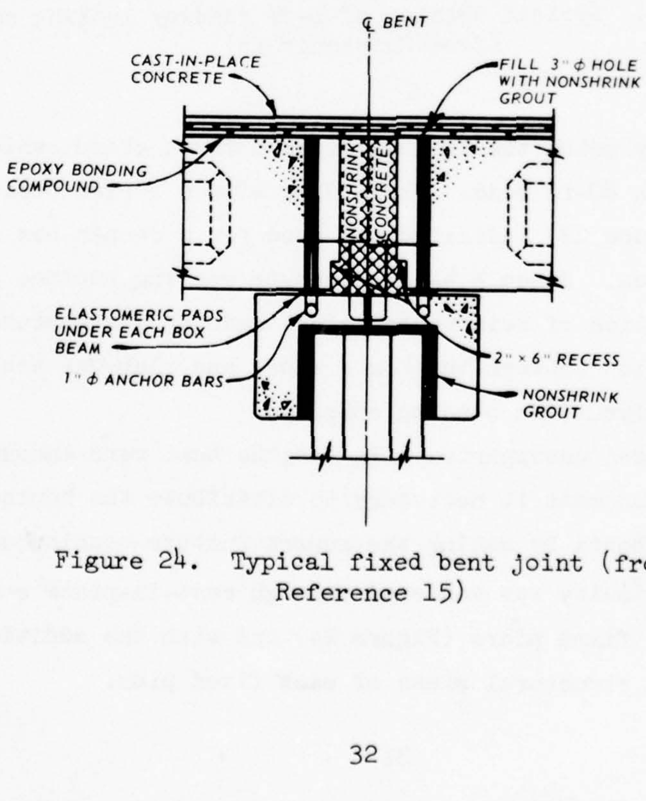


Figure 24. Typical fixed bent joint (from Reference 15)

Rectangular-girder bridges

39. The deck of the Baker River Bridge in Washington is composed of precast slabs and precast beams integrated by cast-in-place longitudinal joints.[7] A modification of the design used for this bridge is shown in Figure 25. The design loading of HS20-44 was used for the 26-ft loading and multiple 25-ft spans supported by pile bents. The superstructure is entirely precast reinforced concrete with the exception of the concrete required in the joints.

40. The precast reinforced concrete beams are designed as simply supported, rectangular beams for dead load and as T-beams for live load. These beam units weigh approximately 6300 lb each and are 10 in. wide,

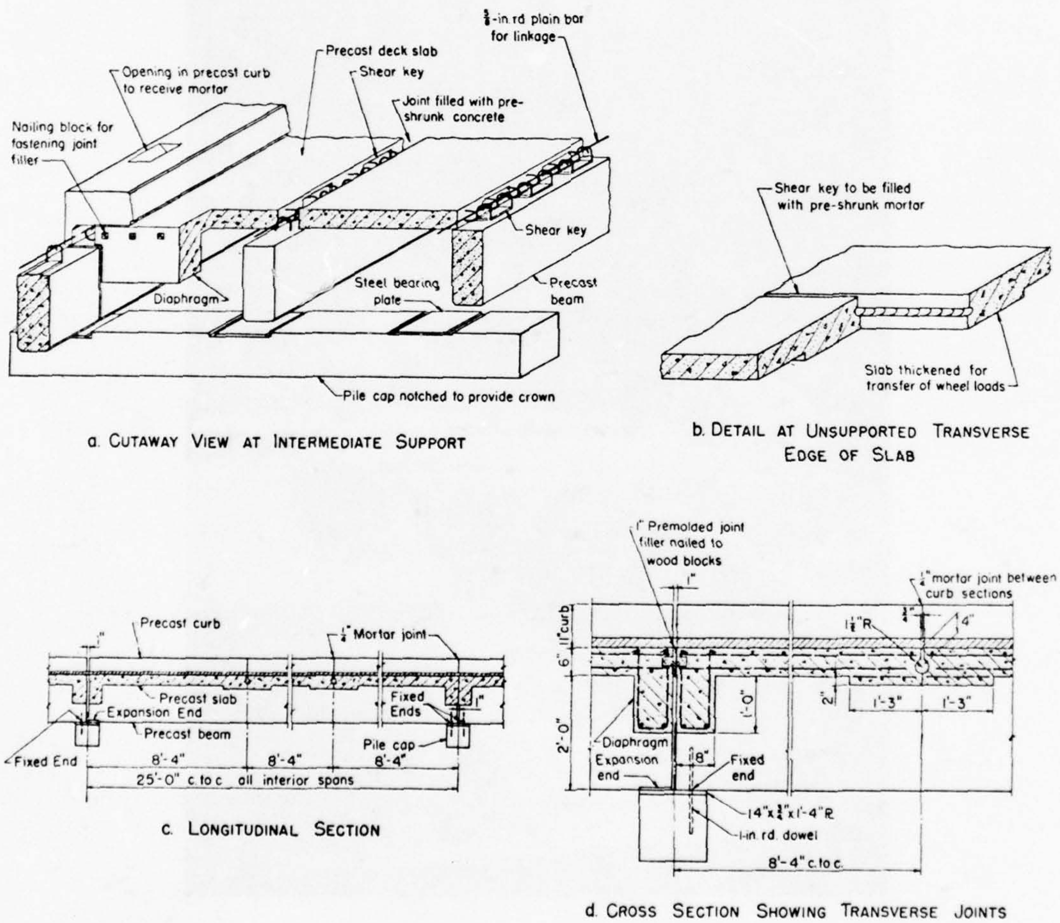


Figure 25. Bridge deck of precast beams and slabs (courtesy of Portland Cement Association[7])

2 ft deep, and 24 ft 11 in. long. Between any two beams, one span of the deck consists of three precast slabs, each approximately 8 ft 4 in. long, 4 ft 2-1/2 in. wide, and 6 in. deep. These deck slabs, weighing approximately 3100 lb each, are designed as simple spans between beams for both dead and live loads.

41. Figure 26 shows the erection of a bridge in Spokane County, Washington, some features of which are similar to the design used for

Figure 26. Erection of a bridge of precast beams and slabs (courtesy of Portland Cement Association[7])

the Baker River Bridge. Here haunches on the 30-ft, 7400-lb beams support the deck slabs. Precast slabs are 5 ft 9-1/8 in. by 15 ft by 5-1/2 in. thick and weigh 6000 lb.[7]

Precast tee-girder bridges

42. The single-tee girder is a popular section for bridge structures on secondary roads and county or town use. This is particularly true in the replacement of existing structures where speed in construction, as well as a low initial cost, is very important. In the span range studied (61 ft), single-tee bridges (Figure 27) showed a definite

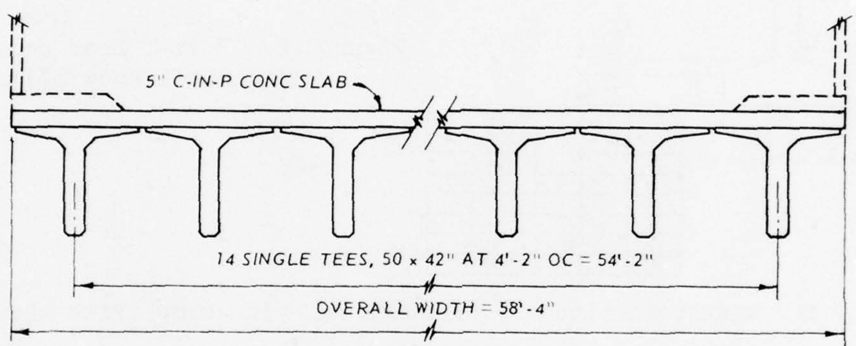


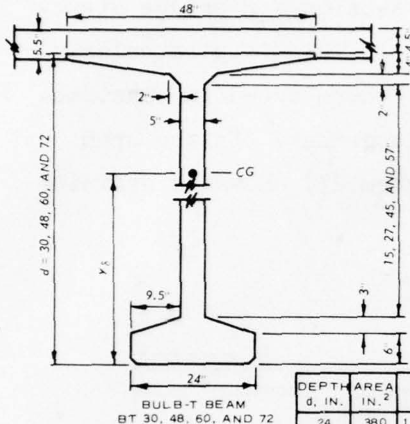
Figure 27. Cross section of single-tee bridge (from Reference 16)

cost advantage in a cost comparison made in Connecticut in the early 1960's.[16] The cost comparison was made on actual bid prices on vehicular bridge structures with (a) steel stringers with cast-in-place concrete slab, (b) prestressed concrete box beams with asphaltic wearing surfaces, (c) AASHO type III I-beams with cast-in-place concrete slab, and (d) single tees with cast-in-place concrete slab. According to Curtis,[16] total costs per square foot of deck were as follows:

System	Cost per Square Foot
Steel stringers	$9.15
Box beams	7.35
Type III, I-beams	6.87
Single tees	6.41

In addition to vehicular bridges, single-tee applications include pedestrian and material handling bridges.

43. In 1959, the Concrete Technology Corporation developed the bulb-T section[17] (Figure 28). The wide top flange ensures lateral



DEPTH d, IN.	AREA IN.^{2}	y_s IN.	MOMENT OF INERTIA IN.^{4}
24	380	12.14	28,900
30	410	14.95	51,100
36	440	17.78	80,700
48	500	23.51	164,000
60	560	29.29	283,200
72	620	35.12	442,800

Figure 28. Bulb-T beam properties (from Reference 17)

stability for transportation and erection and also simplifies the placing of a cast-in-place concrete deck slab.

44. The 60-in. bulb-T girder was used for the Naches River Bridge,[18] Yakima County, Washington. This structure is an example of building a small prestressed concrete bridge with spans longer than ordinary by plant precasting the girders in segments and posttensioning in the field. The bridge, designed for AASHO HS20 loading, consists of six lines of precast, prestressed concrete girders cantilevering 30 ft over piers, which are 155 ft apart (Figure 29). Comparisons were made between various available precast girder shapes with results as shown in Figure 30.

45. The girders had to be hauled 200 miles over the Cascade Mountains. Therefore, to simplify transport and handling, they were detailed in three pieces. The two end pieces, each 62 ft long, were precast with ducts in place for field prestressing. The middle piece, 90 ft long, was plant precast and prestressed, for its own moment envelope plus ducts was included for field prestressing. The middle

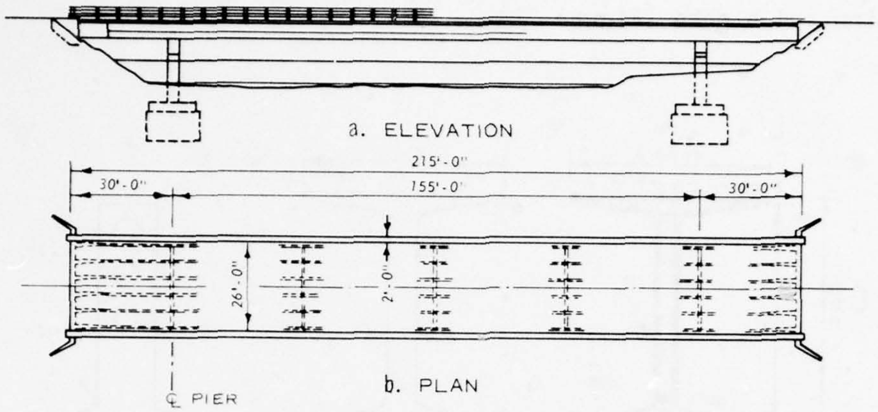
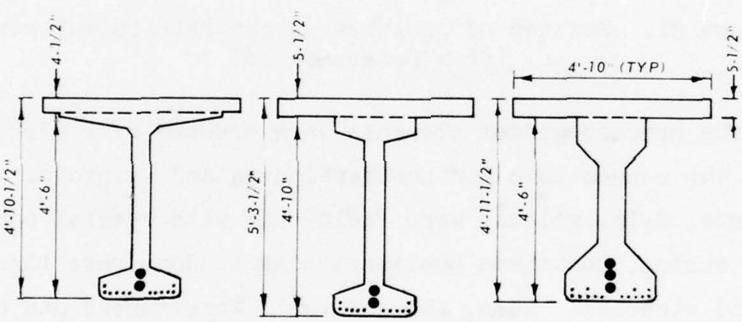


Figure 29. Elevation and plan of the bridge designed for AASHO HS20 loading (from Reference 18)



	54" BULB TEE	WSHD 100	AASHO IV
GIRDER WEIGHT	34 T	36 T	53 T
PRECAST CONCRETE	16 CY	17 CY	24 CY
C-I-P CONCRETE	8 CY	10 CY	10 CY
PRESTRESS	14 STRANDS	14 STR	16 STR
POSTTENSIONING	24 STRANDS	24 STR	36 STR
COST, CONCRETE	$2,400	$2,700	$3,400
COST, ALL PRESTRESS	$1,220	$1,220	$1,670
COST, ONE GIRDER	$3,620	$3,920	$5,070

7000-PSI PRECAST CONCRETE. 270-K 1/2" STRANDS. H-20 S-16 LOADING. 0 TENSION AT B FIBER COST VARIATION RANGE MERELY INDICATIVE, RELATIVE AND PROBABLE.

Figure 30. Comparison of three 120-ft simple span, prestressed concrete highway bridge girders (from Reference 18)

girder piece has a 5-1/2-in. web; the end pieces, for resistance to shear over piers, have 7-in. webs; and the girder ends have stress distribution end blocks (Figure 31).

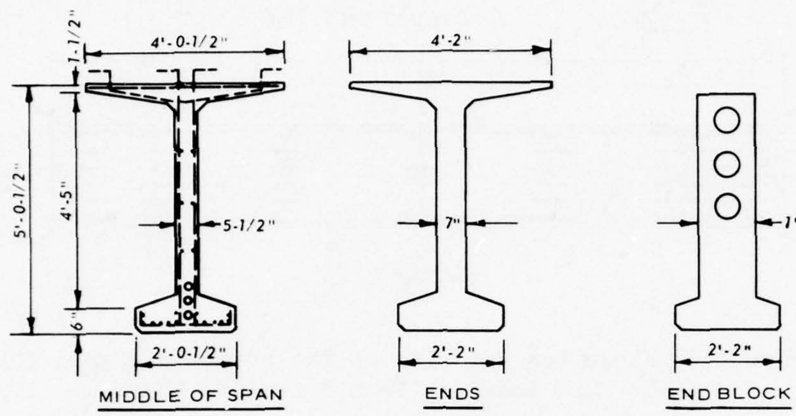


Figure 31. Section of prestressed concrete bulb-T girder (from Reference 18)

46. The precast girder elements were erected over piers and falsework bents; the connections for posttensioning and reinforcing were made; and the joints, 8-in. widths, were field cast with special concrete. After joint curing, the three posttensioning tendons were threaded, anchored, and stressed. Then, the end walls were formed and cast, followed by the intermediate diaphragms at 30- and 38-ft centers, the 4-1/2-in.-thick roadway slab, and finally the curbs (Figure 32).

47. A single-lane precast reinforced concrete bridge developed in England for the temporary replacement of damaged bridges is shown in Figure 33. To allow rapid emergency erection, the bridge deck is entirely precast with the exception of the curbing, which may be cast-in-place without interference to traffic.[7] The deck for this 20-ft span consists of T-girders placed side by side with <-shaped joint between adjacent flanges to ensure proper fit at these joints; the seven units for one span are cast together in the same relative position they will have in the completed structure. These joints are held tight by transverse tie rods, which assist in the lateral distribution of wheel

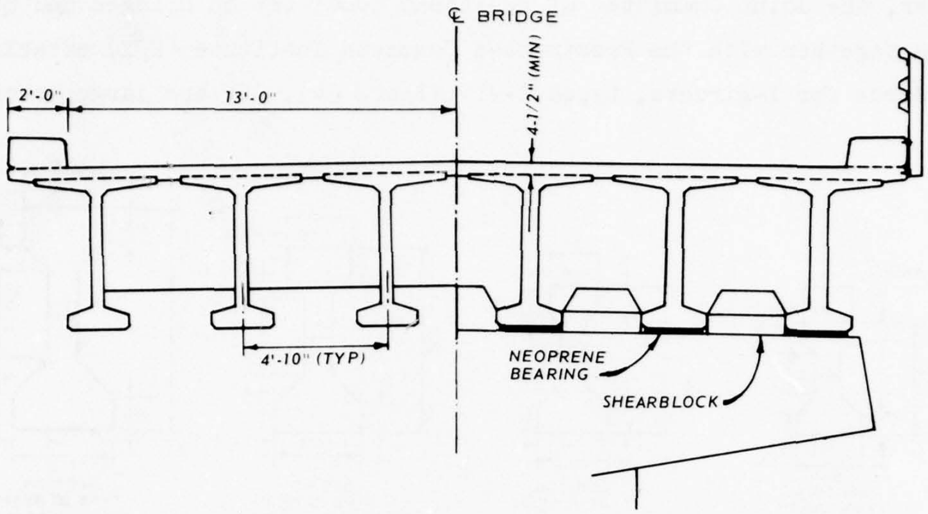


Figure 32. Roadway sections (from Reference 18)

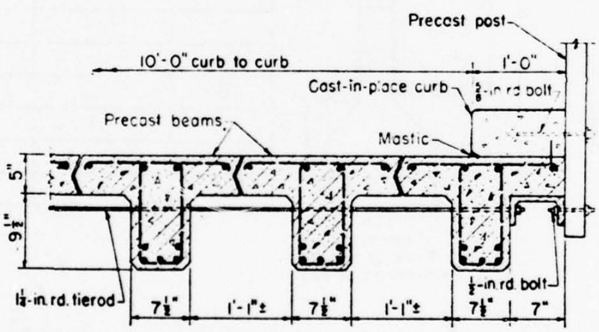


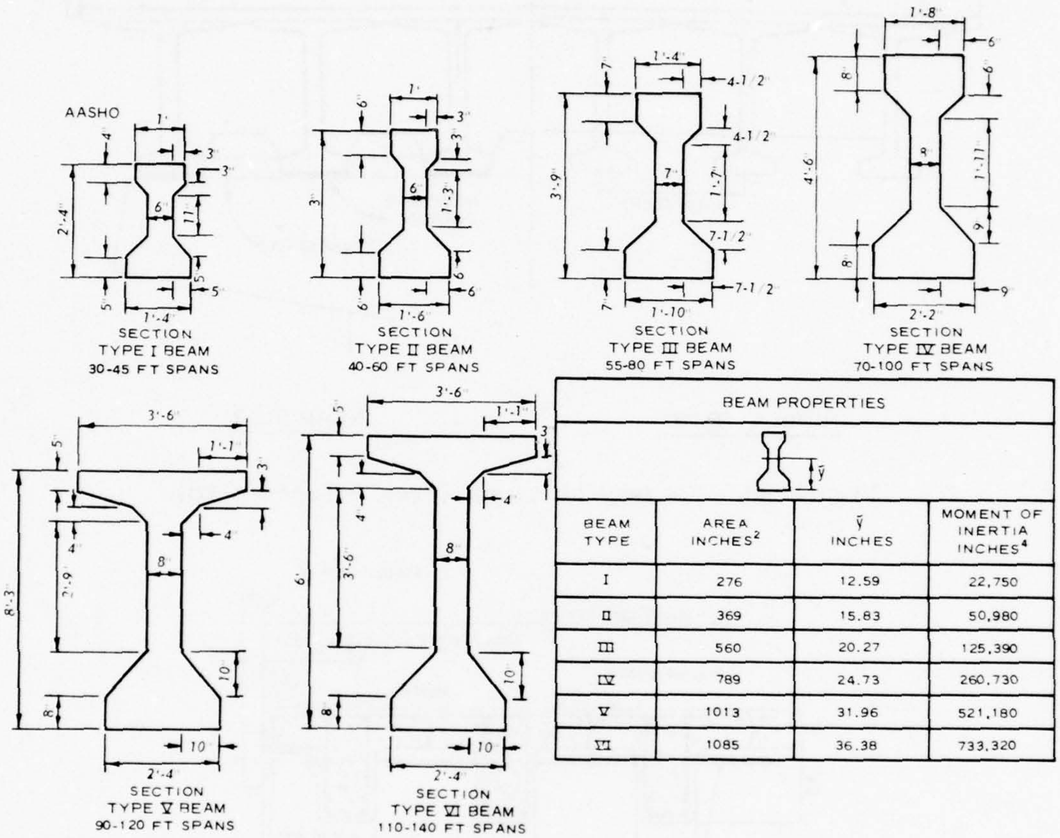
Figure 33. T-shaped precast units for bridge deck (courtesy of Portland Cement Association[7])

loads. At the ends of the span, precast concrete blocks are fitted into the openings between the flanges and the bridge seat and are grouted to create a solid abutment to retain the roadway fill and to give additional rigidity to the beam supports. This closure may also be cast-in-place concrete.

Precast I-girder bridges

48. Since the I-shaped girder is by far the most widely used

member, the Joint Committee of the AASHO Committee on Bridges and Structures together with the Prestressed Concrete Institute (PCI) established standards for I-girders, types I-VI (Figure 34). By and large, such



BEAM PROPERTIES

BEAM TYPE	AREA INCHES^2	$\bar{y}$ INCHES	MOMENT OF INERTIA INCHES^4
I	276	12.59	22,750
II	369	15.83	50,980
III	560	20.27	125,390
IV	789	24.73	260,730
V	1013	31.96	521,180
VI	1085	36.38	733,320

Figure 34. Dimensions and section properties for AASHO standard bridge beams (from Reference 17)

standards have been accepted throughout the country although there are minor modifications to the dimensions in some states. These girders are normally used with a composite cast-in-place deck slab. Diaphragms, either precast or cast-in-place concrete, are used in this type of construction in order to ensure lateral distribution of the live load. Span-spacing capacity for these standard beams is shown in Figure 35.

49. Possibilities of reduced costs and improved construction schedules were important factors in the selection of precast,

prestressed concrete elements for the majority of Illinois Toll Highway bridges.[19] In order to evaluate the performance of a structure characterized by the use of precast concrete, a representative bridge (Figures 36 and 37) was erected in advance of construction of the rest of the Illinois Toll Highway. Load tests were conducted to determine whether the assembly of precast elements behaved as an integral slab and girder system.[20]

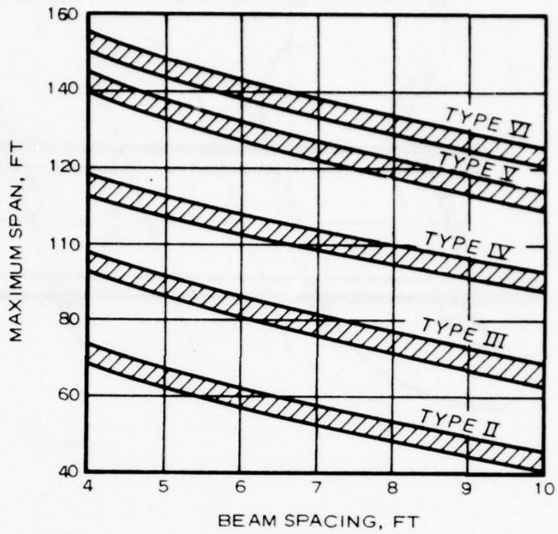


Figure 35. Span-spacing capacity for standard beams (from Reference 17)

50. Precast, prestressed hollow piles 3 ft in diameter with a wall thickness of 4 in. were used as intermediate supports between bridge abutments. After the bridge abutments and piles and pile caps were erected, the precast, prestressed girders were positioned on the structure. Cross sections and reinforcing for the I-shaped girders were as shown in Figure 38. The next stage of construction was to position and secure the precast concrete diaphragms. Precast, prestressed slabs were placed between girders (Figure 39) to serve as a form for the rest of the cast-in-place deck and provide positive slab reinforcement. The cast-in-place concrete was not carried across the supports to preserve a simple test slab. After that phase of testing, the diaphragms and the cast-in-place deck slabs over the supports were then cast, completing construction. The test structure was subjected to severe loads at different stages of construction. The resulting girder and slab moments were, in most instances, far in excess of design moments based on ASSHO H20 truck loads plus impact.[20] Based on these test results, it was concluded that there was no doubt that complete and positive composite action between the precast girders, precast slabs, and cast-in-place slab prevailed throughout the tests.[20]

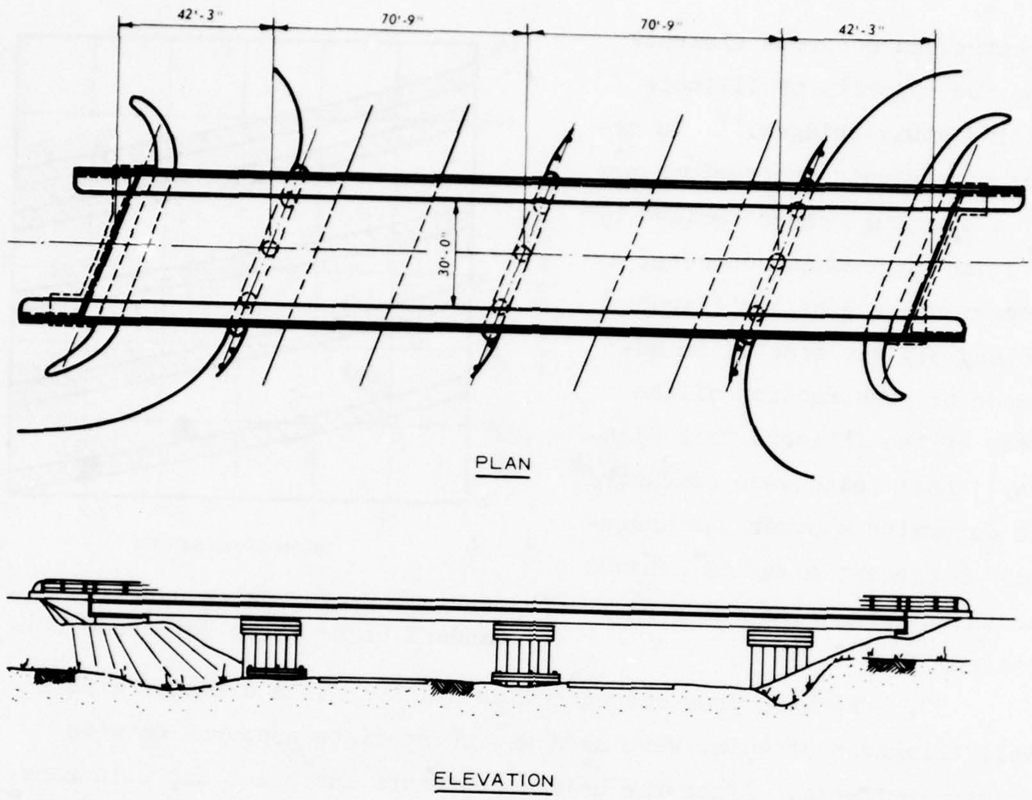


Figure 36. Typical bridge structure on the Illinois Toll Highway (from Reference 19)

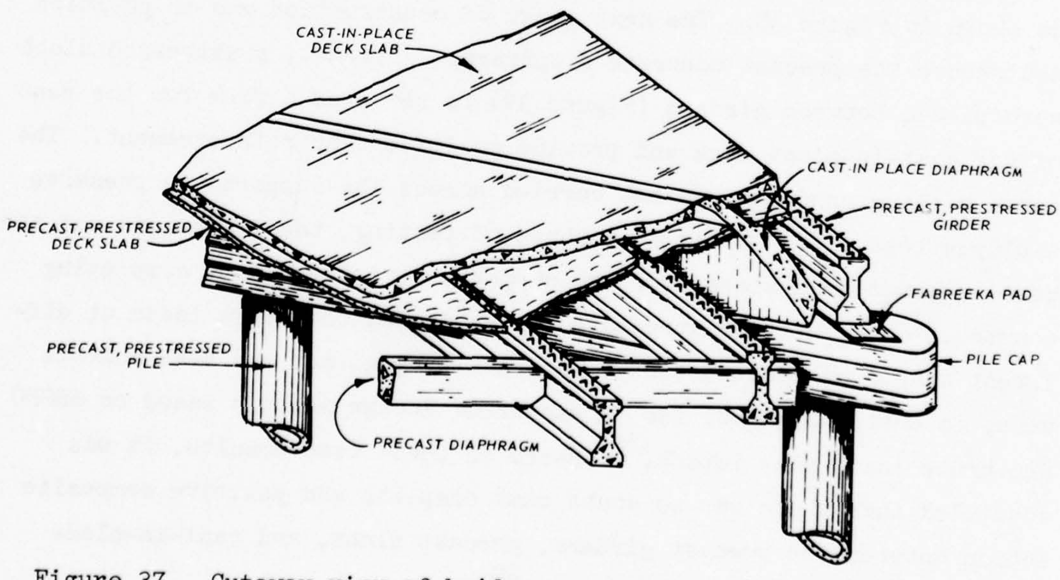


Figure 37. Cutaway view of bridge construction (from Reference 20)

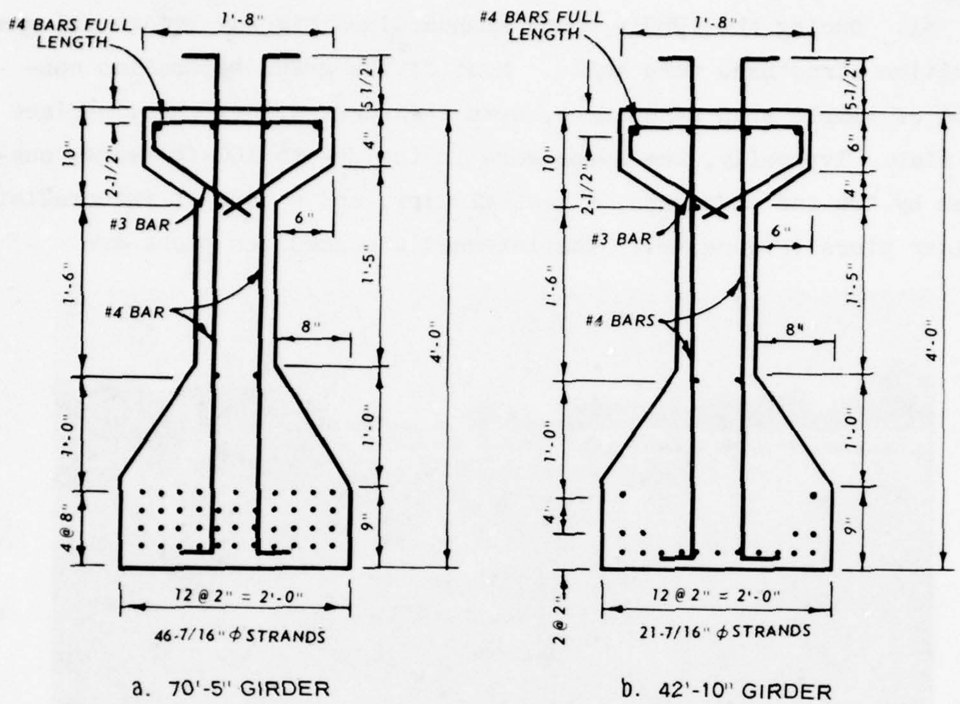


Figure 38. I-shaped girder cross sections and reinforcing (from Reference 20)

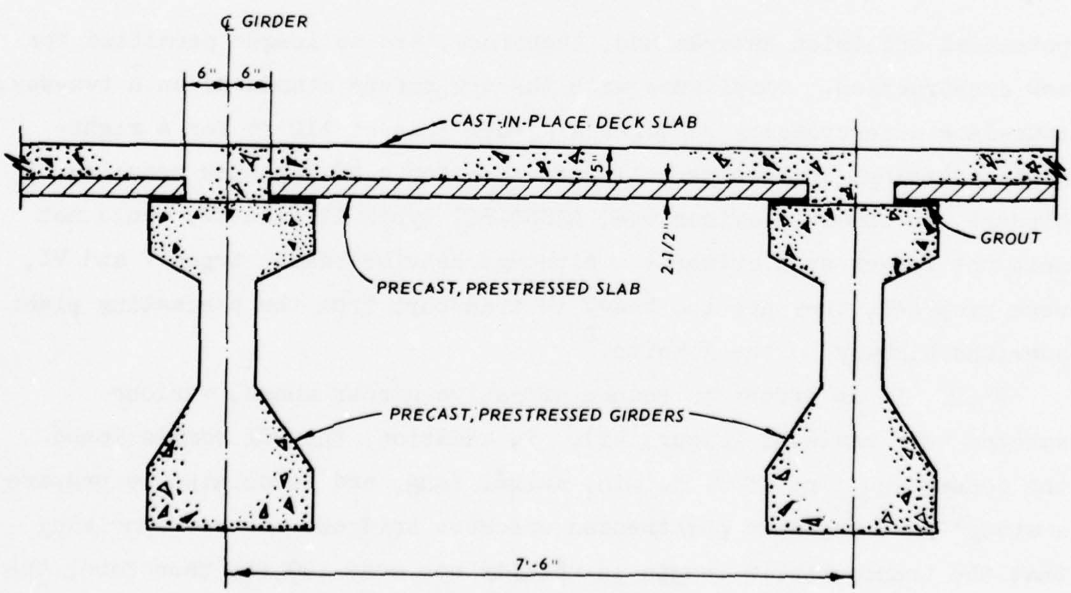


Figure 39. Deck details (from Reference 19)

51. During the 1960's, many standardized highway bridge and grade separation structures were built. Most of the grade separation consisted of simple span structures, span I-girders with a cast-in-place deck slab. Typically, the spans were in the 50- to 100-ft range, supported by two end abutments, a central pier, and a pair of intermediate shoulder piers (Figure 40). The intermediate shoulder piers are

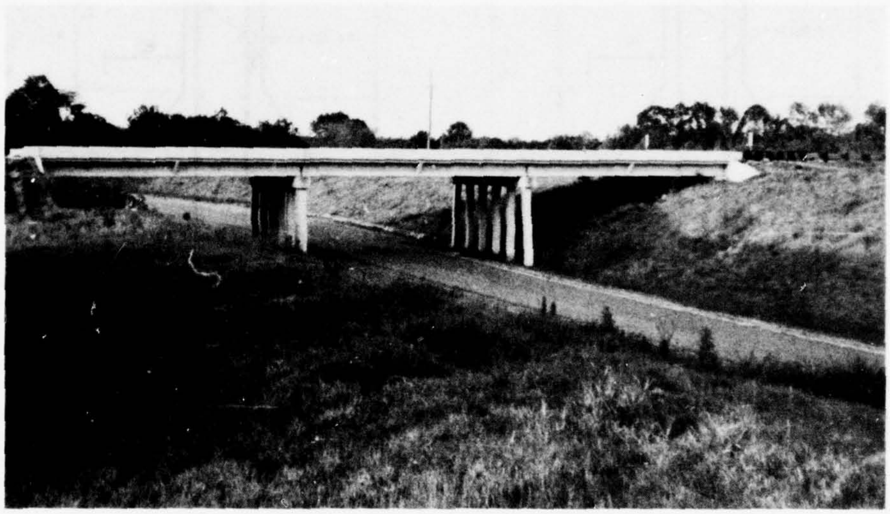


Figure 40. Typical grade separation structure

potential collision hazards and, therefore, are no longer permitted for new construction. Compliance with the new safety standards on a two-way, four-lane undercrossing requires a girder span of 112 ft for a right-angle crossing, increasing to 160-ft span for a 45-deg skew crossing.[21] Girders, in common previous use, AASHO-PCI types III and IV, would not meet the longer span criteria. Although heavier beams, types V and VI, were proposed, they are too heavy to transport from the precasting plant over the highway to the jobsite.[22]

52. In an effort to reduce effective girder spans, various schemes were reviewed (Figure 41). In addition, the PCI commissioned the consulting firm of T. Y. Lin, Kulka, Yang, and Associates to prepare a study[23] on long-span prestressed concrete bridges. It was concluded that the transportable length is usually not over 100 ft; therefore, the problem is how to achieve 160 to 170 ft with 100 ft or shorter members.

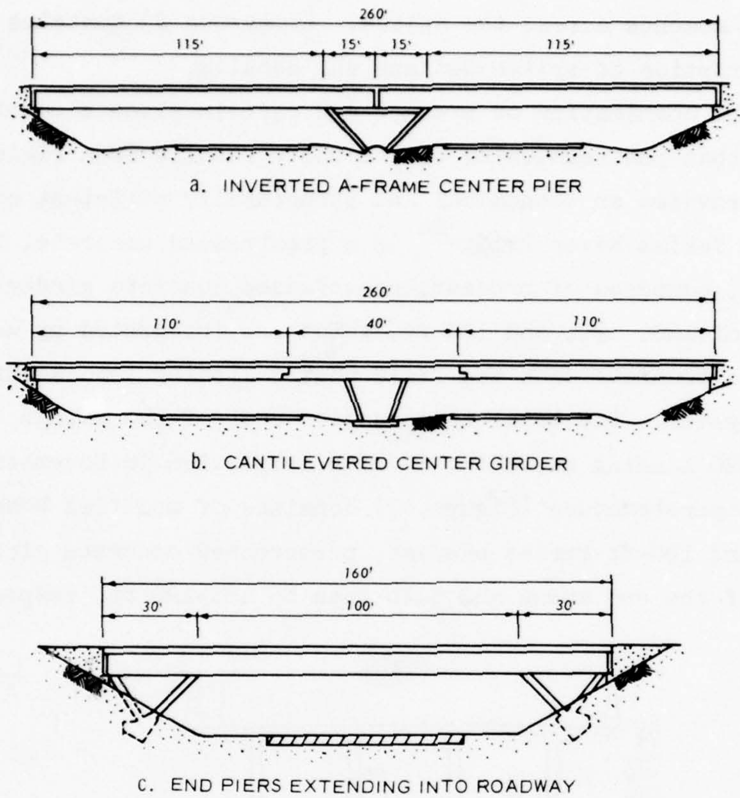


Figure 41. Span-shortening systems (from Reference 21)

Furthermore, the key to the problem is the details of design and construction.

53. Longer spans are possible with existing I-girders by using relatively short precast segments that are easily transported to the site where they are either preassembled and erected, or assembled as they are being erected. In the United States, segmental construction usually joins larger elements than the approximately 10-ft lengths used in other countries because of the ready availability of larger equipment for hauling and erecting. Obviously it reduces the fieldwork and falsework required for splice construction. For example, a 40-ft length of AASHO-PCI type III beam with a deck strip 8 ft wide and 8 in. thick weighs about 56,000 lb, which is easily transportable by truck and trailer.[22] Joints between the ends of segments can be grouted, glued with epoxy resin, or left dry. Longitudinal posttensioning is used to

transmit the moments across the splice. Reference 23 contains a comprehensive description of splice designs and details.

54. The combination of precast and cast-in-place elements, arranged so that posttensioning of the whole results in a rigid frame structure, provides an economical and structurally efficient concrete bridge. The Yakima River Bridge[24] is a prestressed concrete, three-span frame bridge, composed of precast, prestressed concrete girders in all three spans of 120, 190, and 120 ft, which are integrated by means of a cast-in-place concrete deck and field posttensioning into a structurally continuous system. The total construction cost of the bridge designed for AASHO HS20 loading was $254,000 with completion in November 1967. The bridge superstructure (Figure 42) consists of modified Washington State standard 100-ft series precast, prestressed concrete girders with the length of the end spans and main span 85 and 120 ft, respectively.[24]

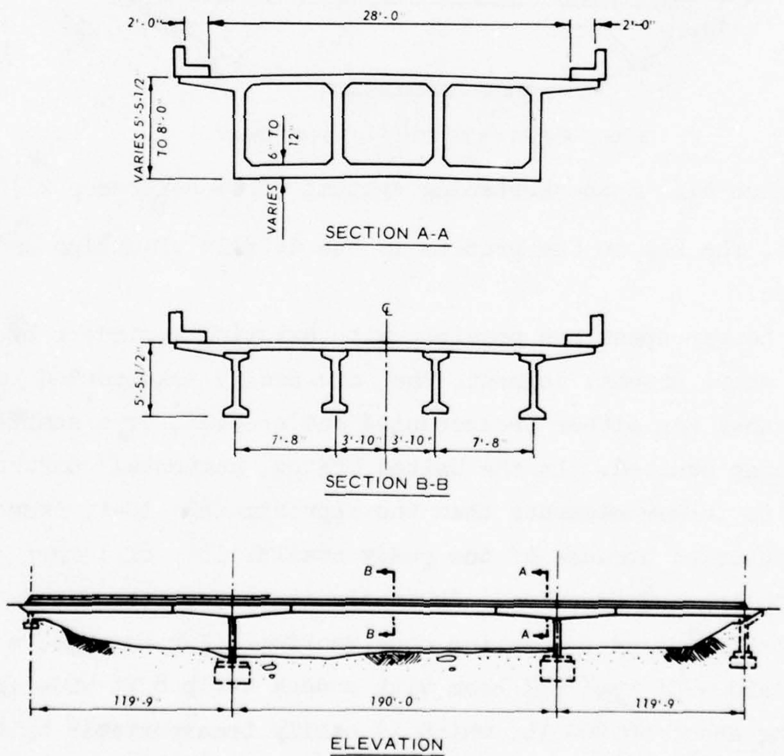


Figure 42. Elevation and sections of the bridge superstructure (from Reference 24)

They are rigidly connected into the cast-in-place concrete boxes over the piers in the maximum negative moment and high shear regions. Construction of the bridge, which required approximately 7 months, was according to the sequence shown in Figure 43.

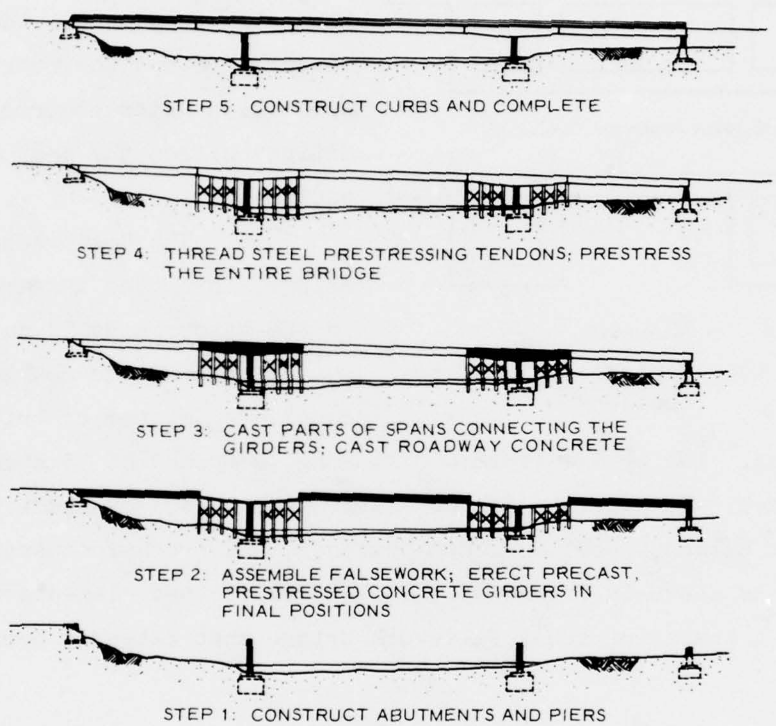


Figure 43. Construction sequence (from Reference 24)

Precast box girder bridges

55. A number of precast, prestressed concrete highway bridges and elevated roadways have been designed as box forms with cantilevered deck slabs. This type of design is frequently known as a spine beam, and the basic section may consist of a single cell or it may be in a multicell form (Figure 44). Such structures are frequently constructed segmentally either in situ or by precasting short lengths of the box section and then posttensioning the segments together to form the required bridge structure. Although various site conditions have a strong influence on the decision whether precasting should be employed in

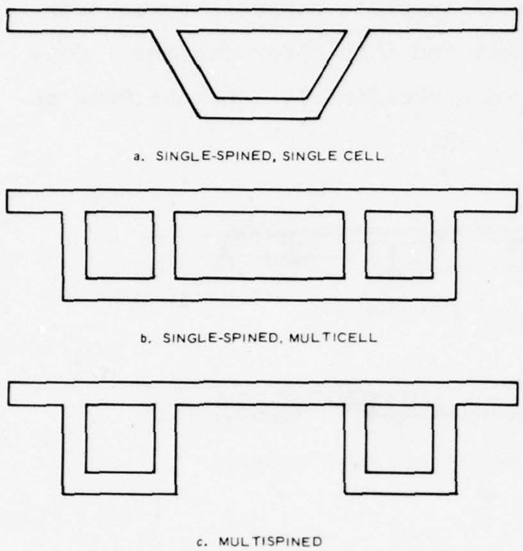


Figure 44. Typical types of box sections

segmental construction, one of the most important factors is the length of the superstructure. Generally, precast segmental construction is likely to be economical for long structures where the savings on formwork and the repetitive production under controlled conditions offset the cost of erection equipment.

56. The Oosterschelde Bridge[25] over the Eastern Scheldt in the Netherlands is an outstanding example of the double-cantilever system of bridge constructions. The bridge is 16,000 ft long, composed of 55 spans of 300 ft each. It consists of very large prestressed cylinder piles, precast pier elements posttensioned together, and precast superstructure elements as shown in Figure 45. The superstructure elements were all set from a traveling steel falsework bridge that extended over two and

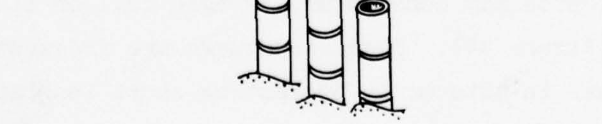


Figure 45. Elements of the Oosterschelde Bridge (after Reference 25)

one-half spans at a time (Figure 46). Elements were brought in under it by barge, then hoisted in symmetrical order about each pier. The joints were concreted, and the primary stressing was done before the next series was hoisted. In total, the bridge consumed 170,000 cu yd of concrete. About 85 percent of this was precast. Three different systems were employed using 3,300 tons of prestressing steel.

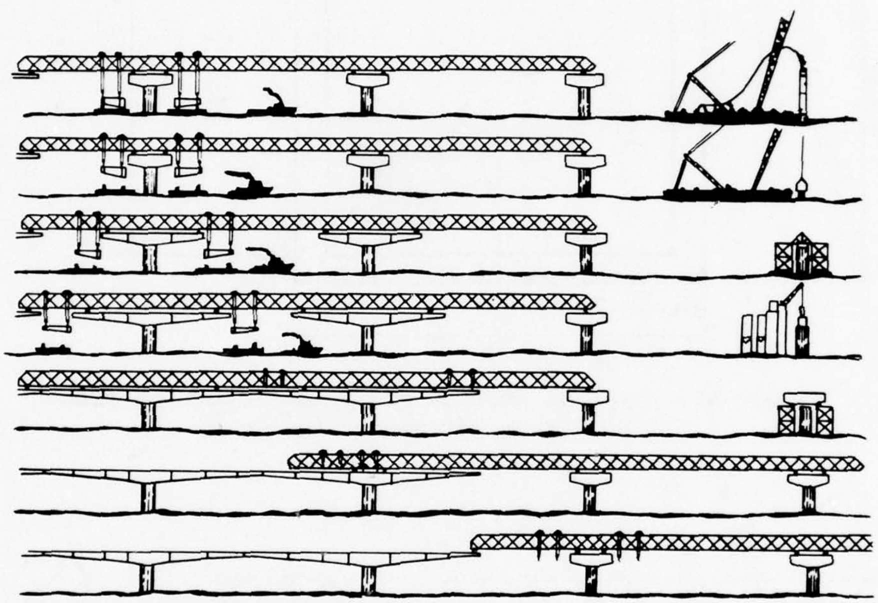


Figure 46. Schematic erection plan for Oosterschelde Bridge (from Reference 25)

57. Considerably smaller precast concrete segments were used in the construction of a private, medium span prestressed bridge in Mexico.[26] This one-lane bridge with a 130-ft central span was designed for an AASHO live load of H15 S-12-44 in such a way that the erection could be performed without the use of falsework or cranes. Because of the limited budget, it was not possible to secure adequate equipment and specialized personnel for the transportation of the precast pieces. Instead, a cableway was used to position the precast pieces (Figure 47), which weighed 4.4 to 6.6 tons. The work can be summarized in two stages, temporary construction stage and permanent stage. Figure 48 shows an elevation of both stages. In this particular project, four precast

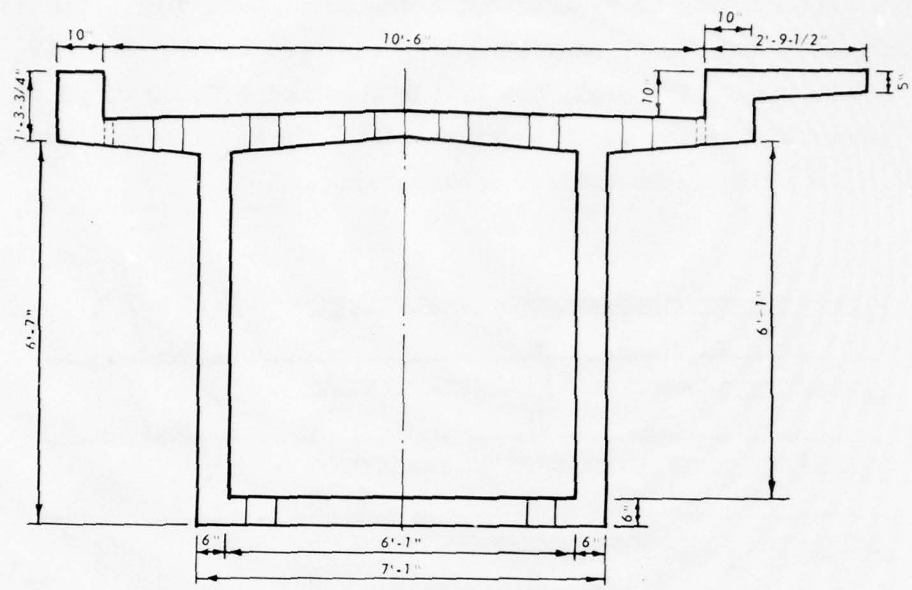


Figure 47. Typical section of precast concrete piece (from Reference 26)

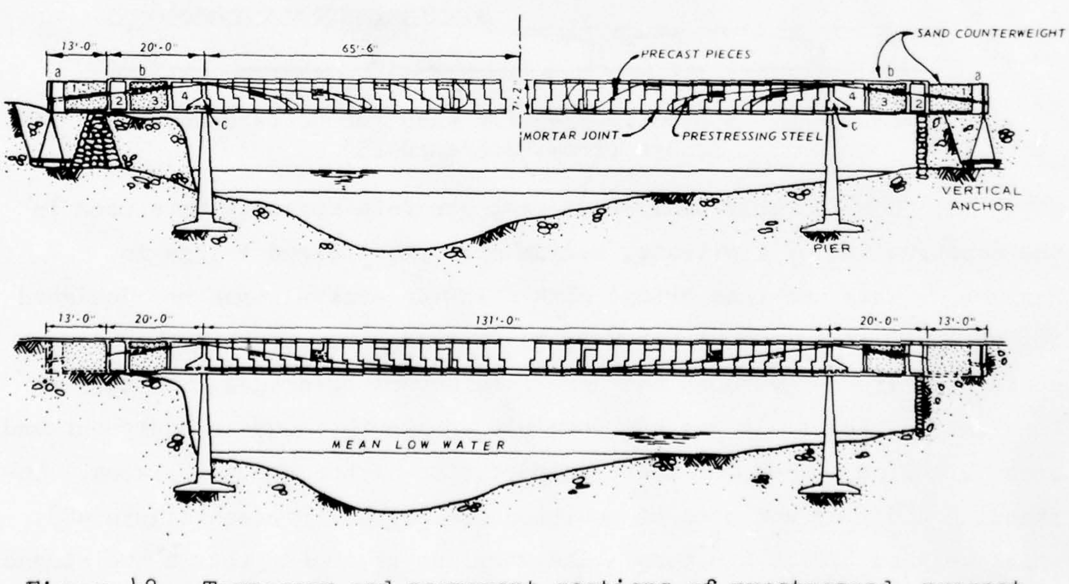


Figure 48. Temporary and permanent sections of prestressed, precast bridge (from Reference 26)

segments were placed daily, two on each site of the bridge. However, Cancio and Munoz[26] believe that it is feasible to place eight segments daily, four on each side, which would leave two phases of the construction stage ready for tensioning in only 1 day. With the proper hauling of segments, they believe it is possible to mount the 38 segments in 5 days.

58. After the required load tests, the functioning of the bridge was found satisfactory, and it was opened to traffic in 1963.

Logging Bridges

59. As a result of the heavy logging and construction equipment, and off-highway logging trucks used in the Pacific Northwest, it is common to build logging bridges for loads two to three times the standard AASHO HS20 loads. For example, the entirely precast Solleks River Bridge,[27] 230 ft long between supports (Figure 49) and 15 ft wide between curbs, was designed for a 75-ton truck. Erection was accomplished by a

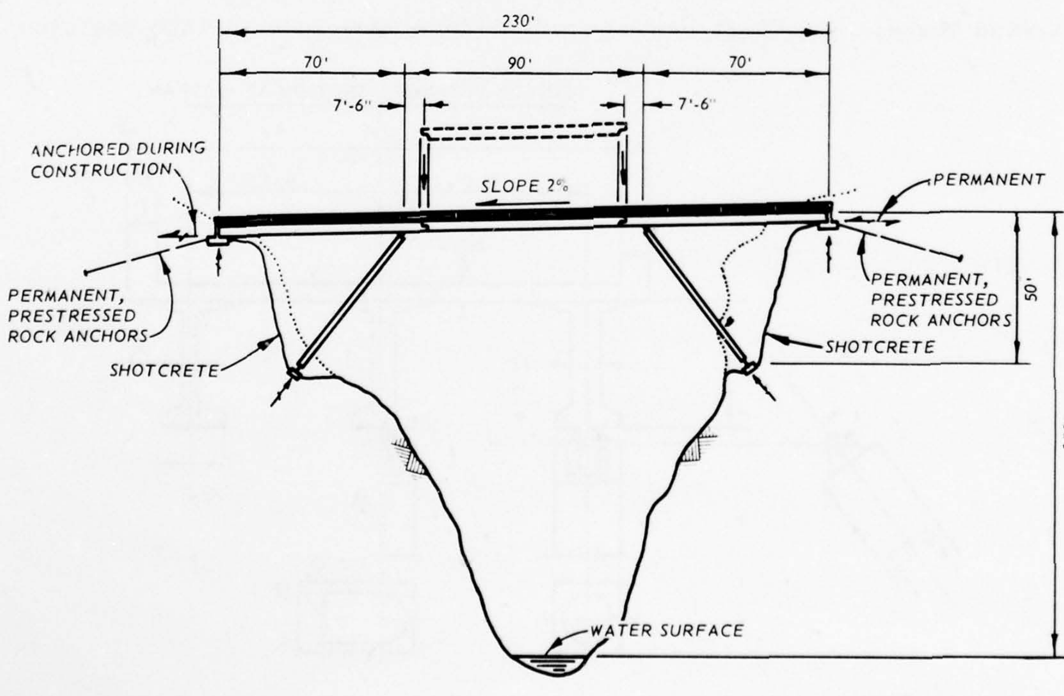


Figure 49. Profile of the Solleks River Bridge (from Reference 27)

1200-ft span skyline similar to those used in logging. The long span was dictated by the topography, an available spar tree, and the need for sufficient sag to carry loads up to approximately 20 tons.

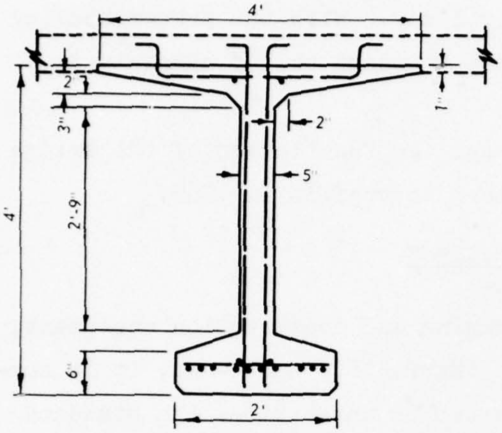


Figure 50. Precast, prestressed lightweight concrete girder section (from Reference 27)

60. Bridge construction began with excavating for the abutments and by benching for the strut footings. Precast, prestressed lightweight concrete struts, 64 ft 6 in. long and 2 ft 2 in. square in section with 1-ft-5-in.-diam core, were erected on the lower pins and guyed in the inclined final position. The 77-ft-6-in. end-span girders (Figure 50) were placed and pinned to the abutments. Girder webs were thickened at bearing points (Figure 51) to resist shear loads concentrated there. The 75-ft center-span girders were lowered into position

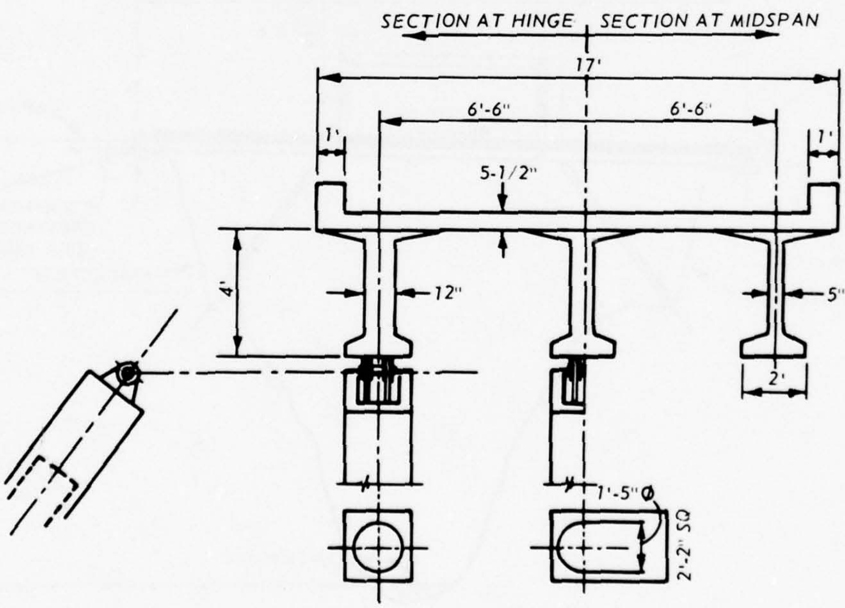


Figure 51. Bridge cross section at hinge and at midspan (from Reference 27)

to rest on side-span girders, which cantilevered out from the struts. The three precast, prestressed bulb-T girders were made continuous by mild reinforcement. The wide flange and thin edge of the girders made forming of the 5-in. cast-in-place composite deck simple.

61. Precast, prestressed girders made of lightweight concrete were also used for the Klickitat River Bridge[28] in Wahkiacus in Southern Washington. A clear span of 130 ft provides a single-lane roadway designed to carry logging trucks on an HS20 loading. Four type IV girders, modified by using a deeper web and adding a 4-ft flange at the top, were used to make a bridge 16 ft wide (Figure 52). The girders

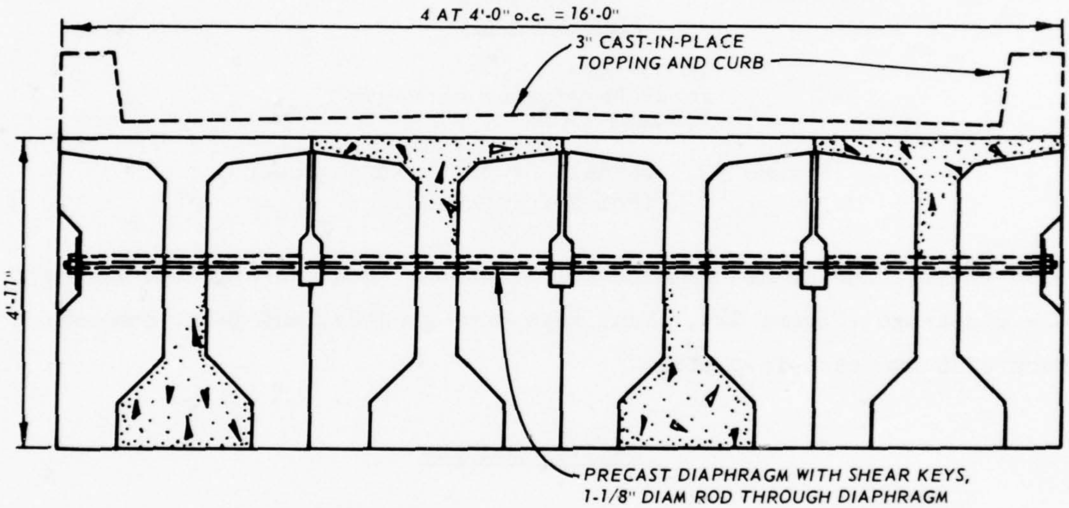


Figure 52. Cross section of the Klickitat River bridge girders (from Reference 28)

(Figure 53) were designed for four different loading conditions: (a) simple span, dead load, (b) cantilever each end 22 ft over supports while handling into position, (c) cantilever one end 22 ft, and (d) dead plus live load for the completed structure.

62. The four girders were cast in Portland, Oregon, and set in position in the casting yard as they would be placed in the bridge. Seven cross diaphragms were then formed simultaneously on all beams. The girders were transported on flatcars to within 500 ft of the bridge

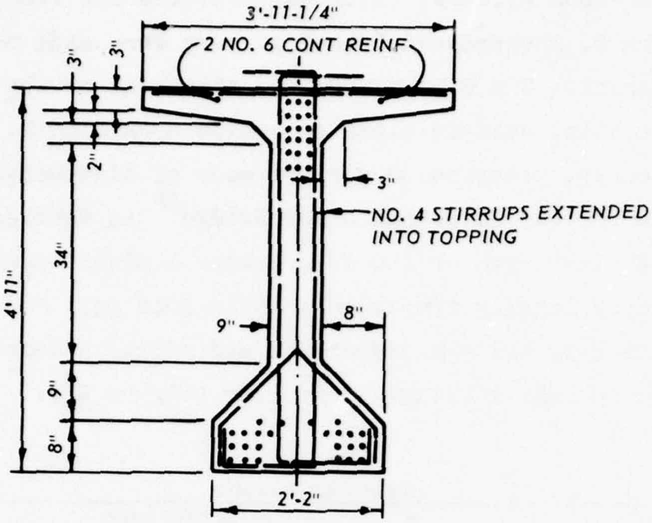


Figure 53. Details of the bridge girder (from Reference 28)

site where three cranes handled the erection. Rods were placed through the diaphragm (Figure 52), shear keys were grouted, and 3-in. concrete deck slab was cast-in-place.

Railway Bridges

63. As a result of its inherent economy, minimum maintenance, rapid construction, and excellent appearance, precast, prestressed concrete has gained wide acceptance for railroad bridges. Specifications for design, materials, and construction of prestressed concrete structures published in 1965 by the American Railway Engineering Association (AREA) initiated a new era in railroad bridge design. This publication,[29] with subsequent supplements, contains design tables for the precast, prestressed box girders for railway bridges shown in Figure 54. The design live load is Cooper E-72 (Appendix C). The designs for the 3- and 4-ft wide single-cell boxes are suitable for spans from 26 to 84 ft. The designs for the three double-cell box widths are for spans

from 26 to 50 ft. Where vertical clearance is not critical, the deeper boxes usually offer an economic advantage.

64. Prior to 1965, numerous railroad bridges were built using precast, prestressed concrete I-girders or box beams for the superstructure. The early application of prestressed box girders was to replace worn-out short-span timber trestles, but the structural efficiency of the box section has now found its place in medium-span bridges.[30] A new 78-mile Palmdale-Colton cutoff line in Southern California, opened to traffic in 1967, had some 42 railroad bridges, 37 of which were prestressed. These prestressed bridges totaled some 4400 ft in length and had span lengths ranging from 20 to as much as 86 ft.[30] Five of these structures had steel girders spanning over highways and used prestressed girders in the end spans. The prestressed girders consisted primarily of box girders (single- and double-cell) and hollow-slab girders. According to Barton,[31] precast girders, in preference to cast-in-place construction, were selected for the Colton cutoff for the following reasons:

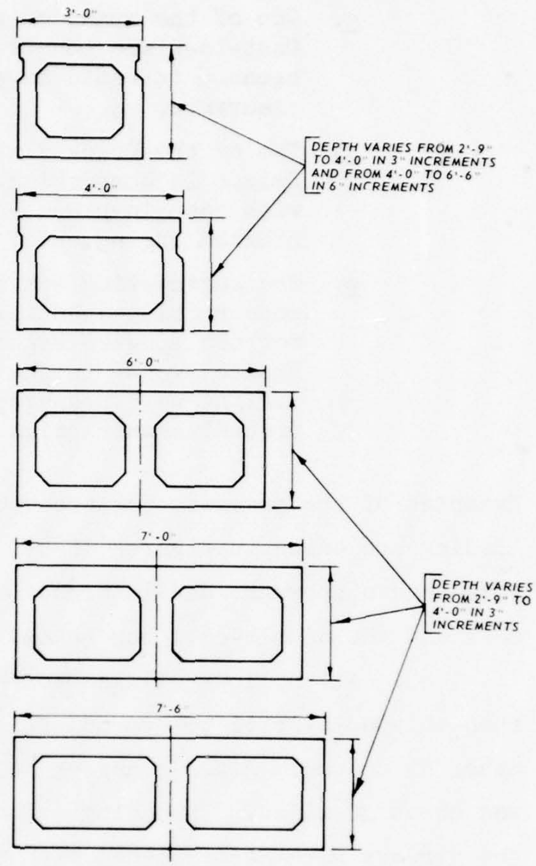


Figure 54. Standard box girders for railway bridges (from Reference 29)

a. A number of the bridges were located in the Mojave Desert where temperature conditions are extreme. Field labor was expected to be available only on a premium wage basis.

b. Bridges over public roads could be built without having the need for falsework and, in some instances, without requiring detours.

c. One of the spans crossed the tracks of another railroad. Cast-in-place construction would have been undesirable because it would have necessitated temporary impaired clearance.

d. Two of the bridges were located in flood control channels. Delays in completion of the project could have occurred with cast-in-place concrete, because falsework was prohibited during the flood season.

e. The engineering staff of the railroad preferred precast construction when the project was initiated. However, for the longest spans described herein, the 86-ft span at Rialto Avenue in the city of San Bernardino, alternative designs were prepared both for cast-in-place as well as precast construction.

Examples of the precast, prestressed girders designed for Cooper E-72 loading are shown in Figures 55-57. These girders incorporate transverse end diaphragms and intermediate diaphragms within both the single-cell and the double-cell box beams.

65. All hollow-cellular box girders were fabricated in Arizona, then shipped by rail to two unloading points, one at Palmdale and the other at Colton. After transfer to trucks, the maximum length of haul was about 30 miles. Unloading at the railroad siding and erection of the girders were accomplished with truck cranes having capacities of 35, 45, 50, 75, and 115 tons. The cranes worked singly, and in pairs, depending on the size of the girder and the access conditions at the bridge sites. All girders were seated on elastomeric bearing pads extending the full width of the girders. Keyways were grouted with an epoxy grout for shear transfer and also to provide torsional rigidity.

66. Shallow, single-cell, precast, prestressed box girders were utilized in an underpass (Figure 58) carrying Southern Pacific Railroad tracks over a local street in Fresno, California.[30] These box girders (Figure 59) were designed as simply supported to carry a Cooper E-72 loading over spans varying from 51 to 58 ft. All prestressed box girders were fabricated in Sacramento and hauled to Fresno by truck where they were erected in only 2 days. After seating on elastomeric pads designed to accommodate vertical load and temperature, keyways were grouted with an epoxy grout.

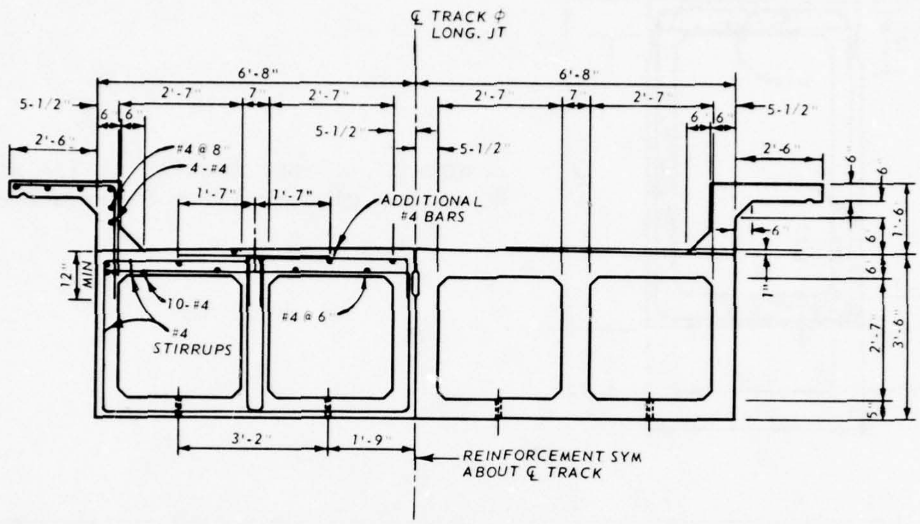


Figure 55. Cross section for 45-ft girder length (from Reference 31)

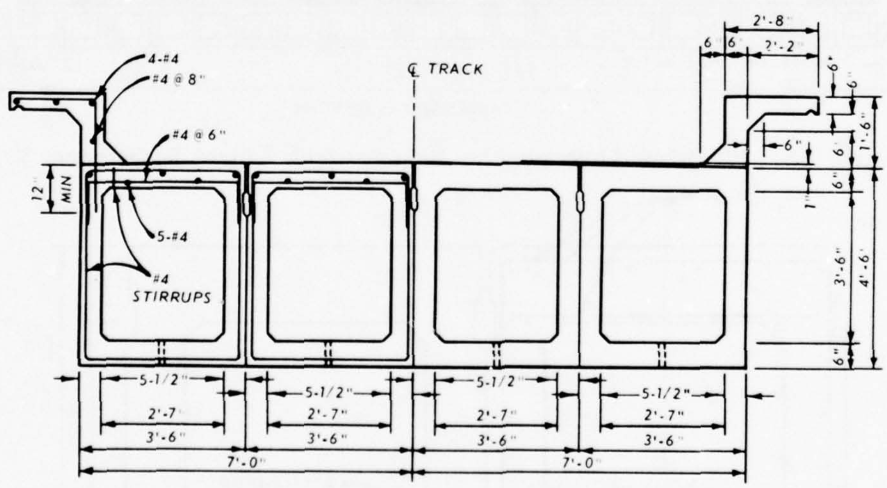


Figure 56. Cross section for 53-ft girder length (from Reference 31)

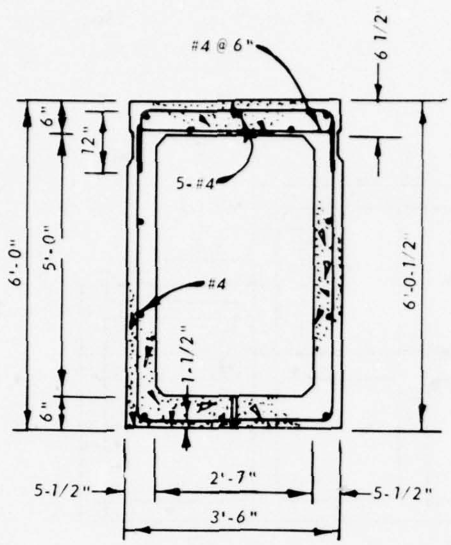


Figure 57. Cross section of 73- and 86-ft box girders (from Reference 31)

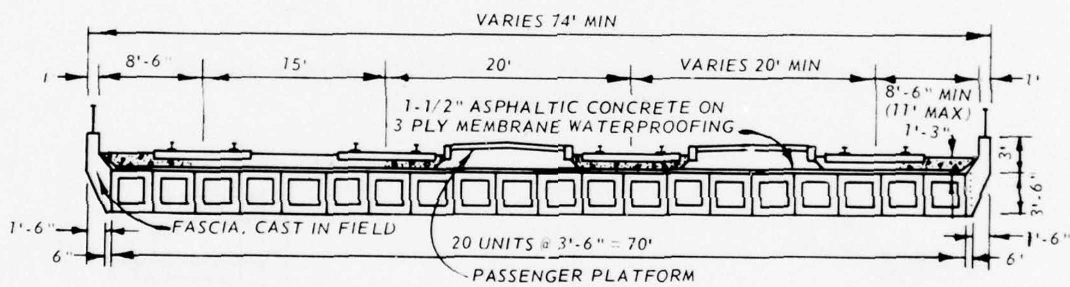


Figure 58. Section through the bridge deck (from Reference 30)

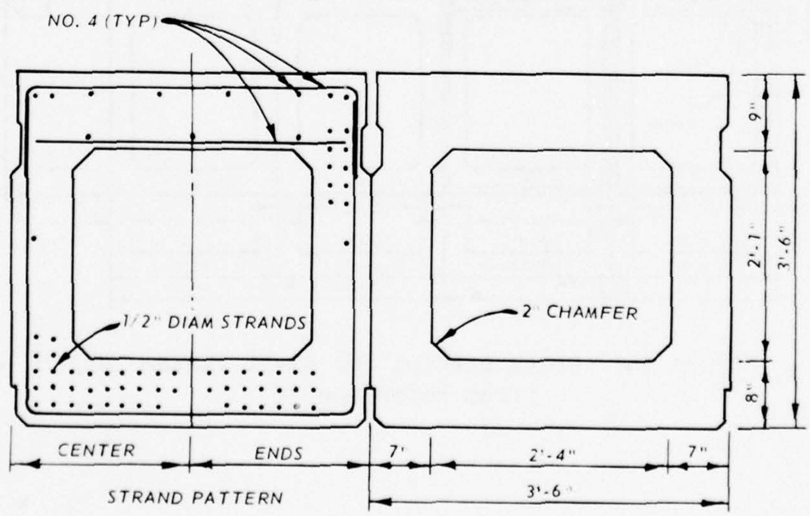


Figure 59. Hollow-cellular box girder details (from Reference 30)

67. The Seaboard Railroad[32] has installed a number of concrete trestles using the double-box design (Figure 60). The double-box

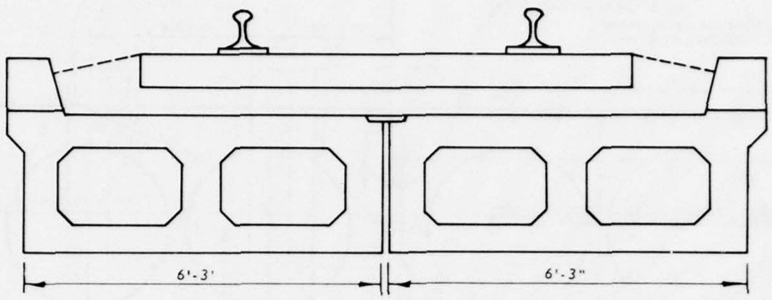


Figure 60. Seaboard Railroad double-box beams
(from Reference 32)

design facilitates erection since only two beams are required to form a complete span. The joint between the two beams is at the track center line, and no shear keys or bonding is used.

68. The Cement and Concrete Association of Australia published a report[33] in 1970 on precast, prestressed concrete bridge girders for replacement of existing timber railway bridges. Twenty existing bridge types, nine of which are in the United States, are described. In addition, 14 proposed bridge sections were considered. Based on this review, the "Standard A" type girder (Figure 61) is recommended as the best design to use for replacement of existing timber trestles. Each unit weighs 28 tons and is designed for spans up to 39 ft with an E-50 loading. The design depth of this girder was selected to enable construction of the substructure, pile caps, and/or head stacks under the existing bridge, yet still maintain the same track alignment. The girders were also designed to simplify the production and speed of assembly on the job.

69. Renewal of the Southern Pacific Company's Dumbarton Bridge[34] across San Francisco Bay is an example of using prestressed concrete to replace portions of an existing wooden trestle. About a half mile of the 1-1/2-mile bridge was replaced with prestressed concrete spans and cylinder piles. Maintaining alignment and rapid completion of construction without greatly delaying or interfering with rail traffic were

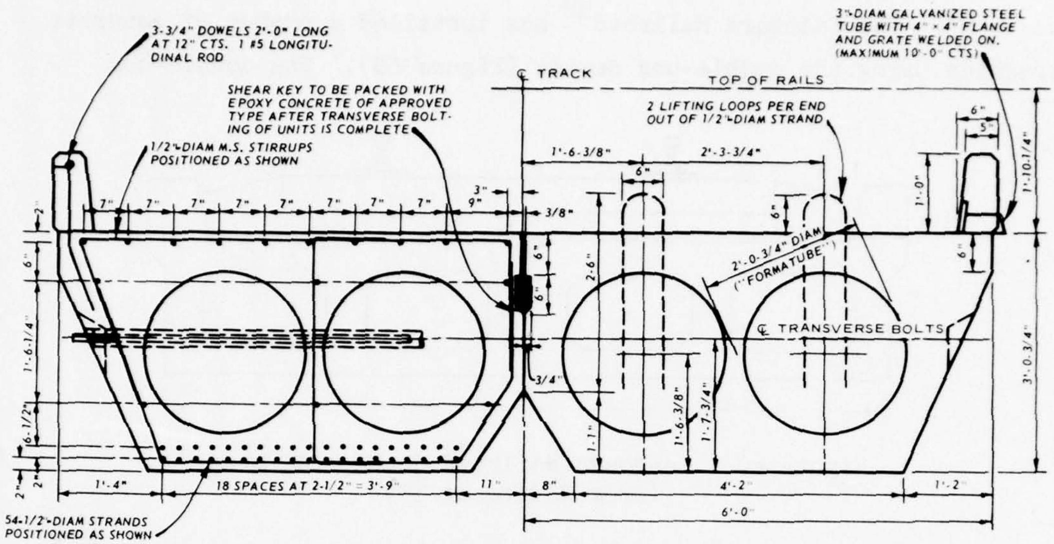


Figure 61. Design of the typical precast concrete box girder section (from Reference 33)

important considerations on this project. The timber trestle replaced was 16 ft wide and supported on pile bents 15 ft on centers. The bents were capped with 14- by 14-in. timbers that supported 12 longitudinal stringers spaced over the 16-ft width.

70. Based on results of an investigation of soil subsurface conditions, a two-pile bent--one piling driven to each side of the existing structure--capped with a structural element was selected. Preliminary designs and cost estimates, including future maintenance costs, were analyzed for several types of piling, caps, superstructures, and span lengths. On this basis, prestressed concrete spans 45 ft long and supported on bents of prestressed concrete cylindrical piles were selected.

71. Precast, prestressed concrete piles with a diameter of 48 in. and 5-in. walls were chosen for the final design. Pile caps were "binocular-shaped" in plan, 6 ft wide at the ends to obtain full bearing on the piling, and 3 ft 6 in. wide in the center. The caps, 5 ft 3 in. deep and 31 ft long, weighed 45 tons. The center of each cap had a 3-ft by 1-ft 6-in. blockout over the center of each pile through which the pile connection was made. To eliminate pile interference, the new bents were located midway between the existing bents. The components

were precast at a nearby contractor's plant, loaded directly on barges, and brought to the jobsite as work progressed.

72. The deck units were constructed in two halves from hollow, double-box units, 6 ft 8-2/5 in. by 3 ft 6 in. by 44 ft 9-3/5 in. long. Web thicknesses ranged from 5 to 8-1/2 in. The units were designed for Cooper E-72 loading in accordance with AREA.[29] The deck units were precast in Arizona and transported to the bridge site on flatcars. Normal rail traffic was diverted during working hours, and a trainload of deck units was hauled onto the bridge. The existing rails, ties, and ballast were removed; then the timber piling was cut off below the new substructure. A floating crane lifted out 45-ft sections of the timber deck. The concrete caps were then swept clean, bearing pads placed, and dowels set in place. The floating crane then moved the deck units into final position, placing them over the dowels. When the second unit was placed tightly against the first, an epoxy resin was poured in the keyway to bond the deck units together. Four panels (180 ft of bridge) were installed in this manner each day.

73. Prefabricated track panels were loaded onto a flatcar, moved to the construction site, then placed on temporary blocking on the new bridge. After properly aligning and bolting each track panel to the previously installed tracks, ballast was unloaded and the temporary blocking removed. The new and original tracks were joined at the end of each workday, and rail service over the entire bridge was resumed.

PART IV: PRECAST CONCRETE PILING

74. Essentially a pile is an elongated or columnar body installed in the ground for the purpose of transmitting forces to the ground. This is accomplished through both the frictional forces on the surface of their shafts and from direct bearing on their bases or points. Generally, one of these components predominates, and the pile is typed as an "end-bearing" or as a "friction" pile.[35]

75. Typical precast reinforced concrete piles commonly used for bridge trestles, and occasionally used for buildings, are shown in Figure 62.[36] When properly constructed and driven, precast concrete piles provide a permanent type of construction, even in salt water, without the need of maintenance.

76. Since piles are subjected to tensile stresses during transportation, driving, and under certain service conditions, the desirability of prestressing is evident. Therefore, prestressed concrete piles are being extensively used throughout the world in both marine structures and foundations. Most prestressed piles are precast in casting yards where modern production methods and quality control generally assure high-quality products. Prestressed concrete piles have been constructed in the form of cylindrical piles ranging from 10 in. up to 13 ft in diameter, as used on the Oosterschelde Bridge in the Netherlands, and up to 260 ft long, as employed in offshore platforms in the Gulf of Maracaibo, Venezuela.[6]

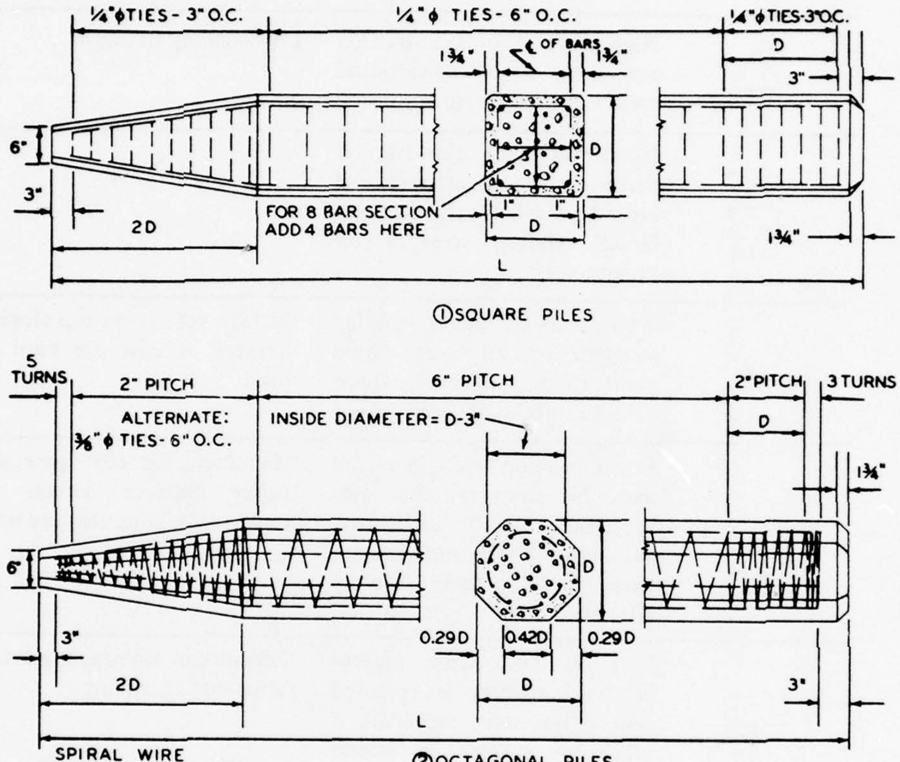
77. According to Gerwick,[6] prestressed concrete piles offer these advantages:

- a. Durability.
- b. Crack-free during handling and driving.
- c. High load-carrying capacity.
- d. High moment capacity.
- e. Excellent combined load-moment capacity.
- f. Ability to take uplift (tension).
- g. Ease of handling, transporting, and driving.
- h. Economy.

i. Ability to take hard driving and to penetrate hard strata.

j. High column strength.

k. Readily spliced and connected.

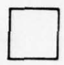
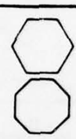
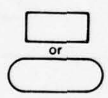
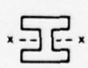


D	16"	20"	24"
SIZE	#5	#4	#3

Figure 62. Typical designs for precast concrete piles (from Reference 36)

There are also several disadvantages to the usage of prestressed concrete piles. A very heavy hammer is required for driving to minimize the intensity of the reflected stress wave and thus prevent pile damage. A special type of driving head is also necessary. The steel tendons used are very sensitive to corrosion due to the small wire size and must be completely covered with grout or concrete. In the design phase, piles resisting both moment and direct load require careful analysis. Piles having an unsupported length must be analyzed as a column to prevent failure through buckling. Typical properties and details of prestressed concrete piles are given in Appendix H.

78. Precast, prestressed concrete piles are manufactured in a variety of shapes[6] (Figure 63); however, most are solid square or

Shape	Advantages	Disadvantages
	Highest ratio of skin-friction perimeter to cross-sectional area. Low manufacturing cost.	Low bending strength.
	Good ratio of skin-friction perimeter to cross-sectional area. Low manufacturing cost. Good bending strength on major axes.	
	Approximately equal bending strength on all axes. Good penetrating ability. Good column stability (l/r ratio)	Surface defects on top sloping surfaces as cast are hard to avoid.
	Equal bending strength on all axes. No sharp corners—aids appearance and durability. Minimum wave and current loads. Good column stability (l/r ratio).	Manufacturing cost generally higher. Surface defects on upper surfaces as cast are hard to avoid.
	May be used where greater bending strength is required around one axis, especially if minimum surface to lateral wave and current forces is desired.	Difficulty in maintaining orientation during driving.
	High bending moment about both axes in relation to cross-sectional area.	High cost of manufacture. Difficulty of orientation.
	High bending moment about axis x - x in relation to cross-sectional area.	High cost of manufacture. Difficulty of orientation.

Note: Hollow cores may be employed with most shapes. Varying cross-sections may be employed along the length of the pile—such as enlarged tips for bearing, enlarged upper sections for moment, or a change to a circular upper section in order to eliminate corners, etc. These changed sections may either be cast monolithically or spliced on at any stage. Change in cross-section should employ a transition section at least twice the length of the radial change.

Figure 63. Cross-sectional shapes for prestressed concrete piles (courtesy of John Wiley and Sons, Inc.[6])

octagonal piles (Figure 64). When this type of pile exceeds approximately 2 by 2 ft, economics dictate that consideration be given to the use of hollow-core circular or octagonal piles. This is particularly true in the case of jetty work where the unsupported length of pile is very great as compared with its cross-sectional area.[37] An advantage of hollow prestressed concrete piles is the combination of light weight for easy handling with maximum economy of material and virtual freedom from cracking. The disadvantages of this type of pile are the requirements for a special type of driving head, a very heavy hammer, and some form of venting near the top to avoid damage from the "hydraulic ram" effect inside the hollow core.

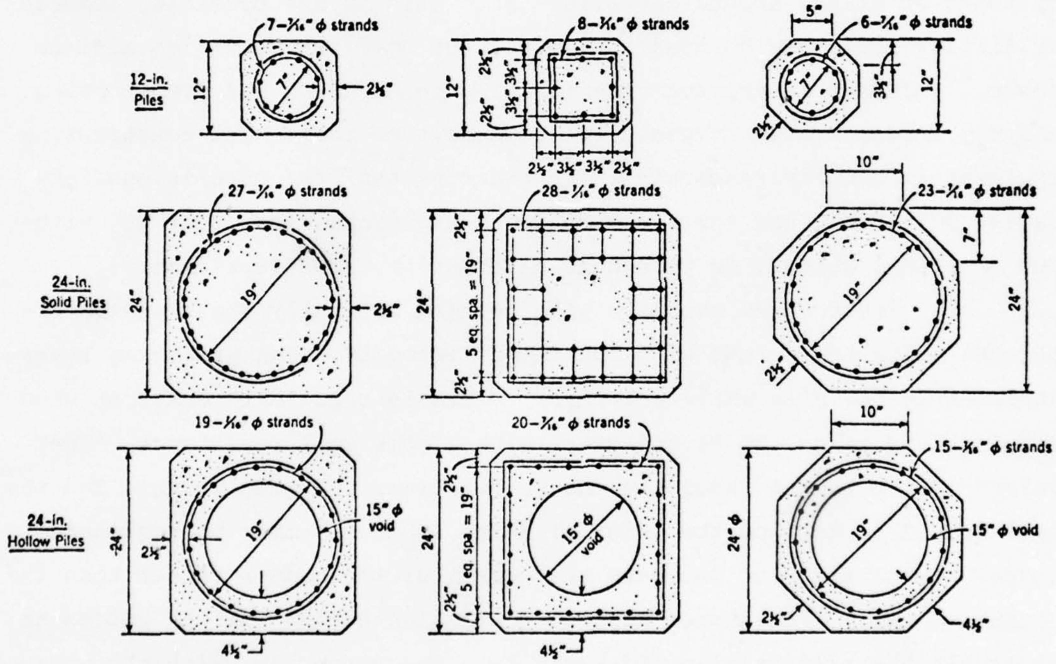


Figure 64. Typical pretensioned pile sections (AASHO-PCI Standard) (courtesy of John Wiley and Sons, Inc.[39])

79. Precast, posttensioned piles are normally competitive with pretensioned piles only when they can be made on the site or are over 40 ft long because of the end anchorage cost associated with them.[38] Posttensioned hollow tube piles with 48- to 72-in. diameters and 5-in. walls have been used extensively, particularly for deep foundations.

These piles are cast in sections with cored holes and aligned horizontally; then, the longitudinal tendons are threaded through, and the whole is posttensioned together. Driving is accomplished in the same manner as standard piles.

80. Experience seems to indicate that a prestress of about 700 psi in the piles will ensure safety during handling and driving under normal conditions.[39] However, prestressed concrete piles must be handled and stored with care to prevent damage to each pile. Piles should be lifted and blocked for storage at predesignated points such that bending stresses will be within acceptable limits. Where the sides and bottom of the pile are accessible, lifting is usually accomplished by tongs or slings around the pile. When this is not possible, inserts or lifting loops may be used. Inserts must have the specified minimum cover.[40] Impact is another consideration in handling and transporting and may impose static stresses of 50 percent or more. The construction engineer is usually responsible for ensuring that the pile is manufactured, delivered, and installed in its design condition, that is, without cracking, damage, or permanent deformation from overstress.

81. Prestressed concrete pile driving generally should be accomplished using heavy rams with low impact velocity, thus producing lower stresses in the pile while driving.[40] This is especially critical when driving long piles (50 ft and over) with little soil resistance. The weight of the hammer should be one to two times the pile weight, and the fall should be kept on the order of 3 ft. When a hammer proves inadequate, it is better to increase the weight of the hammer rather than the height of fall. The hammer must be controlled during fall by guides so as to hit the pile axially and squarely. The manner in which the operator releases the drop hammer and/or restrains it during its fall has an important effect on the actual velocity at impact (and thus on the effective energy delivered).

82. It has been found that pile hammers with an energy within the limits shown below are usually adequate for driving in the moderate to hard driving range.[39] These values are listed for reference rather than for absolute guidance:

Pile Size, in.	Ft-Lb of Energy
10	8,000-15,000
12	15,000-19,000
14	15,000-24,000
16-18	24,000-32,000
20-21	24,000-36,000
24 and over	32,000-38,000

83. In some cases, cracking or spalling has occurred during driving of prestressed concrete piles. This damage or failure can be classified into four types:[40]

<u>a</u>. Spalling of concrete at the head of pile due to a high compressive stress. This may be due to insufficient cushioning material between the pile driver cap and the pile, improper axial alignment of the hammer and pile, irregular cutoff of reinforcing in pile end, lack of adequate spiral reinforcing at the pile head or point, concrete fatigue due to a large number of high stress blows, or from not chamfering the edges and corners of the pile.

<u>b</u>. Spalling of concrete at the point of the pile due to hard driving resistance. Compressive stress when driving on bare rock can theoretically be twice the magnitude of that produced at the head of pile due to hammer impact.

<u>c</u>. Transverse cracking or breaking of the pile due to tensile stress reflected from the tip or head of the pile. This cracking may occur in the upper end, midlength, or lower end of the pile. As previously mentioned, use of a heavier hammer with lower velocity should help this situation.

<u>d</u>. Spiral or transverse cracking due to a combination of torsion and reflected tensile stress. This may be caused by the helmet or pile cap fitting too tightly on the pile and preventing normal rotation, or by excessive restraint of the pile in the leads and rotation of the leads.

84. A number of methods are in current use for lengthening of prestressed concrete piles (Figure 65). The simplest is the epoxy-doweled splice. This method usually has four dowels of deformed reinforcing bar precast into the top section. These dowels are extended 20 to 30 diameters in length into matching corrugated metal tubes precast in the head of the bottom section. Epoxy is poured into the holes and allowed to set (ranges from 30 min to 12 hr, depending on epoxy type

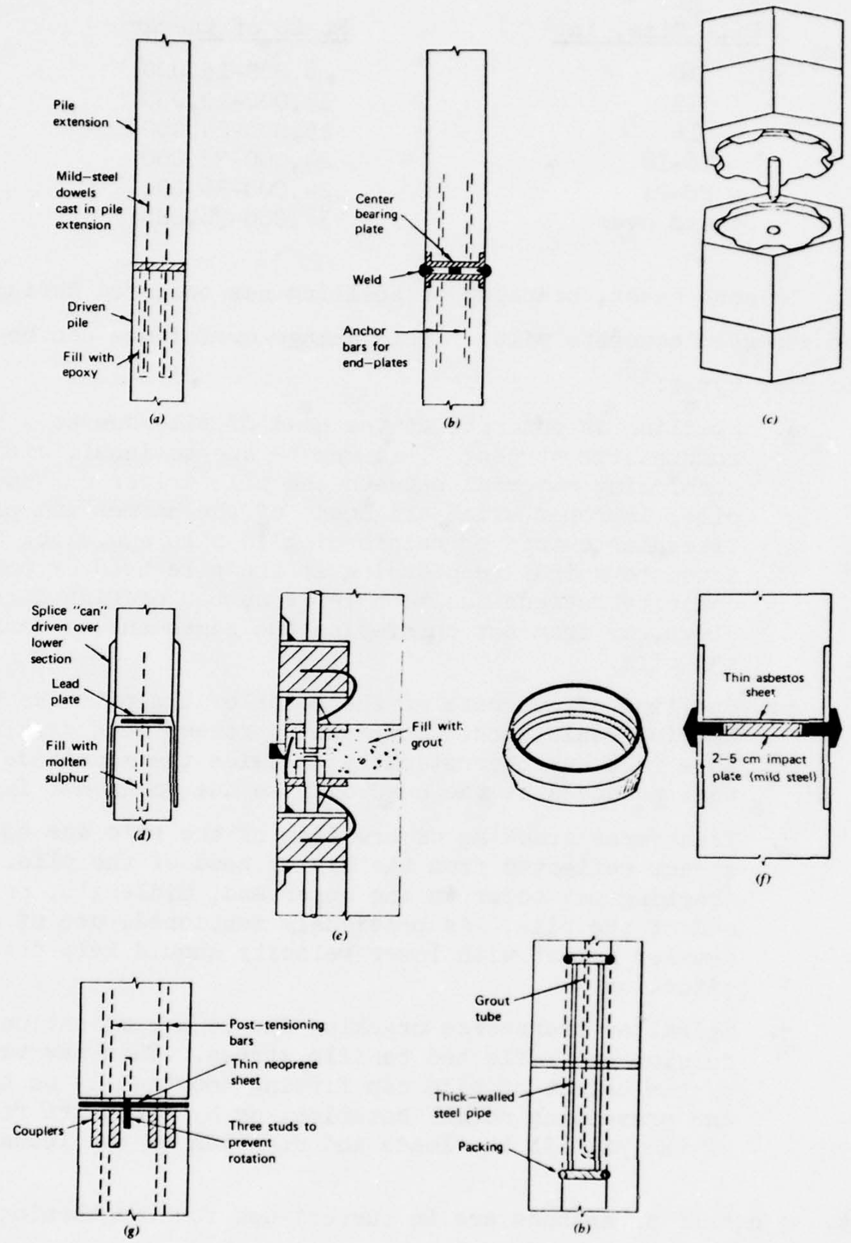


Figure 65. Typical splice details for prestressed concrete piles: (a) epoxy-doweled splice--United States, Norway; (b) welded splice; (c) mechanical splice (Swedish patent); (d) steel splice sleeve or "can"; (e) welded splice--Japanese patent; (f) "Brunsplice" joint--United States patent; (g) posttensioned splice--Great Britain; (h) steel pipe splice for hollow piles--Norway (courtesy of John Wiley and Sons, Inc.[6])

and temperature). The Japanese have adopted a cast steel end piece that facilitates anchoring of the tendons during manufacture and permits rapid jointing by welding. A Swedish mechanical splice engages and locks mechanically, as by a screwed joint or wedge effect. There are friction splices available in which a sleeve is driven over a male casting, locking itself by wedging. Other splices used are a posttensioned splice from Great Britian and a steel pipe splice for hollow piles from Norway. It is important that with any splice, the sections be essentially center-bearing, and the concrete immediately above and below the splice be contained with heavy spirals of steel.[6]

85. The most versatile and widely used connection of precast concrete pile to cast-in-place cap is similar to that used for many years in conventionally reinforced piles (Figure 66). The conventional

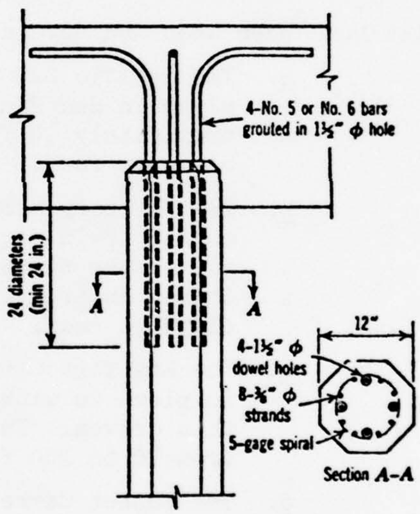


Figure 66. Connection of precast pile to cast-in-place cap (courtesy of John Wiley and Sons, Inc.[39])

reinforcing bars can be precast in the head of the pile, requiring a special driving head, or grouted into either precast holes or holes drilled after driving.

86. Service functions to which prestressed concrete piling installations may best be adopted are:[41]

a. Bearing piles--service stresses are compressive but the piles are subject to recoil during driving.

b. Sheet piles--service stresses are generally flexural.

Tensile stresses result from rebound during the driving process.

c. Combined bearing and sheet piles--driving stresses similar to sheet piles. Service loads may offset part or all of the flexural tensile stress, depending on the relative magnitude of vertical and lateral loads.

d. Outstanding vertical piles of pier or jetty bents--tensile stresses during the driving process, or combined tensile stress under the action of vertical and lateral loads. There is also the possibility of uplift forces.

e. Anchor piles--tensile stress waves during the driving process and maximum tension under a certain combination of service and environmental loads.

f. Fender piles--depending upon lengths, driving conditions, and ship berthing impact, either maximum service flexural tensile stress or maximum tensile stress due to rebound in the driving process may govern.

87. There are many construction sites where prestressed square piles have been used and several of these are:

a. The Pacific Gas and Electric Company's new steam-power plant in San Francisco uses 18-in.-square piles approximately 90 ft long, driven through fill and soft clays to rock.

b. The 43-story Wells-Fargo Building in San Francisco required 18-in.-square piles up to 138 ft long. These piles were tipped with a 3-ft-long steel "H" stub and driven in predrilled holes through sandy clay, sand, and clays to rock.

c. The New York City Bridge has 24-in.-square piles, jetted in place to within a few feet of final tip elevation, then driven. These piles were cast in lengths varying from 70 to 100 ft based on test soil borings.

d. The Bonnet Carre Highway Bridge near New Orleans, Louisiana, used 20-in.-square piles.

88. Octagonal prestressed concrete piles are also widely used, and the following are examples of this construction:

a. The National Art Gallery and Cultural Center of Melbourne, Australia, employs 18-in.-octagonal piles up to 100 ft long and driven through peat and clay to shale.

b. The Ala Moana Building, a 25-story tower in Honolulu, is supported by 18-in.-octagonal end-bearing piles approximately 170 ft long.

c. The Ilikai Building in Honolulu is supported on 16-1/2-in.-octagonal piles approximately 110 ft long. Piles had to be driven through an upper hard coral stratum, sometimes requiring several thousand blows before breaking through.

d. Louisville and Nashville Railroad, Louisville, Kentucky, used 24-in.-octagonal piles.

89. Several examples of the usage of prestressed concrete cylinder piles are:

a. The Oosterschelde Bridge (the Netherlands) used three piles per pier, cast 14 ft in diameter with 14-in.-thick walls and 20 ft in length, then joined together for the desired length.

b. The Dumbarton Bridge Renewal (Southern Pacific Company), San Francisco Bay, used two piles per bent, 48-in. outside diameter with 5-in. walls. The friction piles were 120 ft long, and the end-bearing piles were 60 to 74 ft long with no splices.

c. Construction of Interstate Route 87 in New York and Connecticut used 36-in. outside diameter with 5-in. walls. Splices were made using a combination of dowels and a 4-ft splice boot centered on the joint, filled with a quick-setting plasticized cement (Florok) that solidifies in a few minutes and reaches a strength of 5000 to 6000 psi in about 10 min. Driving could be resumed after 45 min.

d. A wharf project for the Port of Baton Rouge, Louisiana, used cylinder piles. The pile top was fixed to the pile cap girder by setting the heavy cage of mild reinforcing steel in the pile head and securing by a concrete plug.

90. Prestressed concrete sheet piles are being used as bulkhead walls for shoreline construction because of their durability, rigidity, and excellent appearance. One installation is a sheet pile wall in San Francisco Bay, and another typical construction is the sheet pile bulkhead walls at Davis Island, Tampa, Florida, used to protect the shoreline from erosion.

91. Prestressed concrete sheet piles are also used for cutoff walls, groins, wave-baffles, and retaining soil during excavation for foundations. In some recent building foundations, the prestressed concrete sheet piles were installed by a combination of predrilling and

driving. After excavation, the joints were welded and filled with non-shrink grout, and the sheet pile wall served as the permanent foundation wall of the building. When used for waterfront bulkheads and cutoff walls, the joints must be sealed, usually by filling with grout. A number of interlocks have been developed for prestressed sheet piles to give both structural strength and a degree of sand-and-water tightness. The ordinary tongue-and-groove interlock transmits shear but not tension. Steel sheet piles can be cut in half and embedded in the prestressed sheet piles, providing an interlock as tight and having same tensile strength as the steel. A polyethylene interlock has been developed that can be embedded in the concrete that acts both as an interlock capable of some tension and as a water stop.[6] Figure 67 shows the typical cross sections and details of prestressed concrete sheet piles and Figure 68, a plastic interlock detail. Driving concrete sheet piles is assisted frequently by jetting, and accurate setting is essential.

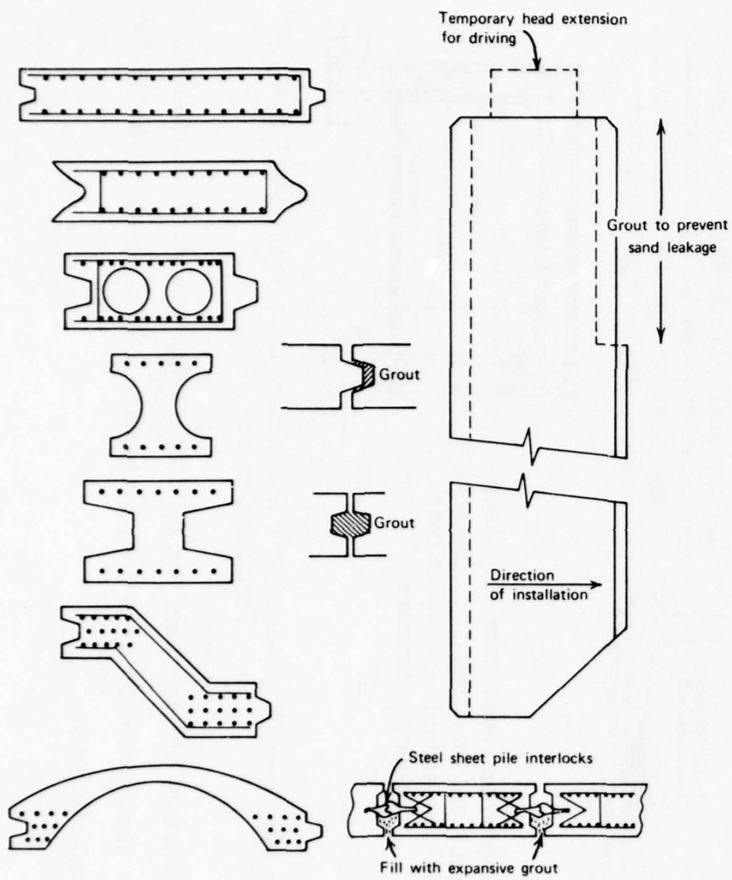


Figure 67. Typical cross sections and details of prestressed concrete sheet pile (courtesy of John Wiley and Sons, Inc.[6])

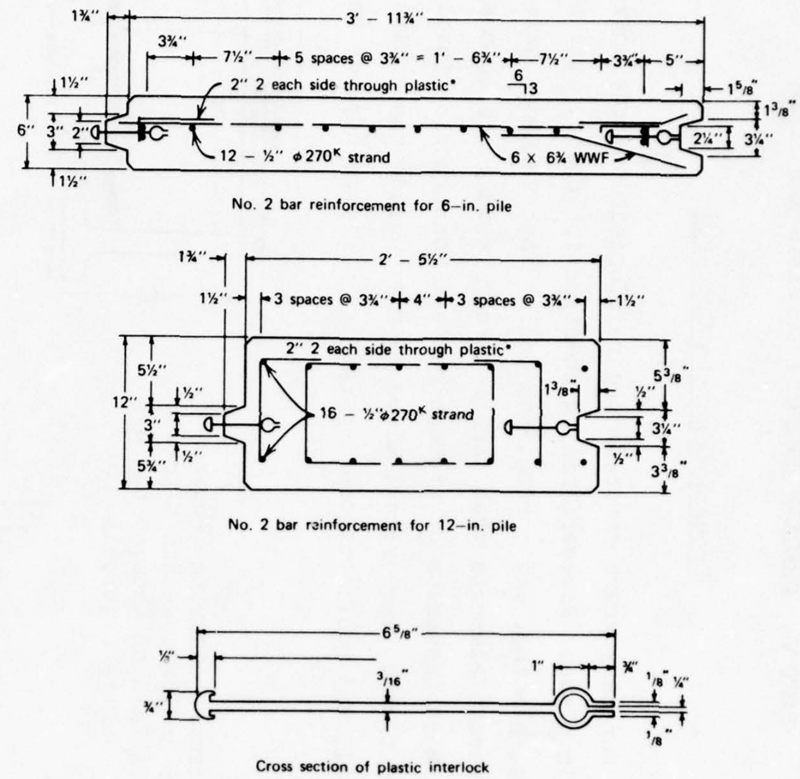


Figure 68. Plastic interlock for prestressed sheet piles (courtesy of John Wiley and Sons, Inc.[6])

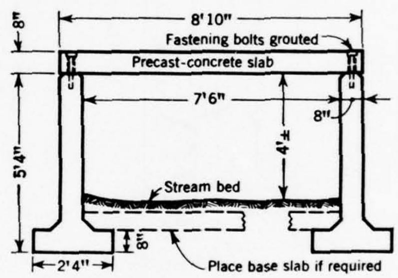
PART V: PRECAST CONCRETE CULVERTS AND PIPES

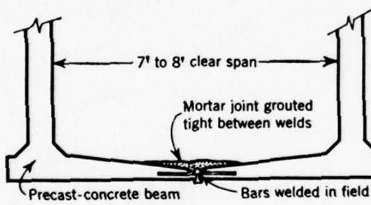
Precast Concrete Culverts

92. For many years concrete and reinforced concrete culverts have been cast in place. However, rising construction costs, time required for forming, placing, and curing, and public inconvenience have created a need for precast elements that can be placed rapidly and economically.

93. Most instances of precast culvert construction involve rectangular boxes. The precast elements may include the entire box, the bottom, wall, and roof sections separately[42] (Figure 69), or the bottom

a. Precast concrete T-beams are turned upside down and a precast slab is laid on them to build a culvert quickly





b. Special T's (L might be a better description) can be used to include a base slab in the three precast pieces needed for a culvert

c. A conventional cast-in-place concrete culvert requires several days to construct and sometimes lengthly detours

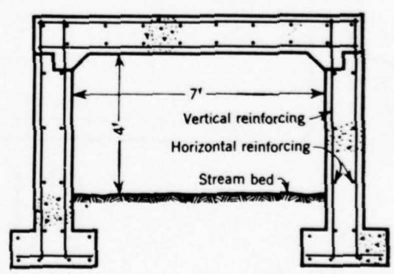


Figure 69. Use of precast T's and slabs in culvert construction (from Reference 42)

end, an inverted "U" section, to form the walls and roof (Figure 70). Very often the bottom is cast in place, with the precast inverted "U" being installed later.[43]

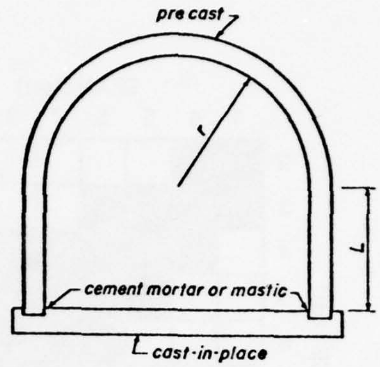


Figure 70. Precast horseshoe culvert (courtesy of Portland Cement Association[43])

94. Curved precast concrete members have been used to form two- or three-hinged arch culverts, as shown in Figure 71.

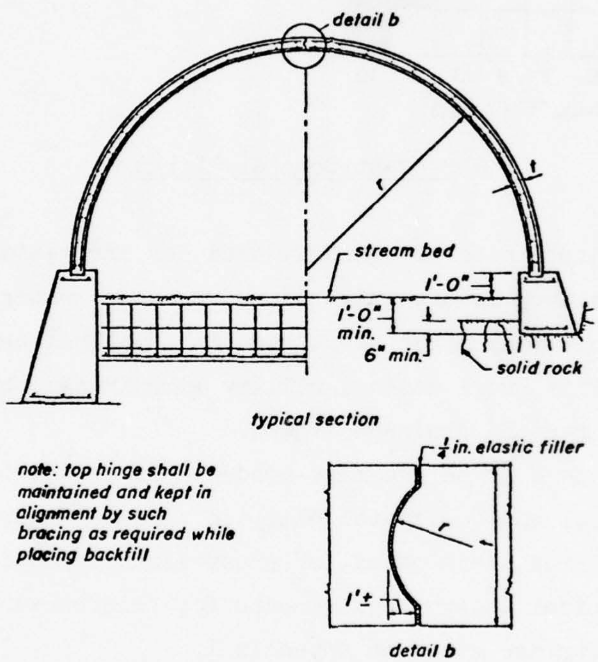


Figure 71. Precast circular arch culvert (courtesy of Portland Cement Association[43])

95. Standard precast concrete box culverts that are plant produced, manufactured under strict quality control procedures, and installed by rapid cut and fill procedures have been developed.[44,45] Figure 72 presents the recommended set of standard sizes produced in the United States and Canada. The design of standard box culverts has been verified by tests to meet the AASHO standards.

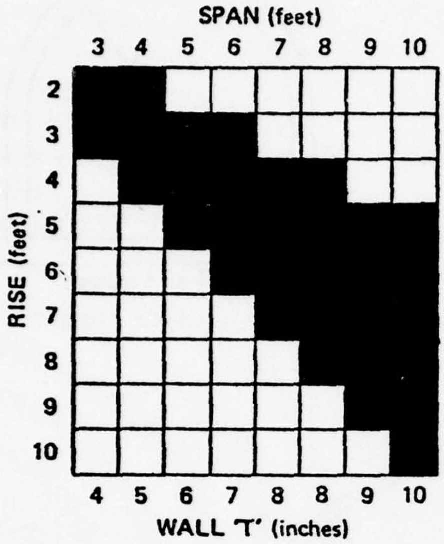


Figure 72. Recommended box culvert sizes and wall thickness (from Reference 44)

Precast Concrete Pipes

96. Concrete pipe is commonly used for irrigation, drain tile, storm sewer, sanitary sewer, culvert, and pressure water pipe. In addition, it has found many other uses, such as bomb shelters, cattle passes, septic tanks, silos, well casing, utility line trunks, bridge pier columns, and half-round drainage liners.

97. Standard pipes are mass produced in cylindrical, arch, flat base, and vertical and horizontal elliptic shapes (Figure 73). They may be nonreinforced, reinforced, or prestressed depending upon the intended use. Typical design requirements for reinforced concrete low-head pressure pipe are given in Appendix I.

98. Manufacturing processes[46] include cast and vibrated pipe, machine-made packerhead pipe, machine-made tamped pipe, machine-made centrifuged pipe, and combinations and innovations of these processes.

99. While special sizes and shapes of concrete pipe can be produced to meet nearly any need, Table 1[47] lists the common pipes that are available from most concrete pipe manufacturers as stock items. In addition, accessory items, such as bends, wyes, tees, connections, and manholes, are available in all common sizes.

100. A variety of standard joints are available to meet the requirements of the installation. They include the bell and spigot, tongue and groove, modified tongue and groove, rubber ring gasket, concrete or steel collar, and cement mortar joint (Figure 74). Joint sealing materials, such as bitumen, rubber, mastic, mortar, and epoxy, are commonly used on joints.

101. Special requirements can be met by the manufacture of concrete pipe in other than common sizes. For example, the use of reinforced circular, arch, or elliptical pipe in diameters to 120 in. is not unusual. Nonreinforced circular pipe, 84 in. in diameter, has been used successfully as highway storm drain by the California Division of Highways. The Bureau of Reclamation has used 156-in.-diam reinforced prestressed circular pipe for the Navajo Indian Irrigation Project in New Mexico. Probably the largest precast concrete pipe used to date in the United States has been the 17-ft-diam circular sections that are part of a storm drain in Troy, Michigan.

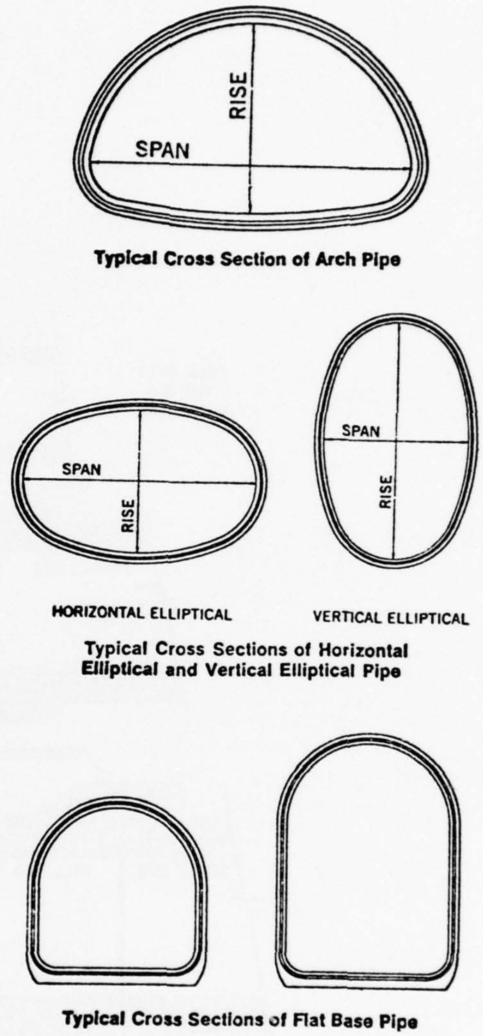


Figure 73. Typical cross sections of concrete (from Reference 47)

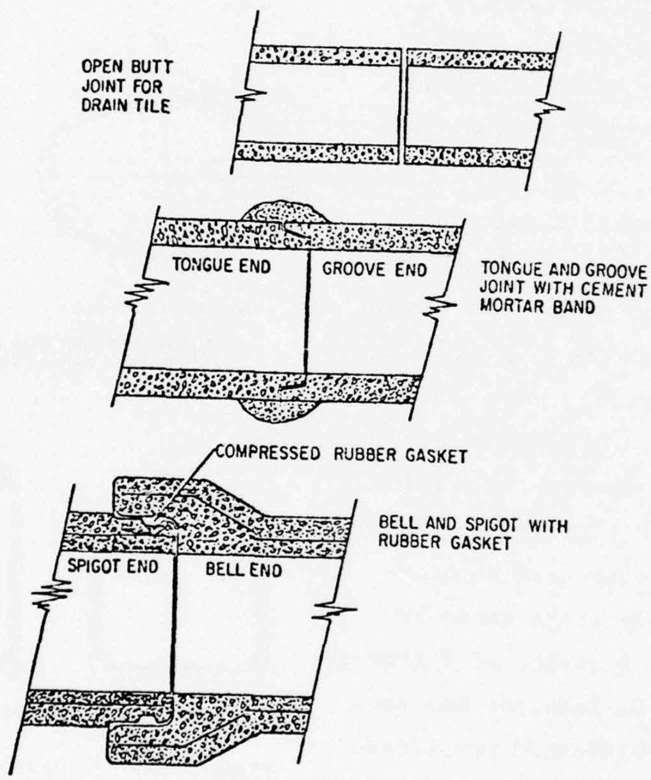


Figure 74. Typical concrete pipe joints
(courtesy of McGraw-Hill Book Company)

PART VI: PRECAST CONCRETE FLOATING STRUCTURES

102. Precast concrete is well adapted for floating structures of all types. The first recorded use of reinforced concrete was the concrete boat that Lambot built about 1858 in France.[48] Reinforced concrete ships were constructed in substantial numbers in World Wars I and II, and a considerable number of concrete floating dry docks and moored floating docks are in service throughout the world.[49]

103. The more recent advent of prestressing makes possible more efficient structural designs since prestressing offers superior performance along with substantial economy.

104. Almost 20 large pretensioned concrete barges have been constructed in the Philippines and have been in practically continuous ocean service since 1964.[50] These barges are generally of 2000-ton capacity and carry both dry cargo and petroleum products.

105. Recently a number of barges and dredge hulls have been built of prestressed concrete in New Zealand for service in the South Pacific.

106. Prestressed concrete barges for the transport of cryogenic materials have been studied and proposed in England.[51] The favorable behavior of prestressed concrete at very low temperatures promises added security for this type of usage.

107. Structural lightweight concrete was used with excellent results and durability in some of the ships constructed during World Wars I and II; it appears that prestressed lightweight concrete may be an ideal material for precast concrete floating structures.[48]

108. Precast concrete pier components capable of handling live loads of 1000 lb/sq ft, high-concentrated wheel loads, and a gantry-type container crane are seen as a means of providing expedient military ports.[52] Conceptually this module is 35 ft wide, 97 ft 6 in. long, and 12 ft deep with a dead load of 970 to 980 short tons. Modules would be precast ashore, loaded on a Seabee barge ship, transported to the TO, unloaded, and floated into place. Through use of four caissons and DeLong jacks, the pier modules would be jacked to the required elevation. After 24-in.-diam precast concrete piles are driven through

precast holes and epoxied to the girders, the caissons and jacks would be withdrawn to be used on another module. In addition to being used as pier components, modules could also be used as a causeway with a roadway width of 35 ft (Figure 75). Similarly, a dedicated elevating system could be used because with the elevating legs for support, the need for piling is eliminated. Such a structure could be easily lowered or raised as necessary during the course of normal ship off-loading. Additionally, it would have the capability of being easily relocated.

109. Large floating platforms consisting of concrete components mass produced ashore, constructed in modules, launched, towed to the site, and assembled are envisioned as a means for satisfying forward areas surveillance and basing requirements of the Navy in the mid 1980's.[53] Platform concepts consisting of single-story or multistory decks were classified according to their buoyant elements into three basic types: (a) elevated platforms (Figure 76) supported on vertical, hollow buoyant legs; (b) barge platforms (Figure 77) supported on barge-type hulls; and (c) semisubmersible platforms (Figure 78) supported on vertical legs atop submerged horizontal pontoons. The various configurations were investigated using concrete as the construction material; based on a synthesis of concepts, concrete production, construction methodology, and cost, it was concluded that concrete is a feasible and practical construction material for large ocean platforms.

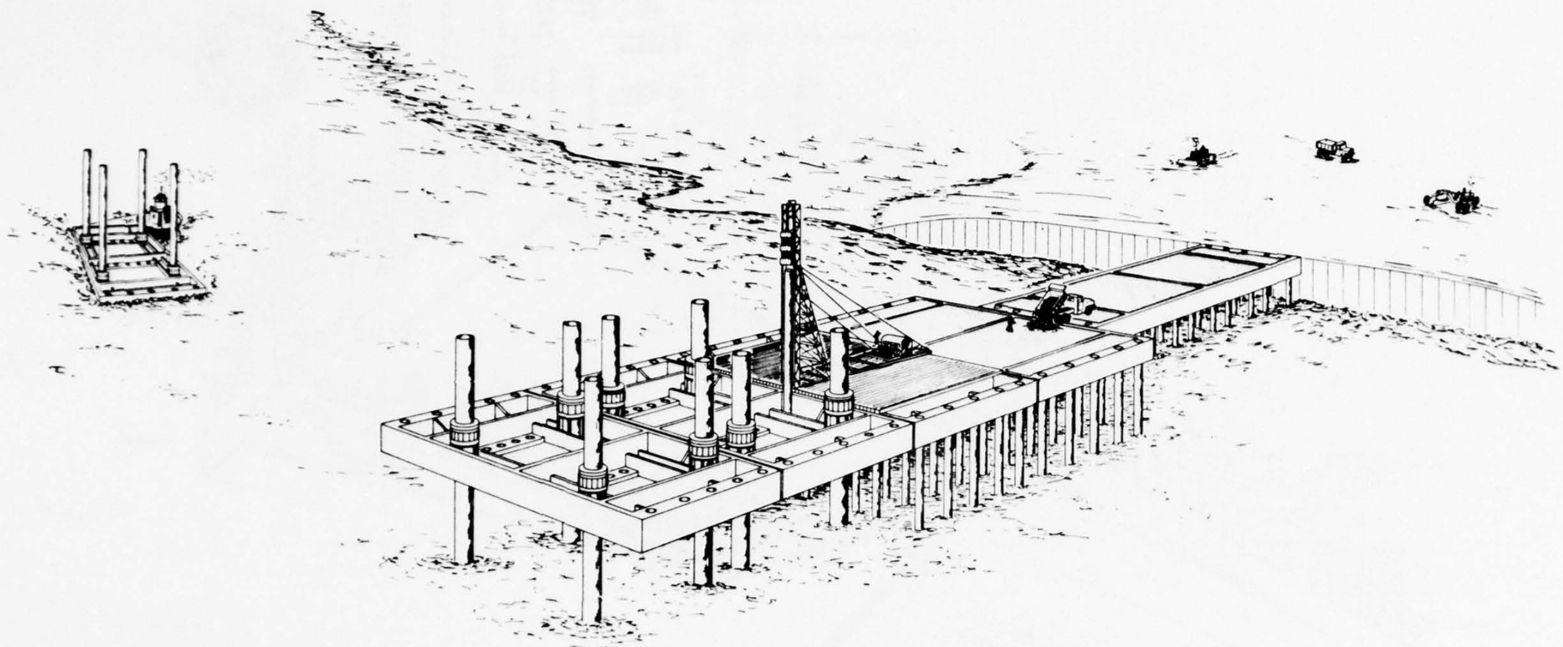


Figure 75. Artist's concept of concrete pier module installation (from Reference 52)

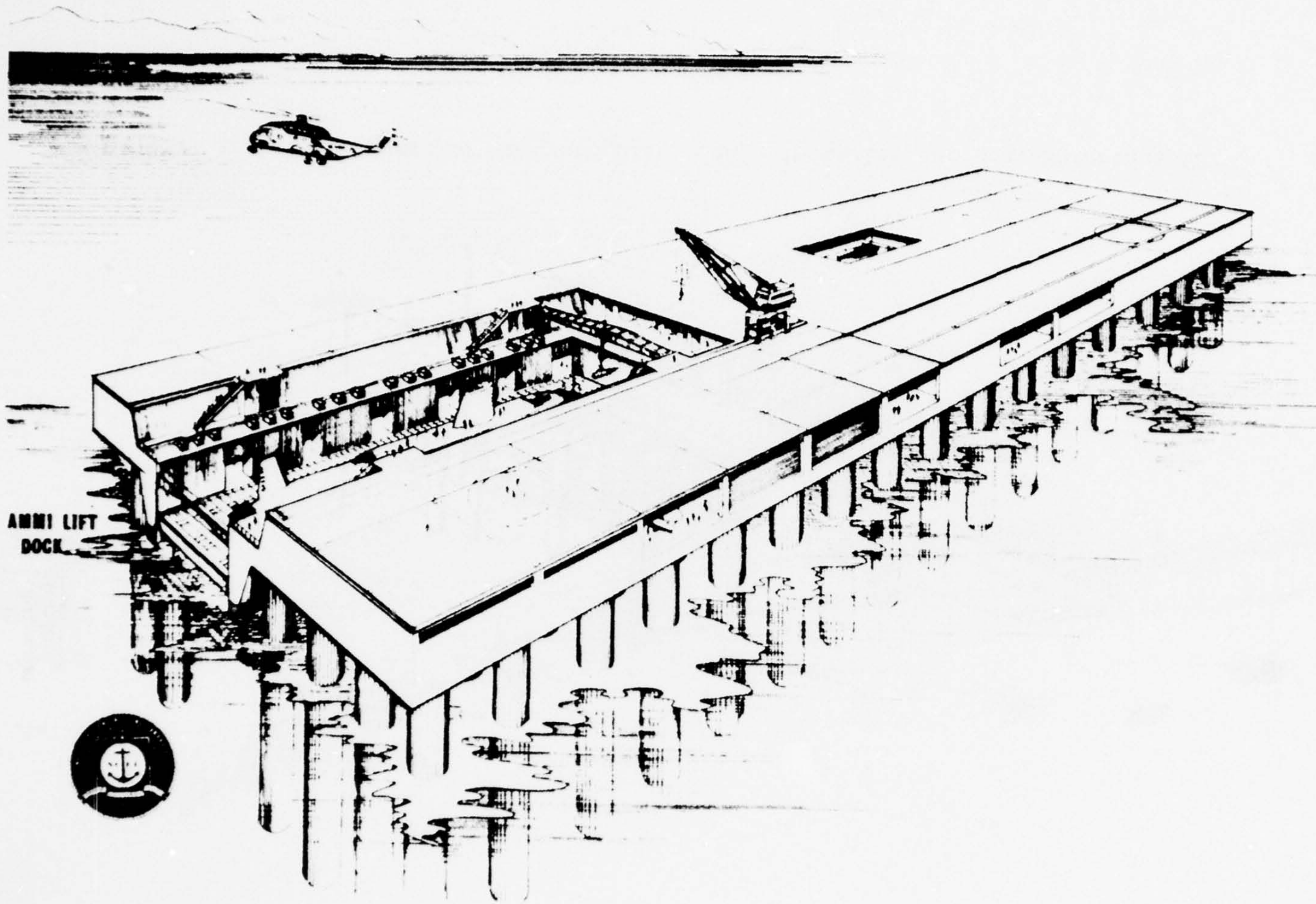


Figure 76. Elevated platform with circular cylindrical legs (from Reference 53)

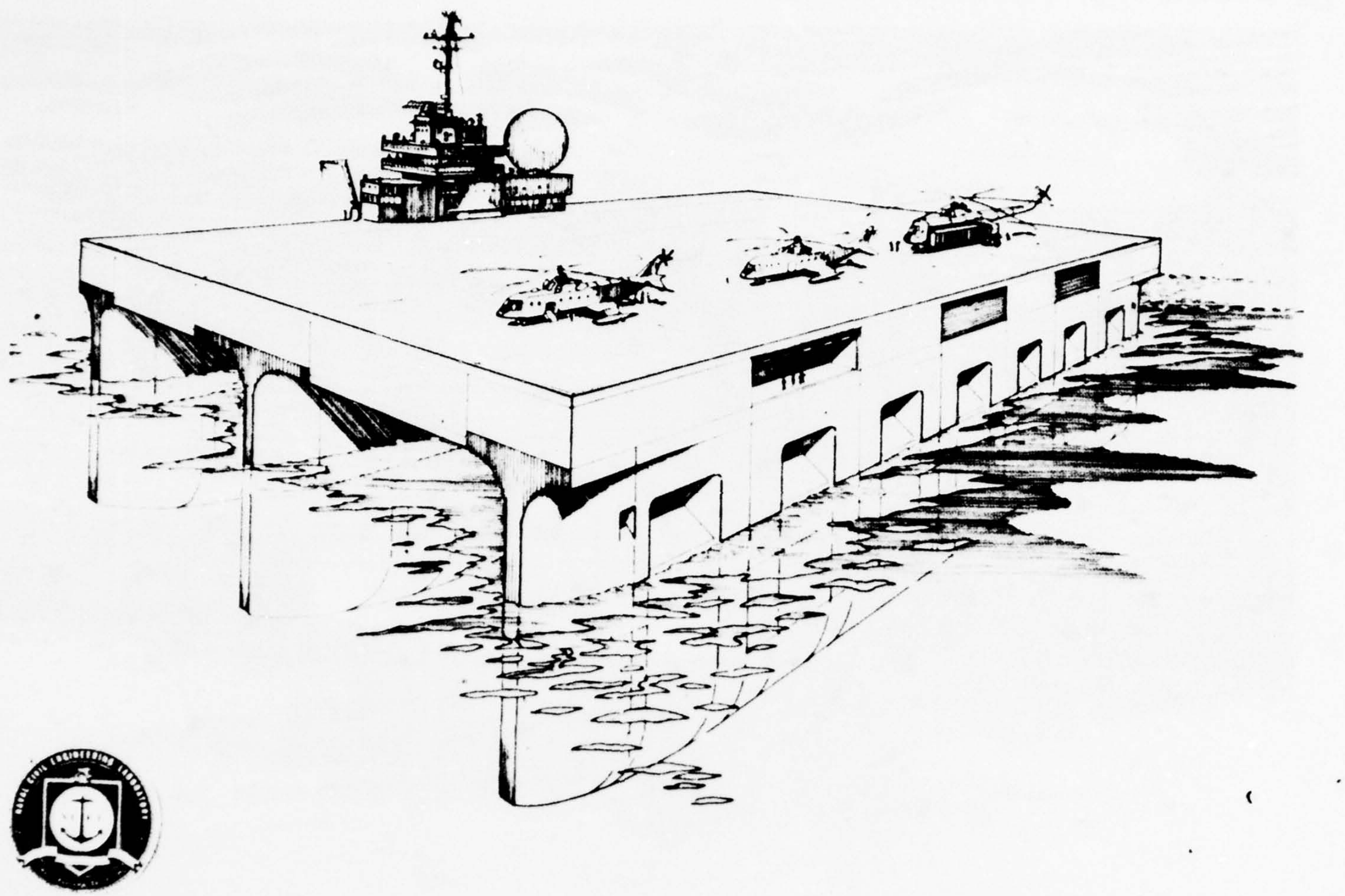


Figure 77. Three hundred- by three hundred-foot MOBS trimaran barge platform (from Reference 53)

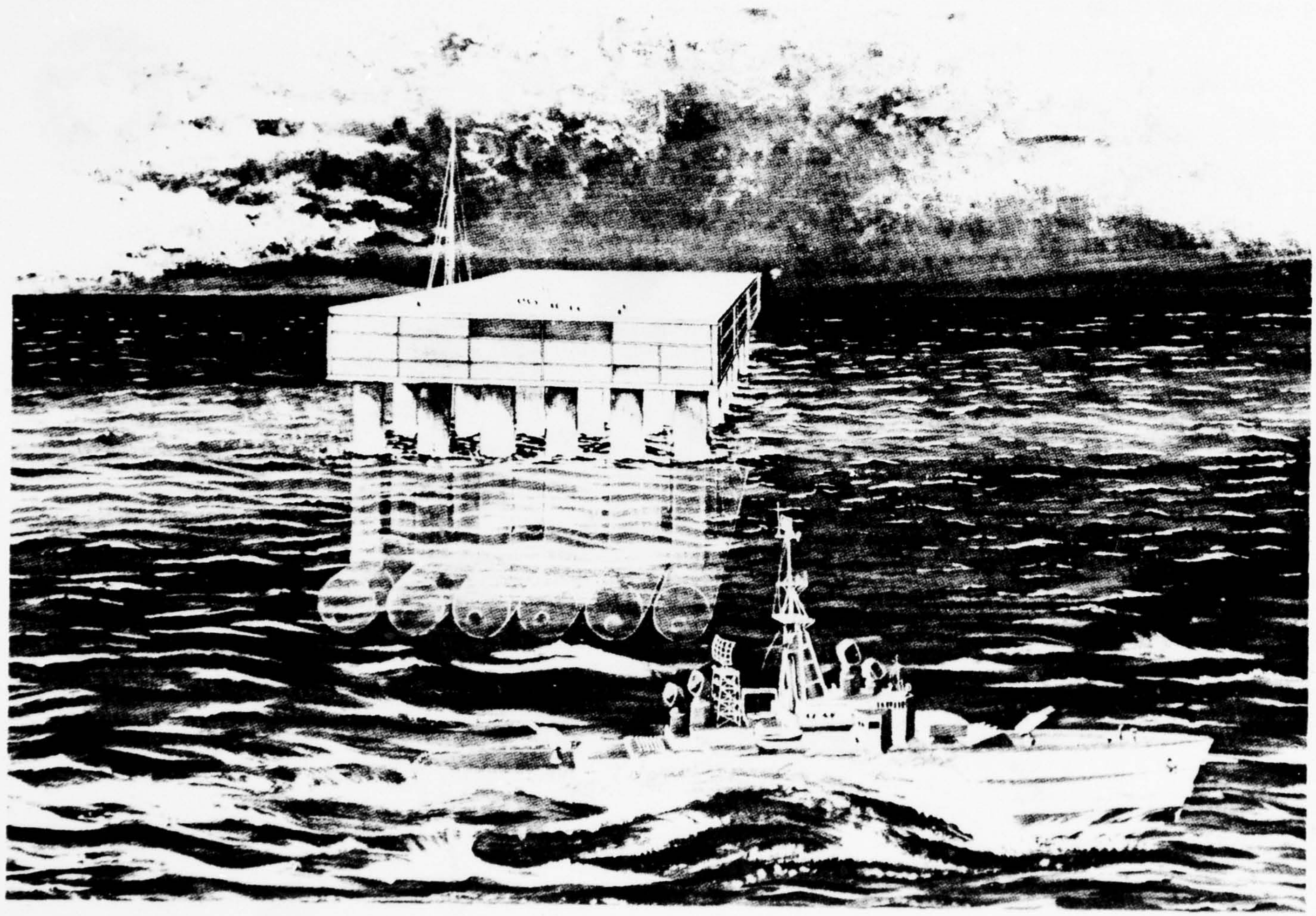


Figure 78. Three hundred- by three hundred-foot semisubmersible platform section (from Reference 53)

PART VII: PRECAST CONCRETE FIELD FORTIFICATIONS

110. Precast concrete field fortifications have been used by U. S. troops during combat operations. They include security/fighting bunkers, protective shelters, and equipment and supplies revetments. A brief discussion of these precast concrete field fortifications is given in the following sections.

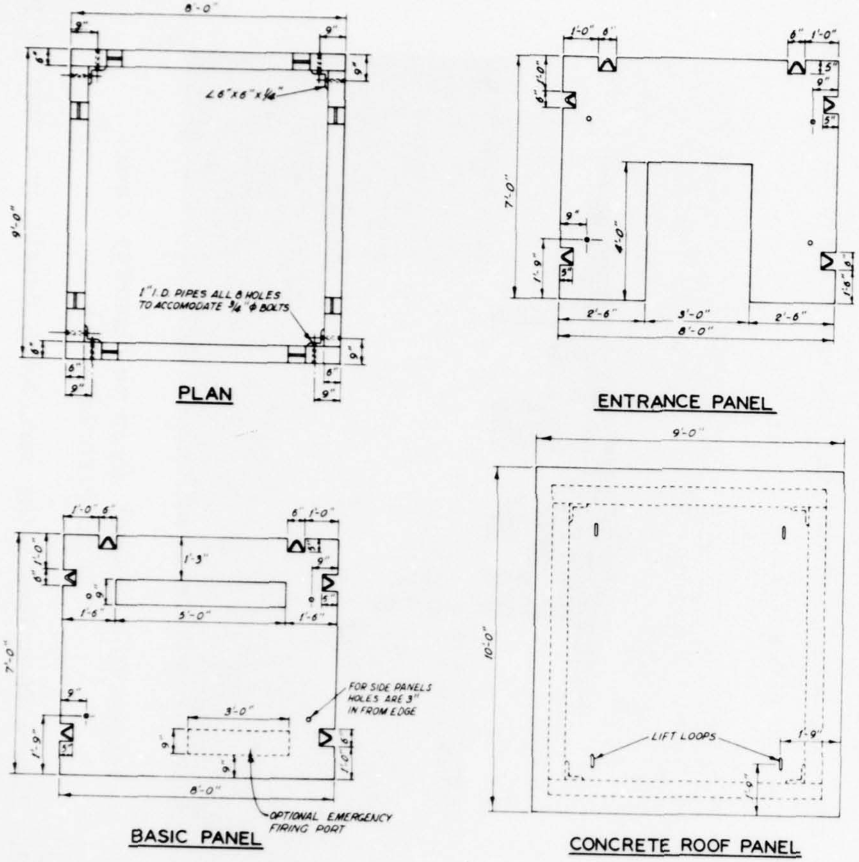
Security/Fighting Bunkers

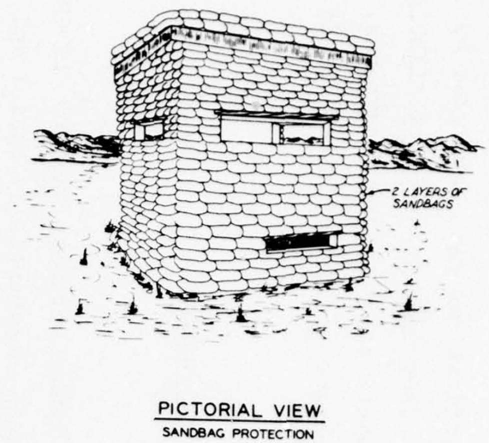
Concrete panel bunkers

111. A typical precast concrete panel security bunker[54] is shown in Figure 79. Security bunkers have been used partially buried and on towers but most often were installed on the ground surface. The firing ports are large for maximum visibility and are located on the front wall and each of the two sidewalls.

Figure 79. Precast concrete security bunker (from Reference 54)

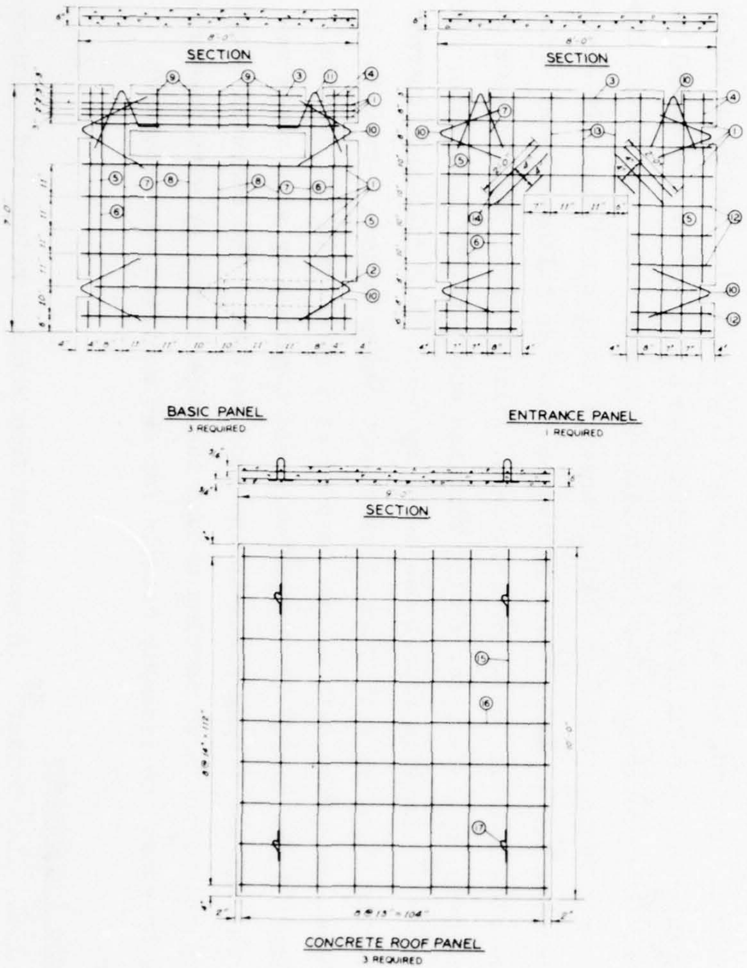
112. Figure 80 presents the structural detail of a typical precast concrete panel security bunker. This structure is designed to be





BILL OF MATERIALS			
ITEM	UNIT	QUANTITY	REMARKS
1. CONCRETE (3000 PSI)	CU YD	7	
2. REBAR #4	20' PC	55	(1100 LF)
3. BOLTS/NUT 3/4" φ 7"	EA	16	
4. 6" x 6" x 1/4" STEEL∠ 12" LG	EA	8	
5. 1" I.D. PIPE 6" LONG	EA	16	

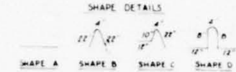
Figure 80. Structural plans for precast concrete panel security bunker (from Reference 54) (sheet 1 of 2)



REBAR SCHEDULE

ITEM	SHAPE	QUANTITY	LENGTH	TOTAL LENGTH
1	A	24	7'-10"	187'-11"
2	A	9	6'-10"	61'-6"
3	A	4	4'-10"	19'-4"
4	A	24	0'-10"	19'-11"
5	A	8	3'-10"	30'-8"
6	A	10	6'-10"	68'-4"
7	A	8	6'-5"	51'-4"
8	A	15	4'-10"	72'-6"
9	A	15	1'-1"	16'-3"
10	B	18	4'-0"	72'-0"
11	C	6	4'-0"	24'-0"
12	A	12	2'-4"	28'-0"
13	A	3	2'-10"	8'-6"
14	A	4	2'-0"	8'-0"
15	A	18	9'-10"	177'-0"
16	A	18	8'-10"	159'-0"
17	D	4	3'-8"	14'-8"

SHAPE DETAILS



NOTES 1. ALL REBARS #4
2. MAINTAIN 1 IN CLEARANCE BETWEEN REBARS AND CONCRETE SURFACES UNLESS OTHERWISE NOTED
3. DESIGN STRESS FOR REBAR STEEL IS 20,000 PSI
4. IF MG FIRING PORT IS DESIRED INCREASE HEIGHT OF FIRING PORT SHOWN FOR BASIC PANEL AS REQUIRED. INCREASE SHOULD BE MEASURED DOWN FROM TOP SURFACE OF EXISTING PORT

Figure 80 (sheet 2 of 2)

prefabricated in a rear area and transported to where needed for assembly.

113. Protection provided by this bunker is excellent, especially if loose earth is pushed up or sandbags are stacked against the walls and over the roof.[54]

Modified concrete arch bunkers

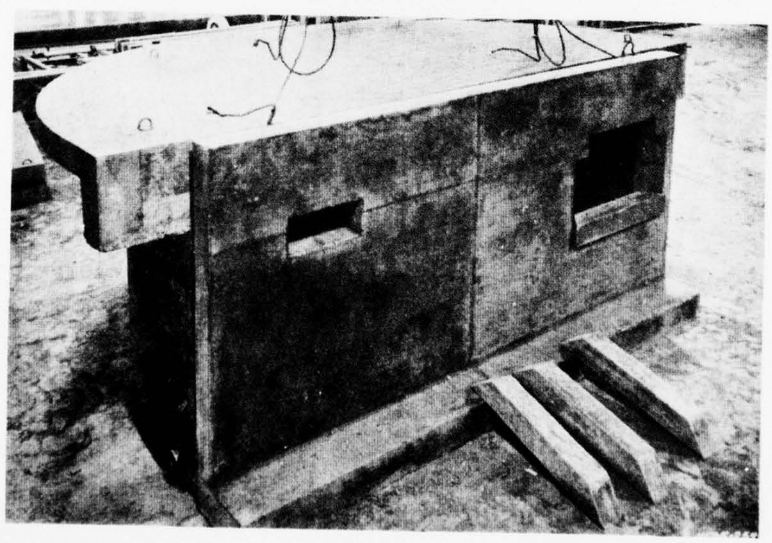
114. This bunker[55] was developed from components of the concrete arch shelter (see paragraph 122). The height of a shelter arch section was increased to provide the basic unit of the bunker. An end wall section from the concrete arch shelter was used as the roof, and a rectangular concrete section was designed as a backwall for the bunker (Figure 81).

115. The modified concrete arch bunker was semicircular in plan and consisted of three components: a 6-ft-high arch section, a rectangular backwall section, and a roof section (Figure 81a). The 6-in.-thick arch section had a 6-ft interior radius plus a 1-ft-6-in. horizontal extension, thus providing a 7-ft-6-in. inside dimension at the center line of the arch width. The 6-in.-thick backwall section and the 6-in.-thick roof section had an 8-in.-thick by 1-ft-6-in.-wide bulkhead beam. The arch section had four 8-in. by 1-ft-6-in. firing ports, and the back wall had one 8-in. by 1-ft-6-in. firing port and one 8-in. by 2-ft-6-in. firing port. By removing four loose 6-in. by 6-in. by 2-ft-6-in. concrete blocks, the 8-in. by 2-ft-6-in. firing port can be made a 2-ft-6-in. by 2-ft-6-in. emergency exit or can be used as a quick exit for grenade throwing (Figure 81b). The bunker was held together by wire ropes secured through the firing ports to the roof section. The backwall section was secured to the arch section around the pipe struts by wire rope also. Figure 82 shows the assembly details for the modified concrete arch bunker.

Concrete log bunkers

116. This bunker[55] is assembled from precast reinforced concrete logs of various lengths with interlocking ends (Figure 83). In the TO, the arrangement of the logs to form a fighting fortification would be left to the discretion of the tactical commander who could select a configuration to meet his specific requirements. Figure 84 presents the

a. Front view



b. Rear view (three blocks are stacked on the block in the emergency exit to form a firing port)

Figure 81. Modified arch fighting bunker (from Reference 55)

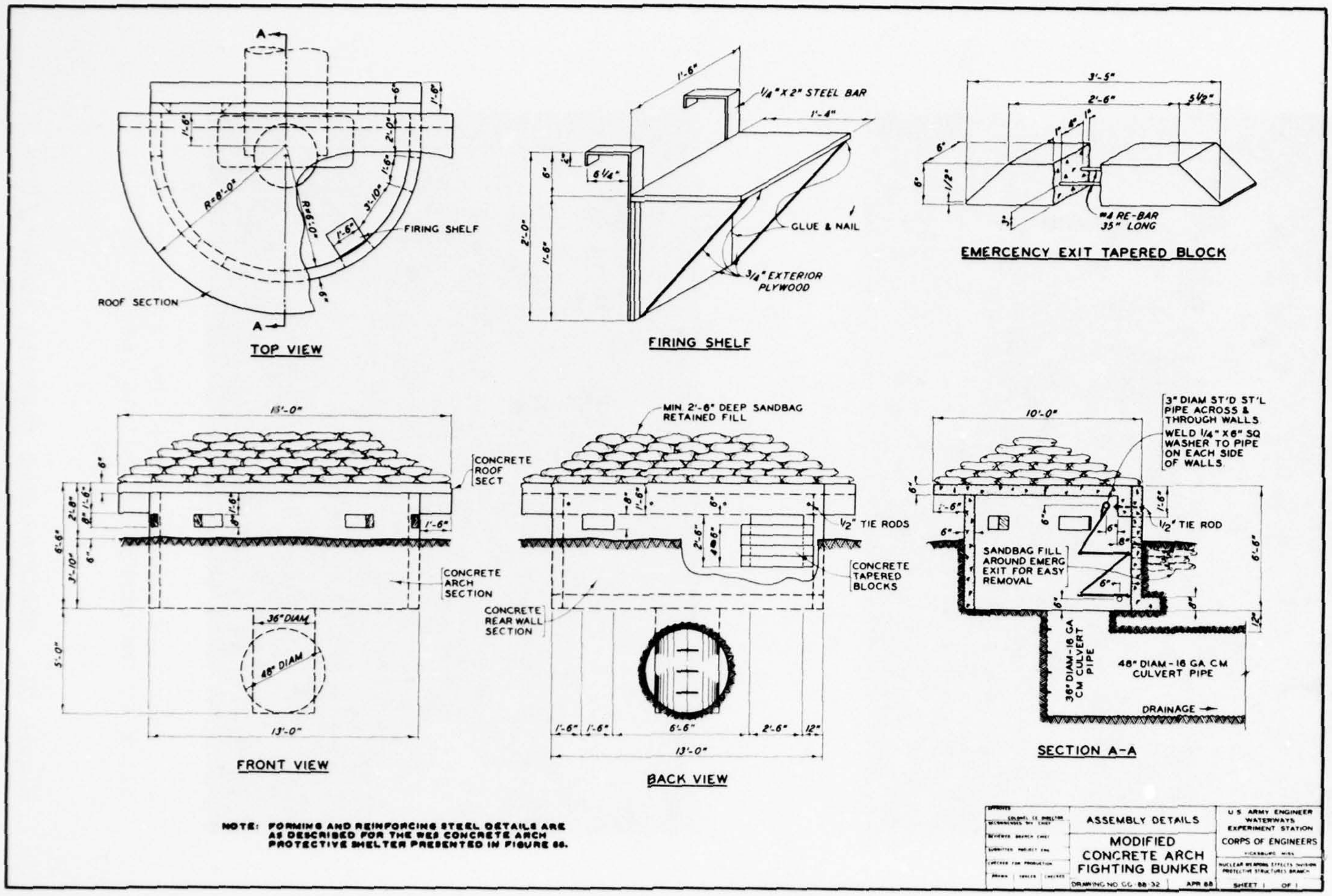
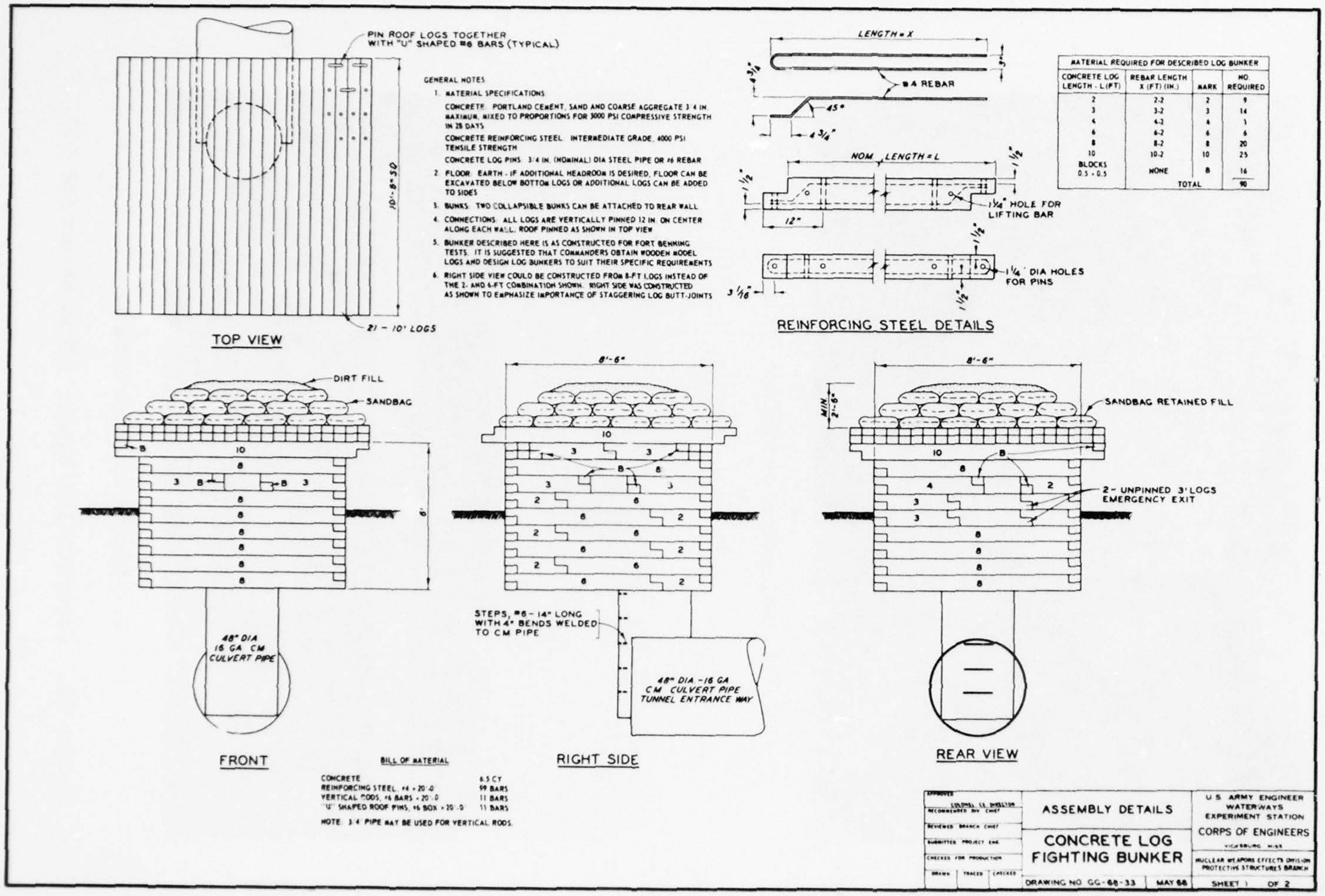


Figure 82. Modified concrete arch bunker (from Reference 55)

a. Installation of bunker (rear view)

b. Completed emplacement

Figure 83. Concrete log bunker (from Reference 55)



MATERIAL REQUIRED FOR DESCRIBED LOG BUNKER			
CONCRETE LOG LENGTH - L (FT)	REBAR LENGTH X (FT) (IN.)	MARK	NO. REQUIRED
2	2-2	2	9
3	3-2	3	14
4	4-2	4	1
6	6-2	6	6
8	8-2	8	20
10	10-2	10	25
BLOCKS 0.5 × 0.5	NONE	B	16
	TOTAL		90

Figure 84. Concrete fighting bunker (from Reference 55) (sheet 1 of 2)

AD-A053 165 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/2
PRECAST CONCRETE ELEMENTS FOR STRUCTURES IN SELECTED THEATERS O--ETC(U)
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UNCLASSIFIED WES-TR-C-78-1 NL

2 OF 3
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OF 3

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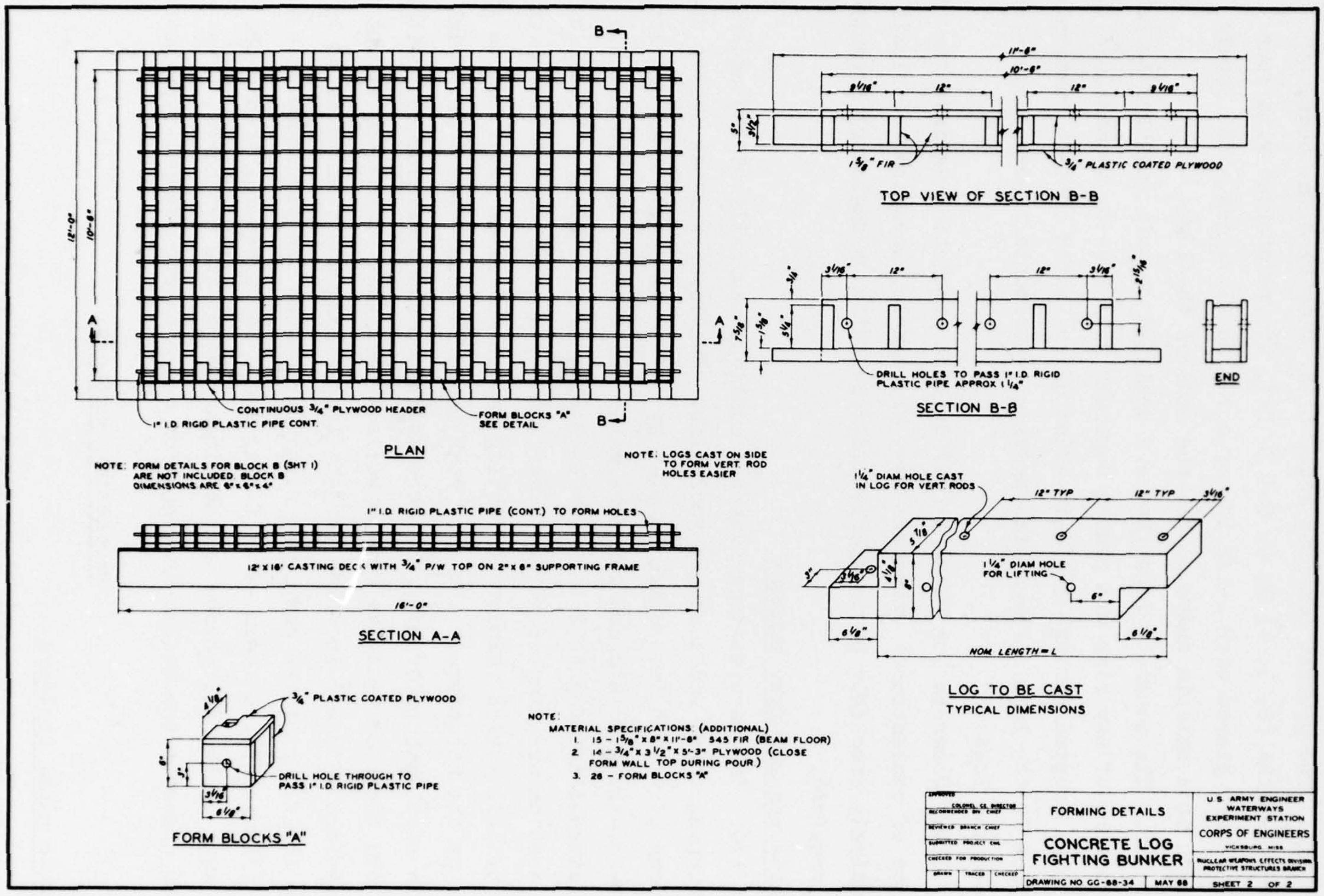


Figure 84 (sheet 2 of 2)

design drawings for a typical concrete log bunker.

117. The precast concrete logs, 6 in. wide by 8 in. deep, of various lengths (2, 3, 4, 6, 8, and 10 ft), are reinforced with four No. 4 rebars placed with 1-1/2 in. of cover on all sides. The rebars are bent in a hairpin shape to fit the ends of the logs.

118. The concrete logs that are designed to join together to make a structure of any size are pinned together with 3/4-in. (nominal)-diam pipe pins dropped through 1-1/2-in.-diam holes spaced at 1-ft intervals and cast in the logs. These pins provide a horizontal shear connection between the logs.

119. Concrete log bunkers provide good protection against the effects of conventional weapons. They are simple, inexpensive, flexible, and quickly erectable by inexperienced crews with no engineering equipment required.

Concrete parapet-type bunkers

120. The parapet-type bunker[55] consists basically of two square telescoping boxes and a square roof slab. The lower box has inside dimensions of 6 ft 6 in. square in plan by 3 ft 6 in high. This section has 6-in.-thick reinforced concrete walls and floor. The top box has inside dimensions of 9 ft 2 in. square in plan by 3 ft high. The walls of this section are also of 6-in.-thick reinforced concrete. A 1-ft-3-in.-wide by 6-in.-thick reinforced footing was formed as an extension to the walls of the structure. The roof slab is 13 ft square and 6 in. thick and is cast with protruding concrete strips on the underside to position and hold the roof relative to the walls. Each wall of the top structure is provided with a 6-in.-high by 5-ft-long firing port, which is 48 in. above the floor of the completed structure. When the structure is assembled (Figure 85), a 16-in.-wide firing shelf is formed all around the inside wall by the difference in the dimensions of the two boxes. Figure 86 presents the design drawings for the concrete parapet-type bunker.

Protective Shelters

Concrete panel shelters

121. The structural plans for a typical precast concrete panel

a. Bunker installation (rear view)

b. Completed bunker

Figure 85. Concrete parapet-type bunker (from Reference 55)

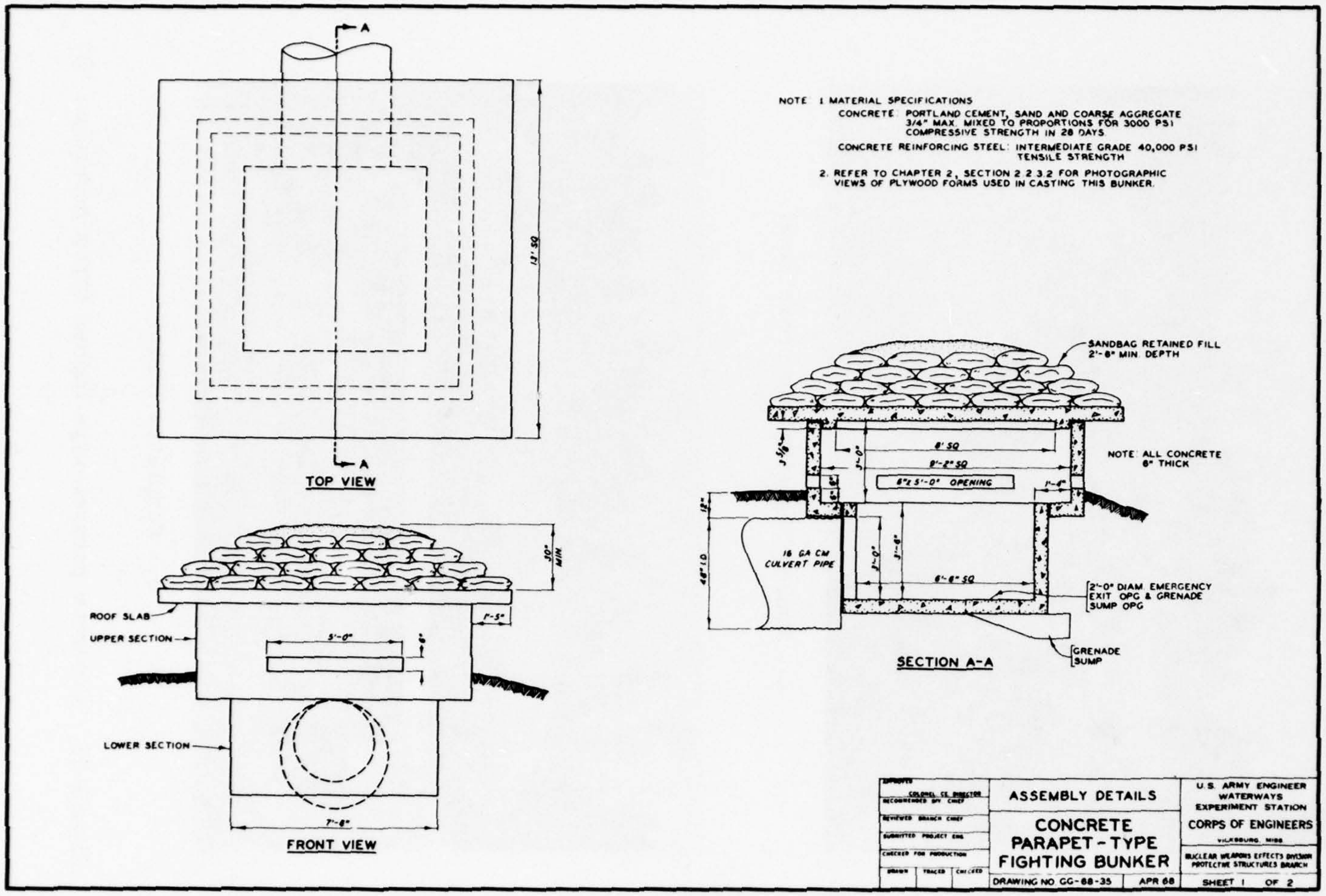
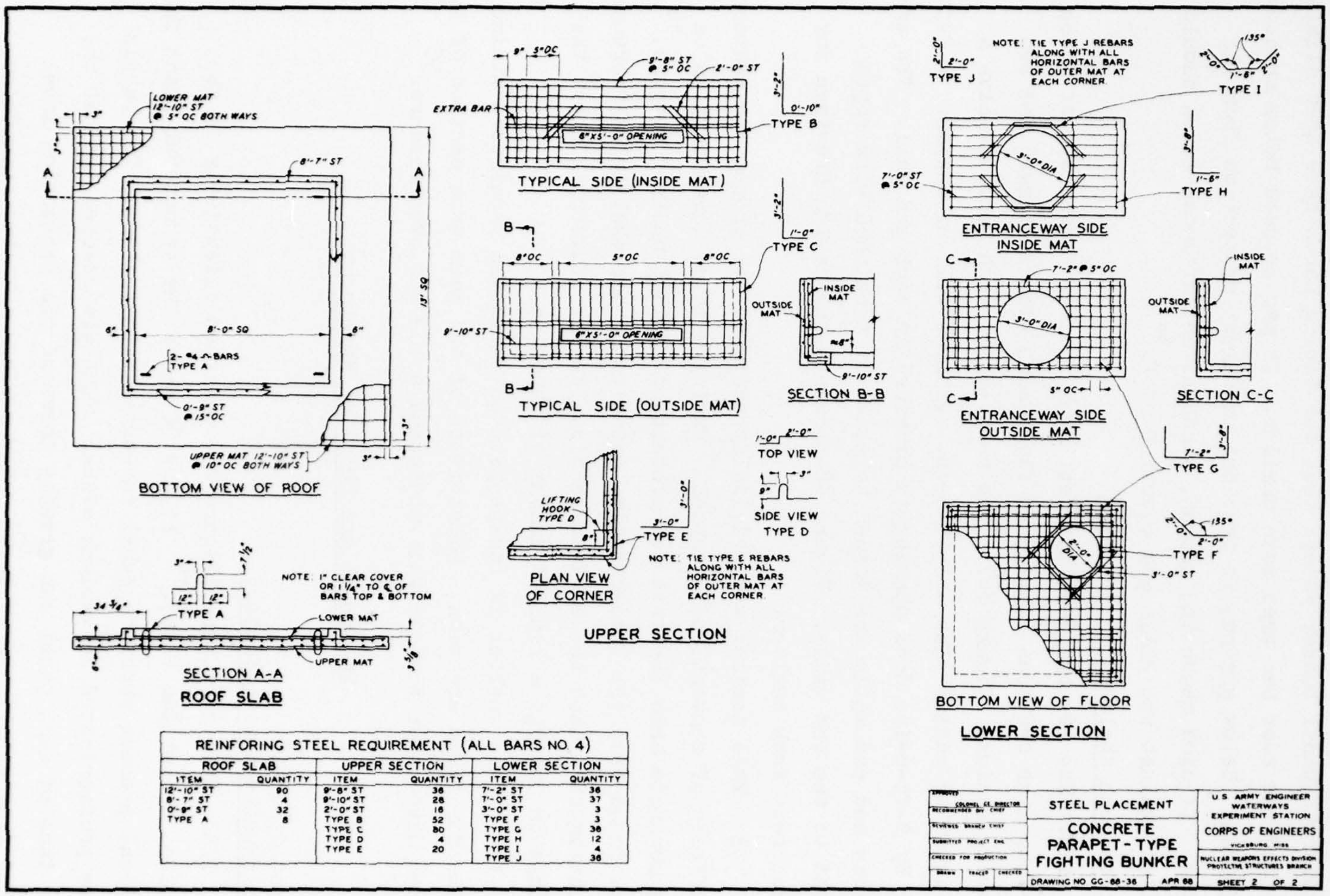


Figure 86. Concrete parapet-type fighting bunker (from Reference 55) (sheet 1 of 2)



REINFORING STEEL REQUIREMENT (ALL BARS NO 4)

ROOF SLAB		UPPER SECTION		LOWER SECTION	
ITEM	QUANTITY	ITEM	QUANTITY	ITEM	QUANTITY
12'-10" ST	90	9'-8" ST	36	7'-2" ST	36
8'-7" ST	4	9'-10" ST	28	7'-0" ST	37
0'-9" ST	32	2'-0" ST	16	3'-0" ST	3
TYPE A	8	TYPE B	52	TYPE F	3
		TYPE C	80	TYPE G	36
		TYPE D	4	TYPE H	12
		TYPE E	20	TYPE I	4
				TYPE J	36

Figure 86 (sheet 2 of 2)

quarters shelter are shown in Figure 87. This shelter is identical with the concrete panel bunker except that the firing ports have been eliminated and the roof has been made smaller. It may be used below or above the ground. Below ground, it provides excellent protection from all weapons. If used above the ground, sandbags and/or loose earth should be piled against the walls and over the roof.[54]

Concrete arch shelters

122. The 12- by 12-ft concrete arch shelter[55] consists of three 4-ft-long arch sections (including floor slab with footings) and two end wall sections (Figure 88). The 6-in.-thick arch sections have a 6-ft interior radius plus a 1-ft-6-in. vertical wall extension. A 2-ft-6-in. by 5-ft-6-in. door opening is provided in each end wall. The arch sections and end walls are joined together by tensioned wire ropes secured to the end walls. Figure 88 presents the design drawings for the concrete arch shelter.

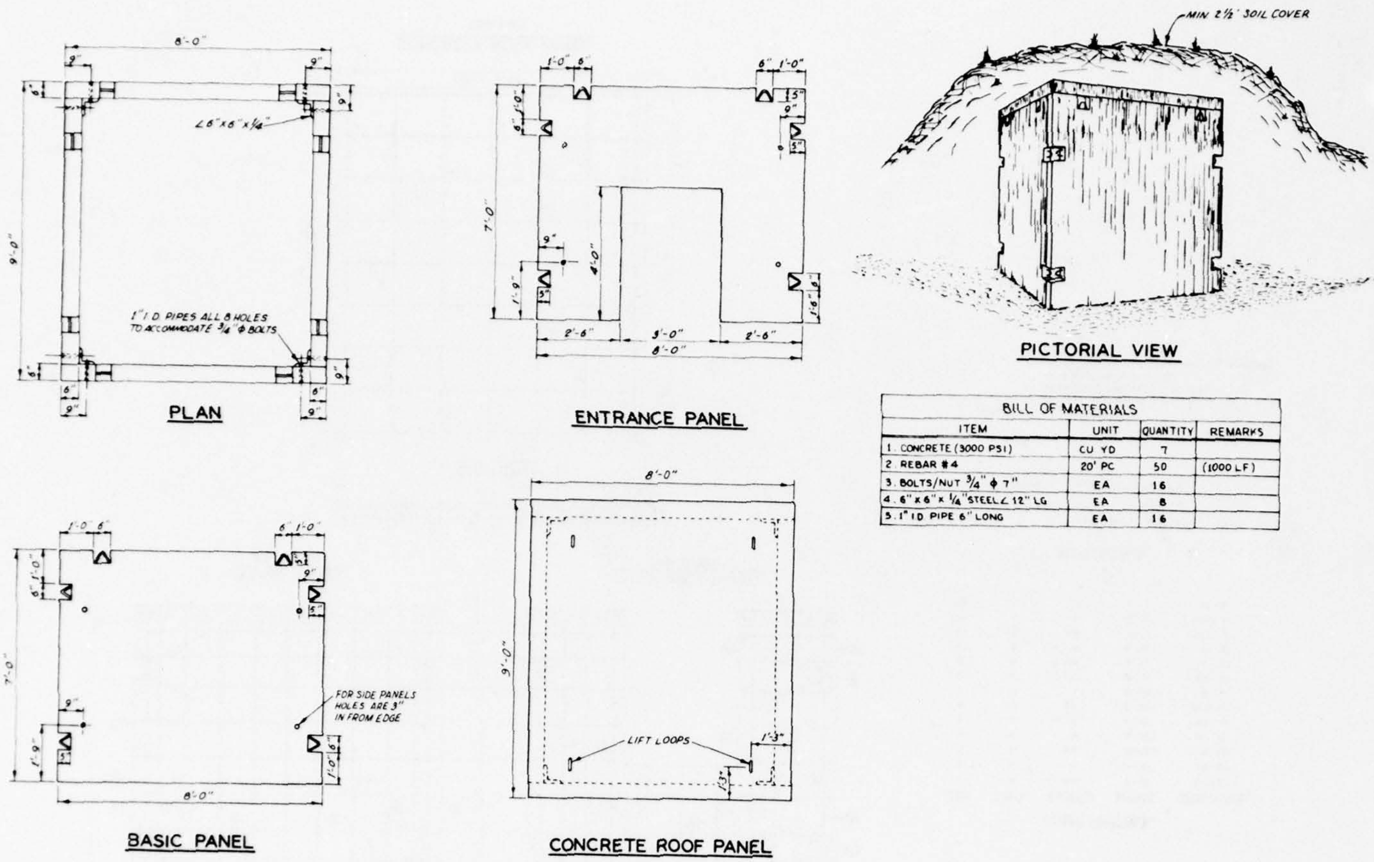
123. This shelter was originally designed for protection against the effects of conventional weapons. During a later investigation on using concrete arch shelters for protection against nuclear weapons,[56] it was found that the load-carrying capacity of the shelter is increased by cutting the floor to the arch section itself. This will allow the footings to undergo a limited amount of punching.

124. This shelter is inexpensive to build and requires a minimum of time for field erection. Model tests of the main arch section of the shelter have shown that it will withstand a 100-psi overpressure.[56]

Equipment and Supplies Revetment

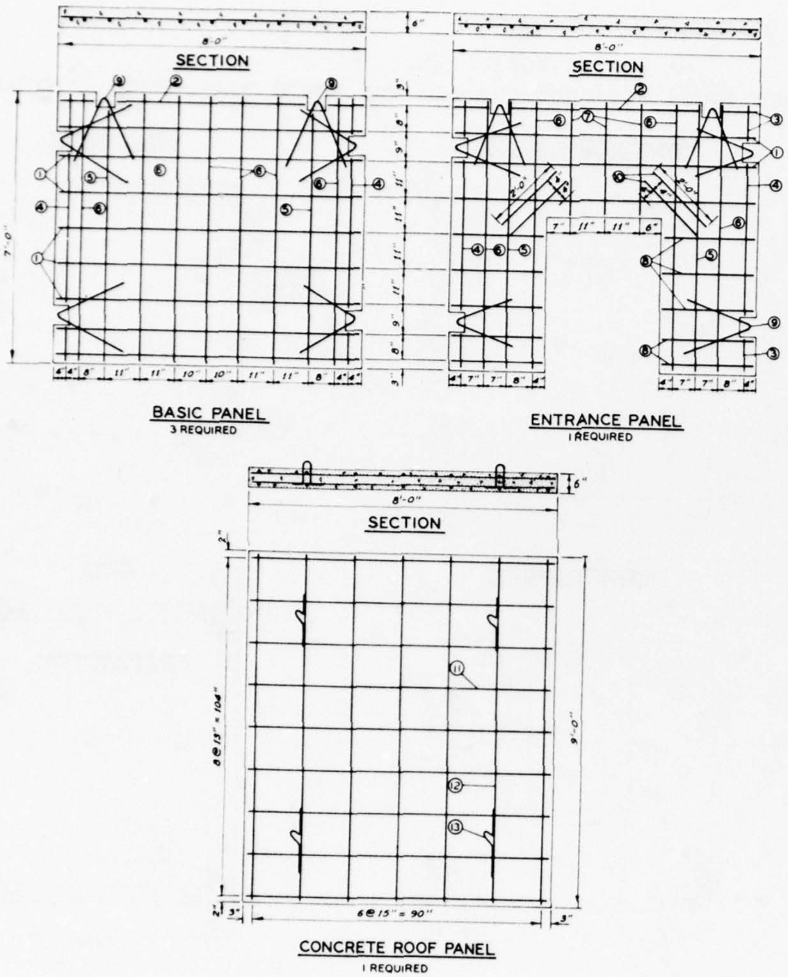
Precast concrete
panel revetment with footers

125. This structure (Figure 89) was used extensively in the Republic of Viet Nam (RVN).[54] Figure 90 shows the structural plans for a typical precast concrete panel revetment with footers. The panels can be prefabricated in various sizes. Sandbags stacked against the outer face of each panel can greatly increase the protection level against fragmentation from large-caliber high-explosive ammunition.



BILL OF MATERIALS			
ITEM	UNIT	QUANTITY	REMARKS
1. CONCRETE (3000 PSI)	CU YD	7	
2. REBAR #4	20' PC	50	(1000 LF)
3. BOLTS/NUT ¾" ϕ 7"	EA	16	
4. 6"x6"x ¼" STEEL ∠ 12" LG	EA	8	
5. 1" ID PIPE 6" LONG	EA	16	

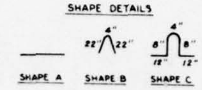
Figure 87. Structural plans for precast concrete panel quarters shelter (from Reference 54) (sheet 1 of 2)



REBAR SCHEDULE

ITEM	SHAPE	QUANTITY	LENGTH	TOTAL LENGTH
1	A	27	7'-10"	211'-5"
2	A	4	4'-10"	19'-4"
3	A	24	0'-10"	19'-11"
4	A	8	3'-10"	30'-8"
5	A	8	6'-5"	51'-4"
6	A	25	6'-10"	170'-9"
7	A	3	2'-10"	8'-6"
8	A	10	2'-4"	23'-0"
9	B	24	4'-0"	96'-0"
10	A	4	2'-0"	8'-0"
11	A	18	7'-10"	141'-0"
12	A	14	8'-10"	123'-8"
13	C	4	3'-8"	14'-8"

SHAPE DETAILS



NOTES
1. ALL REBARS #4
2. MAINTAIN 1 IN CLEARANCE BETWEEN REBARS AND CONCRETE SURFACES UNLESS OTHERWISE NOTED
3. DESIGN STRESS FOR REBAR STEEL IS 20,000 PSI

Figure 87 (sheet 2 of 2)

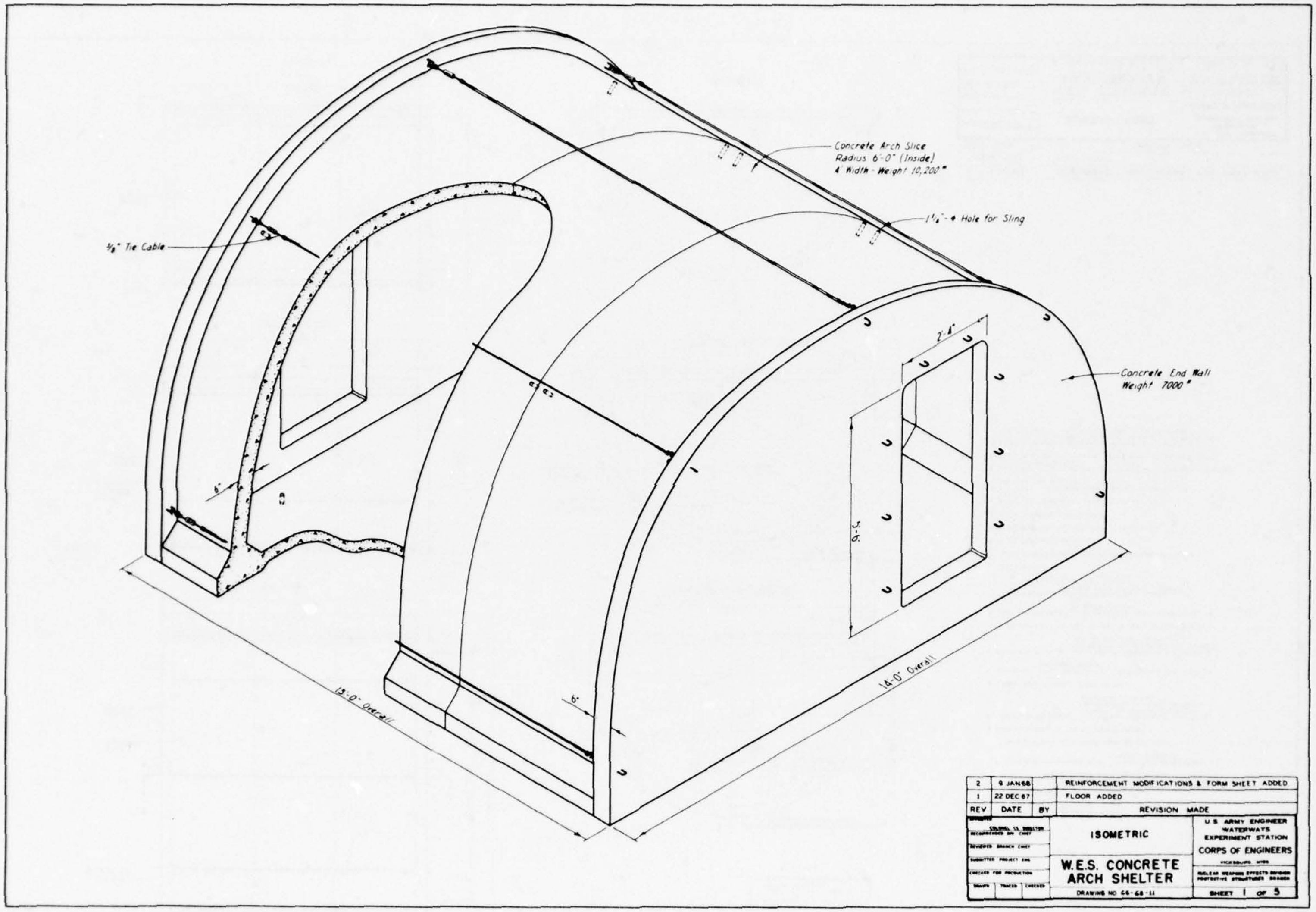


Figure 88. Concrete arch shelter (from Reference 55) (sheet 1 of 5)

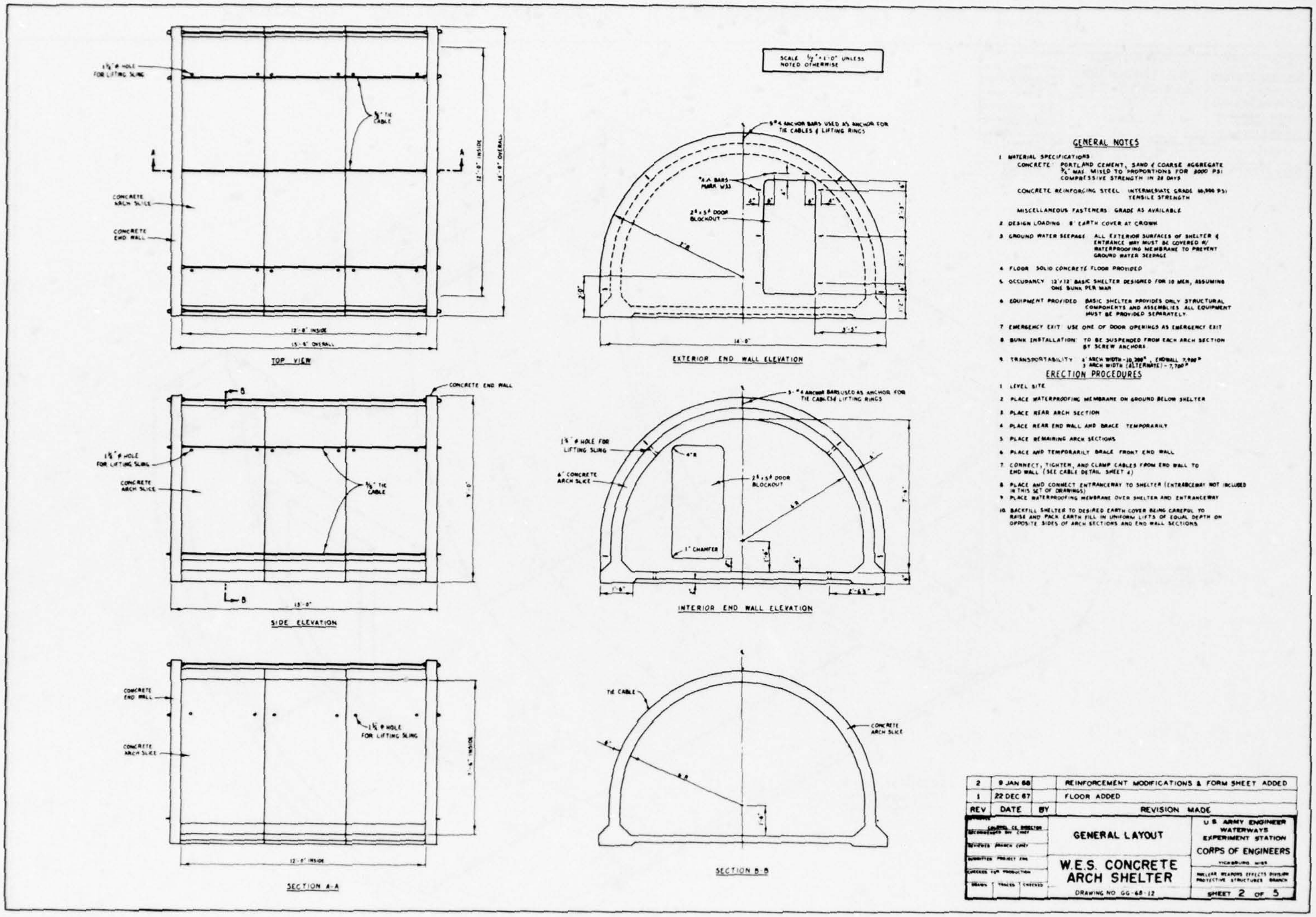


Figure 88 (sheet 2 of 5)

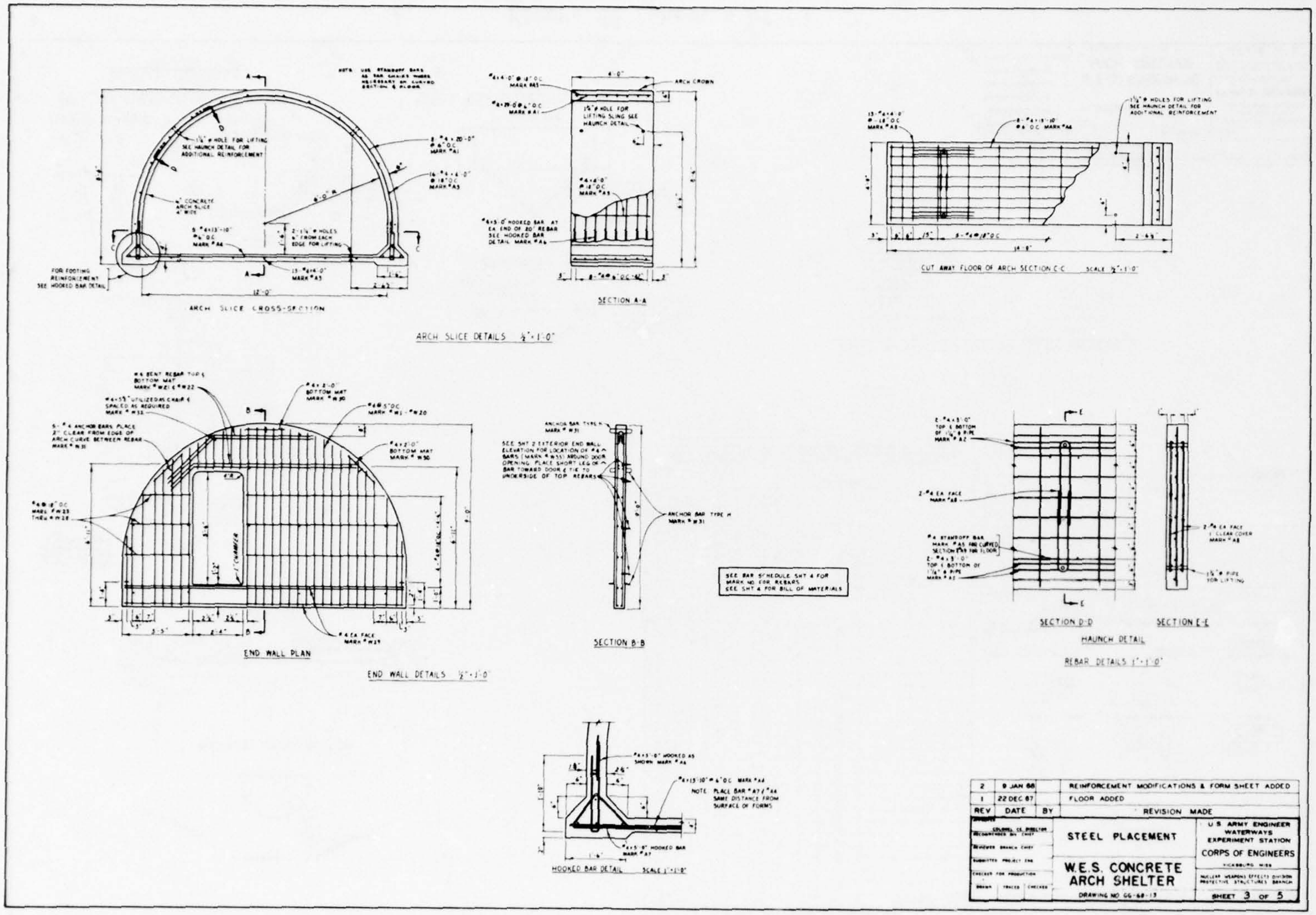
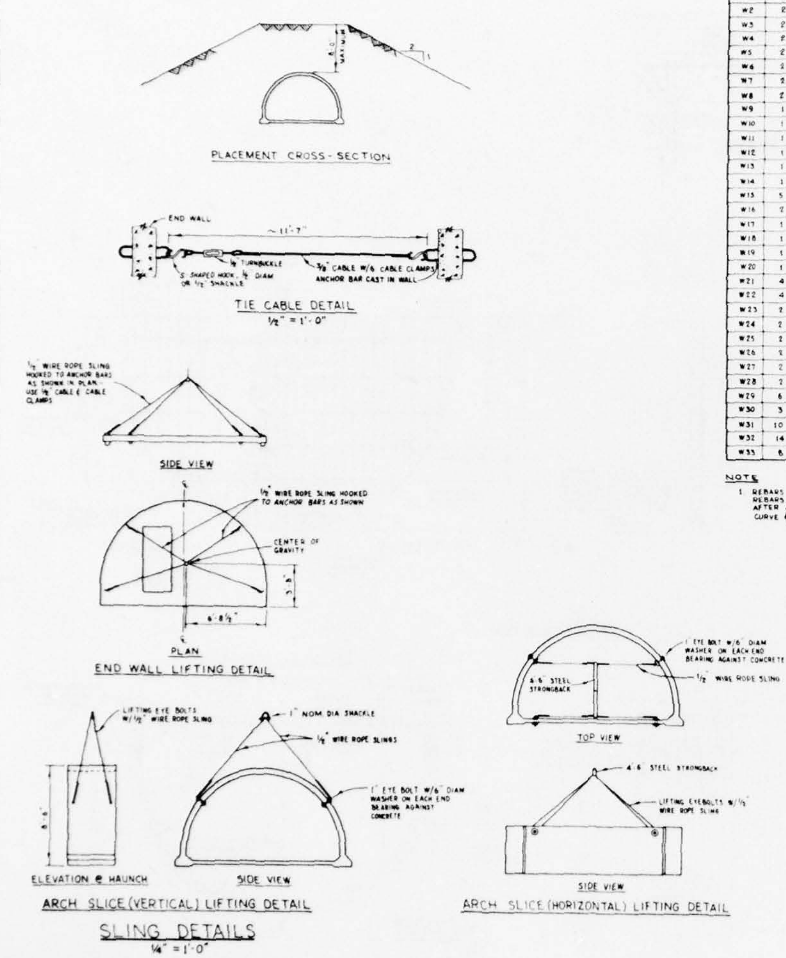


Figure 88 (sheet 3 of 5)

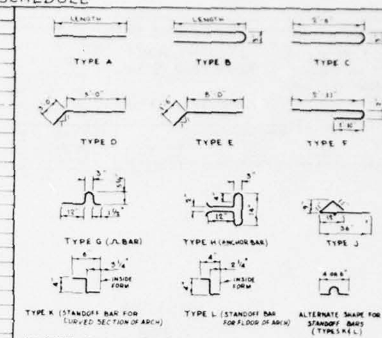


BAR SCHEDULE

ONE END WALL (2 REQ'D PER SHELTER)						
MARK	QUANTITY	SIZE	LENGTH	TYPE	LINEAL FT	REMARKS
W1	2	#4	3'-6"	B	14'	
W2	2	#4	4'-4"	B	18'	
W3	2	#4	5'-5"	B	22'	
W4	2	#4	6'-3"	B	25'	
W5	2	#4	6'-8"	B	27'	
W6	2	#4	7'-2"	B	29'	
W7	2	#4	7'-6"	B	30'	
W8	2	#4	7'-9"	B	31'	
W9	1	#4	8'-0"	B	16'	
W10	1	#4	8'-2"	B	17'	
W11	1	#4	8'-4"	B	17'	
W12	1	#4	8'-6"	B	17'	
W13	1	#4	8'-8"	B	18'	
W14	1	#4	8'-9"	B	18'	
W15	5	#4	8'-10"	B	89'	
W16	2	#4	2'-0"	B	8'	
W17	1	#4	1'-10"	B	4'	
W18	1	#4	1'-8"	B	4'	
W19	1	#4	1'-6"	B	3'	
W20	1	#4	1'-4"	B	3'	
W21	4	#4	8'-0"	D	32'	
W22	4	#4	9'-6"	E	38'	
W23	2	#4	2'-4"	A	5'	
W24	2	#4	3'-1"	A	7'	
W25	2	#4	3'-4"	A	7'	
W26	2	#4	7'-0"	A	14'	
W27	2	#4	7'-7"	A	16'	
W28	2	#4	7'-10"	A	16'	
W29	6	#4	13'-10"	A	83'	
W30	3	#4	2'-0"	A	6'	
W31	10	#4	5'-0"	H	50'	
W32	14	#4	5 1/2"	A	7'	
W33	8	#4	2'-4"	G	19'	
					36 - 20' BARS	

NOTE

1. REBARS MARKED W1 - W20 CAN BE REPLACED W/66 - 8'-10" STRAIGHT REBAR & REBARS MARKED W23 - W28 CAN BE REPLACED W/ 6 - 13'-10" STRAIGHT REBAR. AFTER ASSEMBLING TOP & BOTTOM REBAR MATS CUT REBARS TO FIT ARCH CURVE & DOOR OPENING



ALL DIMENSIONS ARE OUT TO OUT
FOR ALL TYPE B BARS - DOUBLE DIMENSION SHOWN UNDER LENGTH IN SCHEDULE FOR LINEAL FT

ONE ARCH SLICE (3 REQ'D PER SHELTER)						
MARK	QUANTITY	SIZE	LENGTH	TYPE	LINEAL FT	REMARKS
A1	8	#4	20'-0"	A	160'	
A2	32	#4	3'-0"	A	96'	
A3	29	#4	4'-0"	A	116'	
A4	8	#4	13'-10"	A	112'	
A5	15	#4	1'-1"	K	20'	
A6	16	#4	5'-0"	F	90'	
A7	16	#4	5'-0"	J	90'	
A8	16	#4	5'-6"	C	98'	
A9	12	#4	10 1/2"	L	2'	
					40 - 20' BARS	192 - 20' BARS

BILL OF MATERIALS FOR 12' x 12' SHELTER (FORMS NOT INCLUDED)

CONCRETE	12 CY
CONCRETE REINFORCING STEEL #4	200 - 20' BARS
1 1/4" Φ PIPE 6" LONG	4 EA
1 1/4" Φ PIPE 4" LONG	4 EA
1/2" Φ PIPE 6" LONG	6 EA
1/2" Φ PIPE 4" LONG	4 EA
CABLE ASSEMBLY (SEE CABLE DETAIL)	5 EA
REINFORCING STEEL TIE WIRE	
WATERPROOFING MEMBRANE	

REV	DATE	BY	REVISION MADE
2	9 JAN 68		REINFORCEMENT MODIFICATIONS & FORM SHEET ADDED
1	22 DEC 67		FLOOR ADDED

PLACEMENT DETAILS

W.E.S. CONCRETE ARCH SHELTER

DRAWING NO. 66-68-1A

U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MISS.

SHEET 4 OF 5

Figure 88 (sheet 4 of 5)

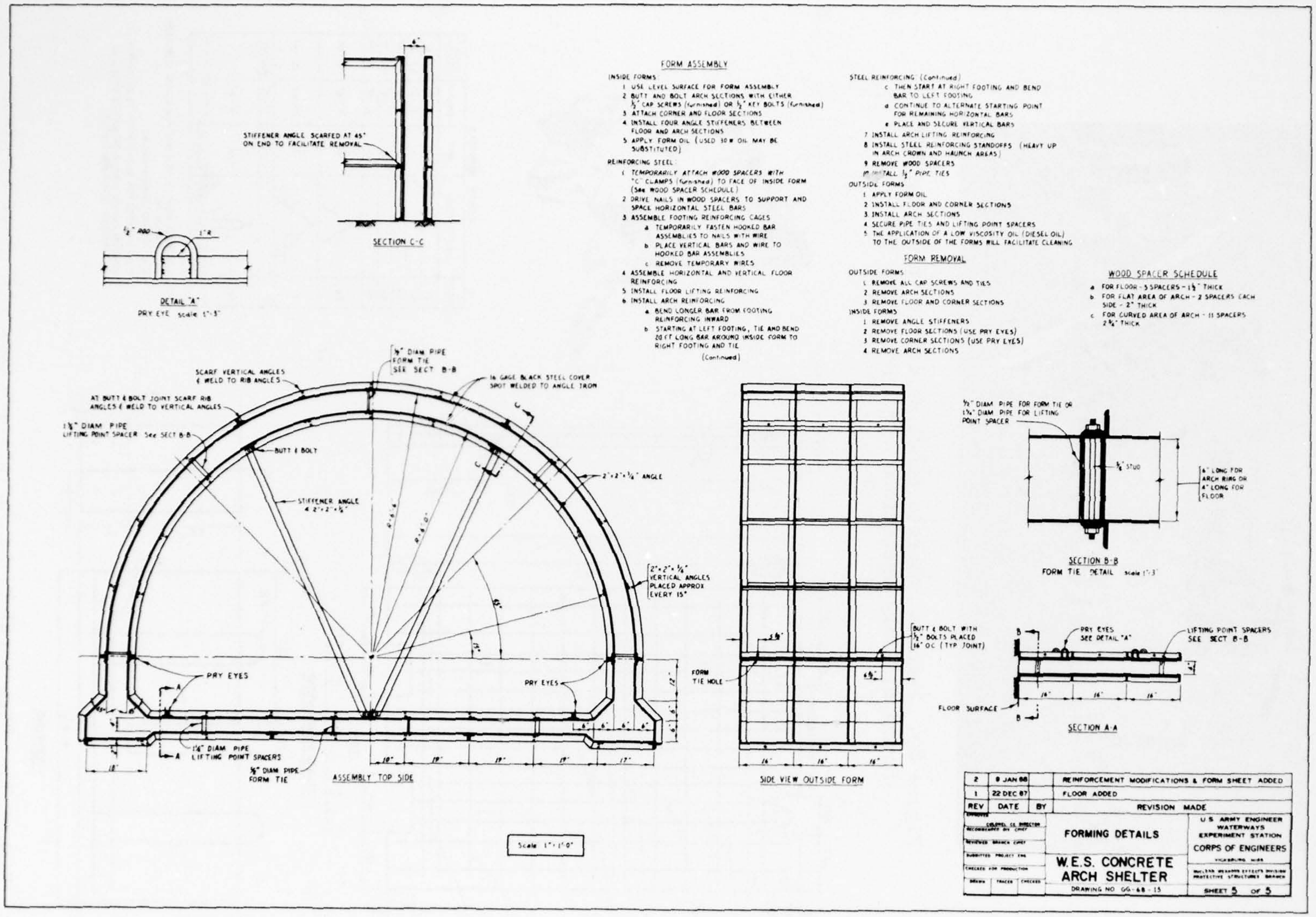


Figure 88 (sheet 5 of 5)

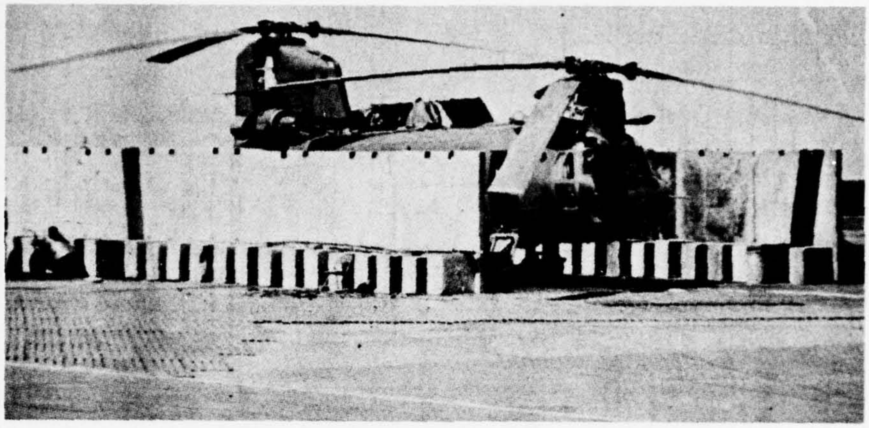
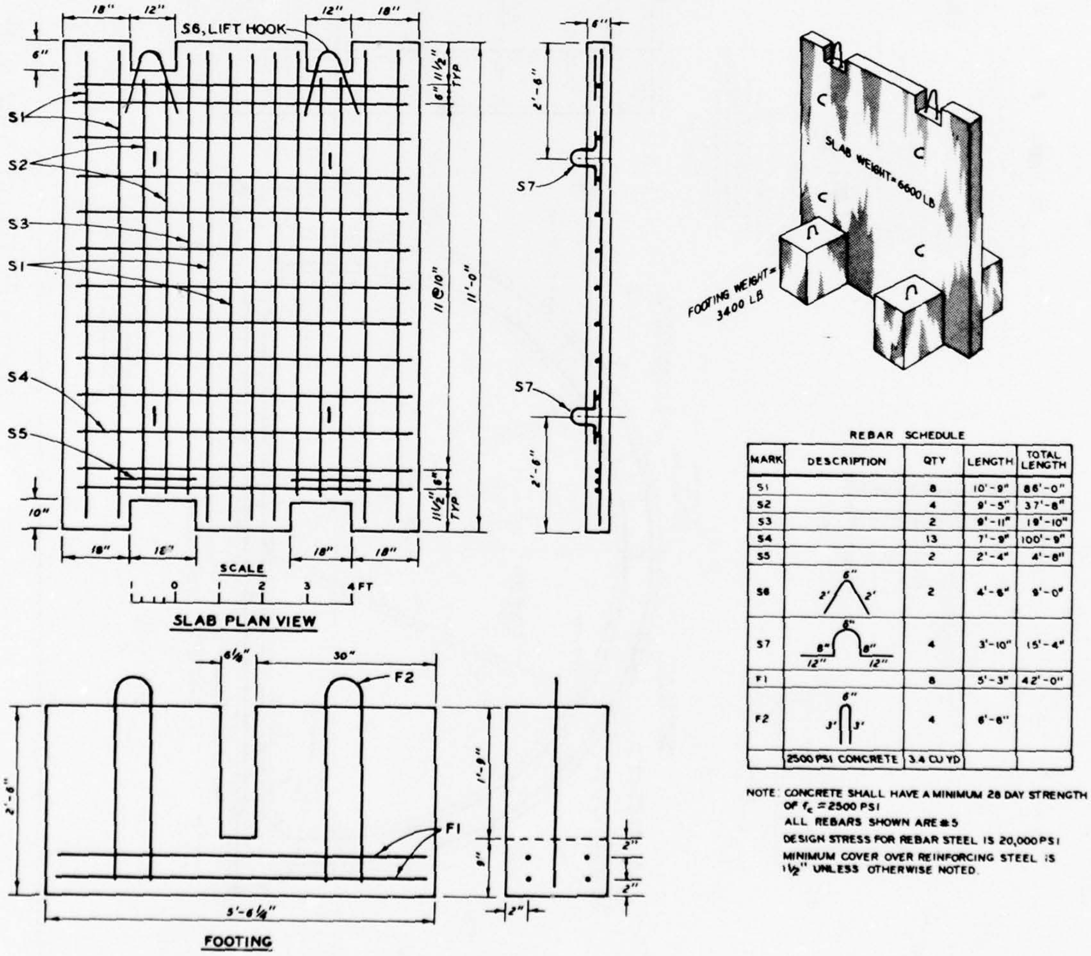


Figure 89. Precast concrete panel revetment in use in RVN during military operations (from Reference 54)



REBAR SCHEDULE

MARK	DESCRIPTION	QTY	LENGTH	TOTAL LENGTH
S1		8	10'-9"	86'-0"
S2		4	9'-5"	37'-8"
S3		2	9'-11"	19'-10"
S4		13	7'-9"	100'-9"
S5		2	2'-4"	4'-8"
S6	6" 2' 2'	2	4'-6"	9'-0"
S7	6" 8" 8" 12" 12"	4	3'-10"	15'-4"
F1		8	5'-3"	42'-0"
F2	6" 3' 3'	4	6'-6"	
	2500 PSI CONCRETE	3.4 CU YD		

NOTE: CONCRETE SHALL HAVE A MINIMUM 28 DAY STRENGTH OF f_c = 2500 PSI
ALL REBARS SHOWN ARE #5
DESIGN STRESS FOR REBAR STEEL IS 20,000 PSI
MINIMUM COVER OVER REINFORCING STEEL IS 1½" UNLESS OTHERWISE NOTED.

Figure 90. Structural plans for precast concrete panel revetment with footers (from Reference 54)

Precast concrete
self-supporting panels

126. These panels are similar to those described in the previous paragraph, but they are cast with triangular rearward-facing flanges that make them self-supporting. Self-supporting revetment panels (Figure 91) offer an advantage over the panel-and-footers design in that

Figure 91. View of back of 9-ft-high self-supporting concrete panel (from Reference 54)

they are easier to set up where the ground surface is uneven or rough.[54] However, the fabrication effort and material costs of self-supporting panels are higher than those of panel-and-footers. Figure 92 gives the structural plans for typical precast concrete self-supporting revetment panels. The protection level provided by this design is the same as that of the panels with footers.

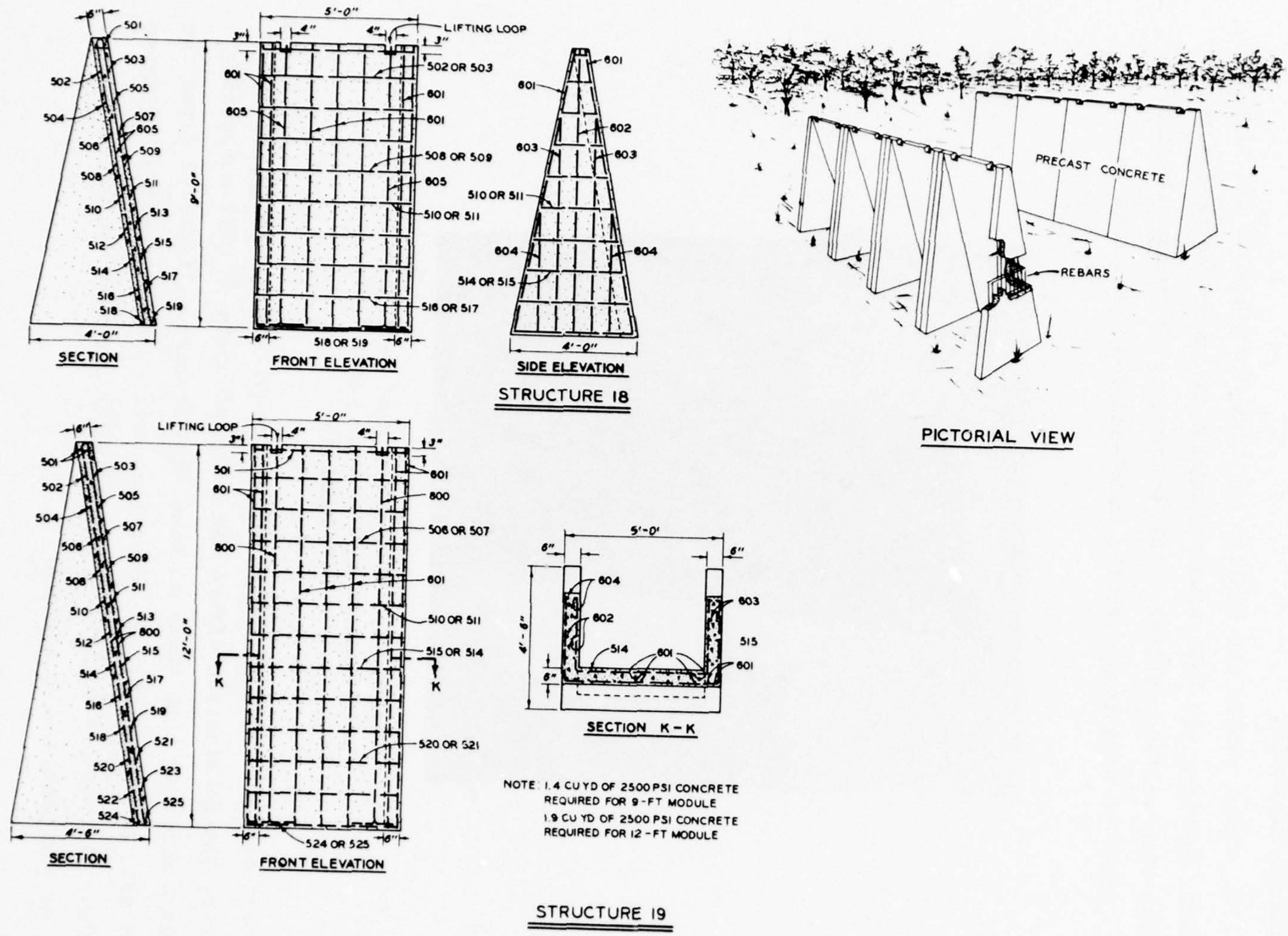
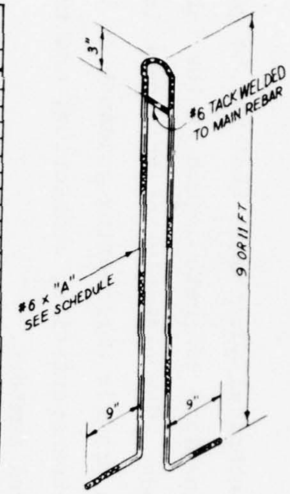


Figure 92. Structural plans for precast concrete self-supporting panel revetment (from Reference 54) (sheet 1 of 2)

REBAR SCHEDULE HEIGHT: 12', BASE 4'-6", WEIGHT: 7700 LB							
REBAR NO.	SIZE	QTY	TOT LENGTH	A	B	C	REMARKS
501	#5	1 EA	10'-4"	4"	4'-10"	4"	A B C
502		1	4'-10"	4"	4'-2"	4"	A B C
503		1	6'-2"	8"	4'-10"	8"	
504		1	5'-6"	8"	'-2"	8"	
505		1	6'-10"	1'-0"	4'-10"	1'-0"	
506		1	6'-2"	1'-0"	4'-2"	1'-0"	
507		1	7'-6"	1'-4"	4'-10"	1'-4"	
508		1	6'-10"	1'-4"	4'-2"	1'-4"	
509		1	8'-2"	1'-8"	4'-10"	1'-8"	
510		1	7'-8"	1'-8"	4'-2"	1'-8"	
511		1	8'-10"	2'-0"	4'-10"	2'-0"	
512		1	8'-10"	2'-0"	4'-2"	2'-0"	
513		1	9'-6"	2'-4"	4'-10"	2'-4"	
514		1	8'-10"	2'-4"	4'-2"	2'-4"	
515		1	10'-2"	2'-8"	4'-10"	2'-8"	
516		1	9'-6"	2'-8"	4'-2"	2'-8"	
517		1	10'-10"	3'-0"	4'-10"	3'-0"	
518		1	10'-2"	3'-0"	4'-2"	3'-0"	
519		1	11'-6"	3'-4"	4'-10"	3'-4"	
520		1	10'-10"	3'-4"	4'-10"	3'-4"	
521		1	12'-2"	3'-8"	4'-10"	3'-8"	
522		1	11'-6"	3'-8"	4'-2"	3'-8"	
523		1	12'-10"	4'-0"	4'-10"	4'-10"	
524		1	12'-2"	4'-0"	4'-2"	4'-0"	
525		1	13'-6"	4'-4"	4'-10"	4'-4'	
601	#6	14	188'-0"	12'-0"	—		A
602		4	47'-4"	11'-10"	—		
603		8	72'-0"	9'-0"	—		
604		8	40'-0"	5'-0"	—		
605		2	51'-6"	25'-0"	SEE DETAIL		

REBAR SCHEDULE HEIGHT: 9', BASE: 4'-0"; WEIGHT: 5500 LB							
REBAR NO.	SIZE	QTY	TOT. LENGTH	A	B	C	REMARKS
501	#5	1 EA	10'-4"	4	4'-10"	4"	A B C
502		1	5'-2"	6"	4'-2"	6"	A B C
503		1	6'-6"	10"	4'-10"	10"	
504		1	5'-10"	10"	4'-2"	10"	
505		1	7'-2"	1'-2"	4'-10"	1'-2"	
506		1	6'-8"	1'-3"	4'-2"	1'-3"	
507		1	8'-0"	1'-7"	4'-10"	1'-7"	
508		1	7'-4"	1'-7"	4'-2"	1'-7"	
509		1	8'-8"	1'-11"	4'-10"	1'-11"	
510		1	8'-2"	2'-0"	4'-2"	2'-0"	
511		1	9'-6"	2'-4"	4'-10"	2'-4"	
512		1	8'-10"	2'-4"	4'-2"	2'-4"	
513		1	10'-2"	2'-2"	4'-10"	2'-8"	
514		1	9'-8"	2'-9"	4'-2"	2'-9"	
515		1	11'-0"	3'-1"	4'-10"	3'-1"	
516		1	10'-10"	3'-1"	4'-2"	3'-1"	
517		1	11'-8"	3'-5"	9'-10"	3'-5"	
518		1	11'-2"	3'-6"	4'-2"	3'-6"	
519		1	12'-6"	3'-10"		3-10'	
601	#6	14					A
602		4	35'-4"	8'-10"	—	—	
603		8	56'-0"	7'-0"	—	—	
604		8	32'-0"	4'-0"	—	—	
605		2	39'-4"	19'-8"	—	—	



DETAIL REBAR NO. 605

Figure 92 (sheet 2 of 2)

PART VIII: FABRICATION, HANDLING, AND ERECTION

127. Many of the technical advantages that may be gained by using precast instead of cast-in-place concrete depend on the fabrication, handling, and erection methods. The objective of this part is to review contemporary practice and to provide engineering guidance on the fabrication, handling, storage, transportation, connection, and erection of precast concrete structural members.

Fabrication

128. Precast concrete elements are fabricated either in a permanent manufacturing plant or in a temporary jobsite plant. The permanent plant can economically incorporate more sophisticated machinery and equipment along with the flexibility to adjust to a variety of products, whereas the jobsite plant is tailored to the specific needs of that particular project.[6] A typical combat zone concrete precasting facility for prefabricated shelters, bunkers, and other small precast concrete parts is described in TM 5-302.[57] A suggested concrete precast facility for producing concrete military bridges (Appendix D) is given in Appendix F.

129. In general, the manufacturing plant comprises the following minimum elements:

- a. Area for concrete plants and prestressing beds.
- b. Area for storage forms and raw materials.
- c. Area for storage of finished products.

130. Some guideline principles for manufacturing of precast concrete elements are given in the following paragraphs.

Proper drainage and road

131. Efficient and adequate surface drainage must be provided in all work areas and in storage areas. Areas adjacent to prestressing beds should be paved in order to reduce the possibility of contamination of strand surface and beds by dirt and mud, to facilitate drainage, and to increase the efficiency of the operation.

Beds

132. Foundation for beds should be stabilized to prevent differential settlement. Foundations may be pile supported or of the gravity-spread footing type. Height of bed should be set at best working level, particularly where considerable handwork is required.

Forms

133. Forms are generally designed for multiple reuse and should, therefore, be of steel, concrete, fiberglass, or heavy wood framing of equivalent strength. Accurate alignment of forms must be maintained during the casting operation. Form joints should be smooth and tight enough to prevent leakage of mortar. Forms must be cleaned immediately after removal of product. Particular attention must be paid to removal of grout from joints in working forms and from holes for affixing inserts.

Protection of steels

134. Proper storage must be provided for prestressing steel, mild reinforcing steel, and inserts to keep them clean and dry. High-strength steel is much more susceptible to corrosion than steel of lower strengths. Care should be taken in the storage of prestressing steel to prevent galvanic action that can occur when dissimilar metals are adjacent with an ionized medium common to both. Strand surface should always be inspected prior to placing concrete, and any found contaminated should be cleaned with an effective solvent.

Mixing and placing concrete

135. Proven procedures for mixing and placing concrete are described in detail in the following ACI publications:

ACI 614--Recommended Practice for Measuring, Mixing and Placing Concrete

ACI 306--Recommended Practice for Winter Concreting

ACI 605--Recommended Practice for Hot Weather Concreting

Curing

136. The ACI recommended practice for optimum curing for precast units should be followed:[58]

a. Initial curing. Immediately after the completion of the casting operation for molded precast units, each article should be covered or enclosed by two layers of an approved water-saturated fabric until placed in position for final curing. The length of initial curing for units going into final steam curing will vary with steam curing temperature. From 1 to 4 hr is indicated, the higher the temperature, the longer the period.

b. Final curing. For final curing each article may be cured in the place in which cast under the original covering that must be kept thoroughly saturated for the entire curing period. For final curing each article may be moved at any time to a special curing chamber, where it may be left uncovered in an atmosphere completely saturated with a mist spray of either water or steam. In lieu of this treatment, final curing may be accomplished under two layers of an approved wet fabric thoroughly and continuously saturated with water for the entire curing period. The temperature of a curing room at atmospheric pressure should be maintained uniformly at some value between 50 and 180°F. Final curing may be performed under a pressure between 100 and 150 psi in saturated steam at 335 to 366°F.

Handling

137. Handling of the precast concrete units involves removal of the unit from the mold or form, transportation to temporary storage yard, loading, then transportation to the construction site, unloading, storage at the site (sometimes), and finally erection and attachment to the structure.

138. Since the pickup points are critical, precast concrete units should be lifted only at the designated points. When the units are stored, they must be similarly supported. Care should be exercised in handling units to avoid impact and unusual loading, such as lateral loads, vibration, and distortion.

139. Lifting loops for picking and handling must be designed with a safety factor of 6, i.e., their ultimate capacity should be 3X (dead load + impact) where impact = 100% dead load.[6] Embedment should be adequate to prevent pullout bond failure.

140. The angle that the sling or line makes with the lifting loop, at all positions during picking and handling, should be considered

and provision made therefor. Consideration should also be given to sway or swing, i.e., bending of the picking loop sideways. This will cause sharp bending stresses in the picking loops and may result in local concrete crushing.

141. Fabricated lifting inserts (e.g., fabricated plates) may be used, provided the following rules are applied:[6]

- a. Their pullout value is ensured by mechanical or positive fastening in the concrete.
- b. There are no welds transverse to the principal tension.
- c. Plates are thick enough in themselves to withstand bearing from shackle pins--no built-up washers or cheek plate reinforcement of the eye.
- d. Eyes are designed for shear, moment, and tension on the minimum section.
- e. Steel used is ductile (serious failures have occurred when hard-grade brittle steels were used).

142. One popular type of lifting equipment is a rubber-tired, self-propelled, straddle machine (Figure 93). Straddle carriers are

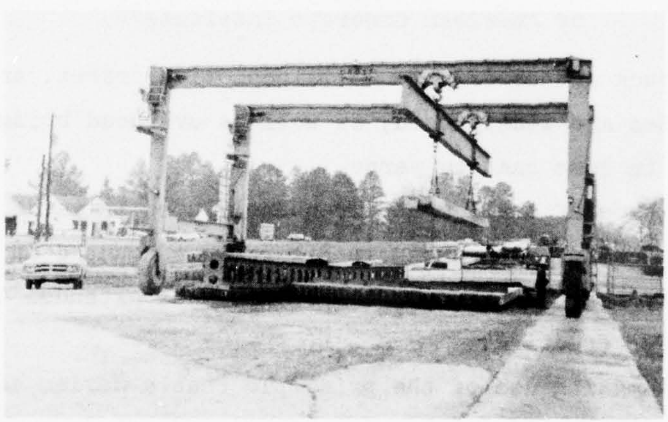


Figure 93. Straddle carrier

efficient machines for moving precast concrete units about the casting yard and loading them onto vehicles for transportation to the jobsite. These machines are made with inside clear widths ranging from 12 to 40 ft and heights from 12 to 40 ft and with wheel basis to suit the particular plant usage.[59] Although large and seemingly awkward, these machines are constructed with 90-deg pivot steering so they can maneuver in the narrow aisles usually found in storage yards. Capacities up to 100,000 lb are available. Long girders can be handled by two machines in tandem.

143. The machine shown in Figure 94 is a heavy-duty forklift with an extra wide frame to enable it to carry long cored slabs.

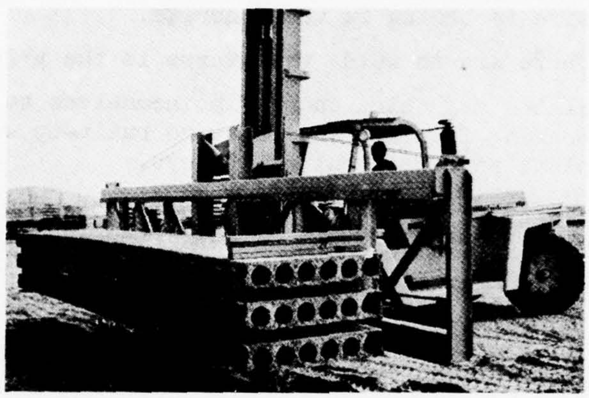


Figure 94. Forklift machine (courtesy of American Concrete Institute[59])

144. Truck cranes (Figure 95), locomotive cranes, and small hydraulic cranes are widely used, as well as overhead bridge cranes and gantry cranes in some casting yards.

145. A type of small crane frequently used in yards and for erecting is the hydraulic model shown in Figure 96. Mounted on a truck, the crane is easily maneuverable yet the boom can be extended to make the crane useful for erecting.

146. By making use of the principle that a device can be attached to any surface by creating a vacuum between the two, vacuum lifters have been developed for lifting precast concrete units[59] (Figure 97). One advantage of vacuum lifters is the reduction in handling time; it takes only a few seconds to attach or release the lifter.

147. Precast units should be stored in such a manner that each unit supports only its own weight, without any load imposed by other units.[59] Points of contact between units must be provided with protective material to prevent breakage.

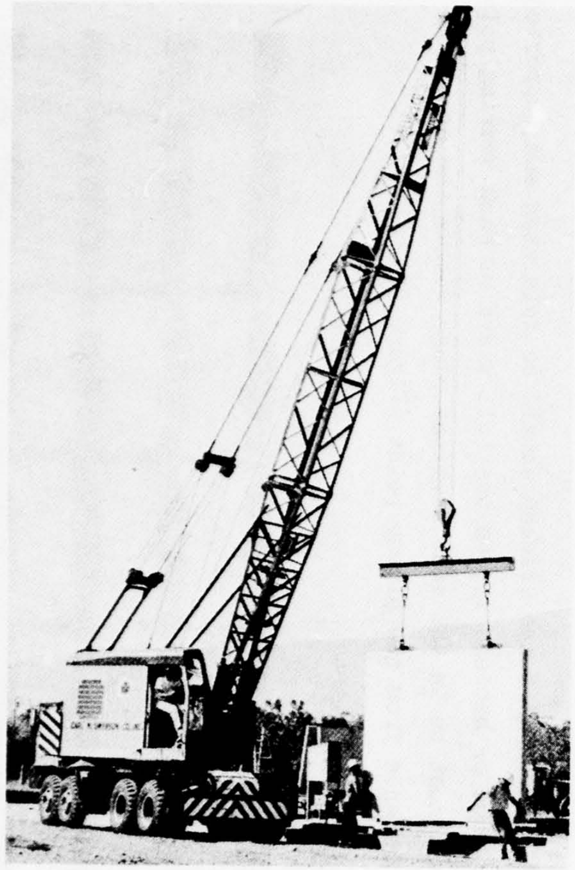


Figure 95. Truck crane (courtesy of American Concrete Institute[59])

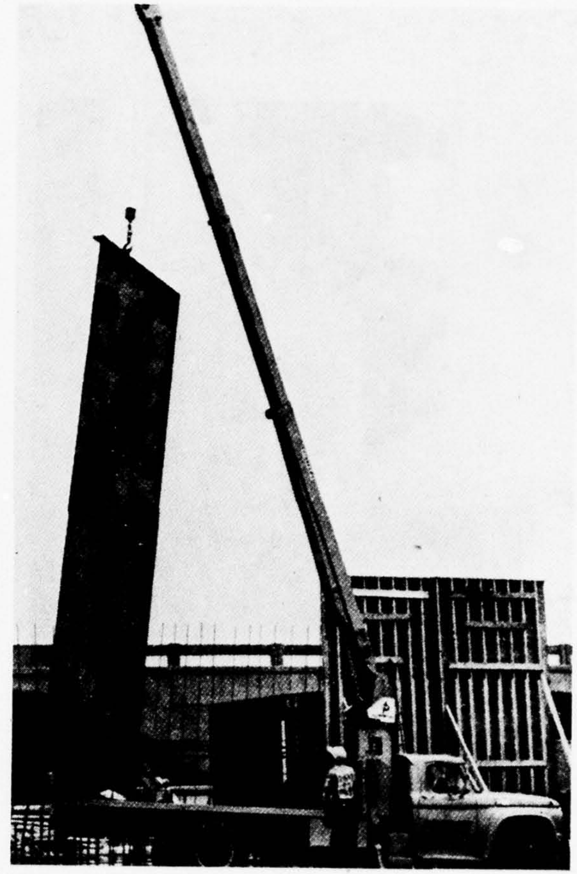


Figure 96. Hydraulic crane (courtesy of American Concrete Institute[59])

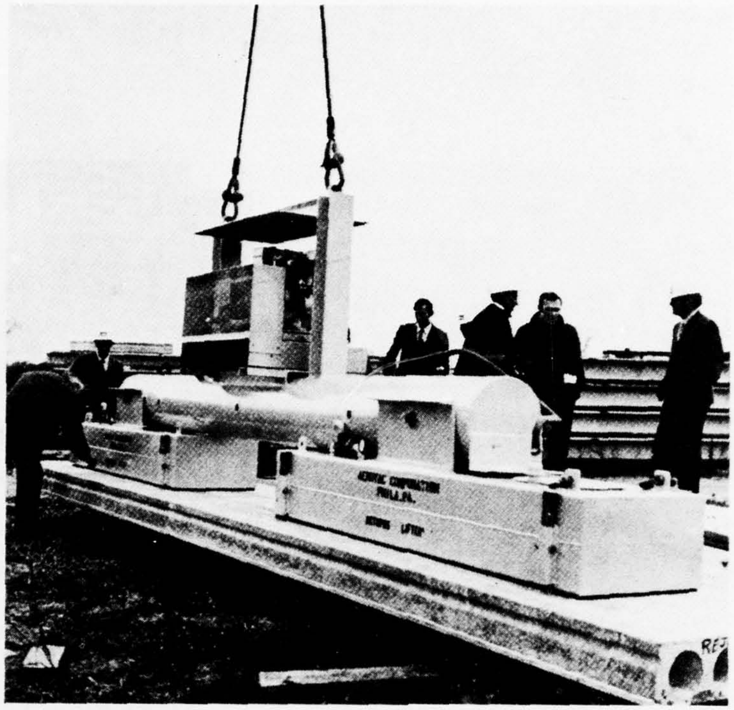


Figure 97. Vacuum lifter (courtesy of American Concrete Institute[59])

148. Units that are stacked should be separated and supported on strips of wood or battens across the full width of each bearing point.[59] All battens must be in the same vertical plane within the specified maximum distance from the pickup point (Figure 98).

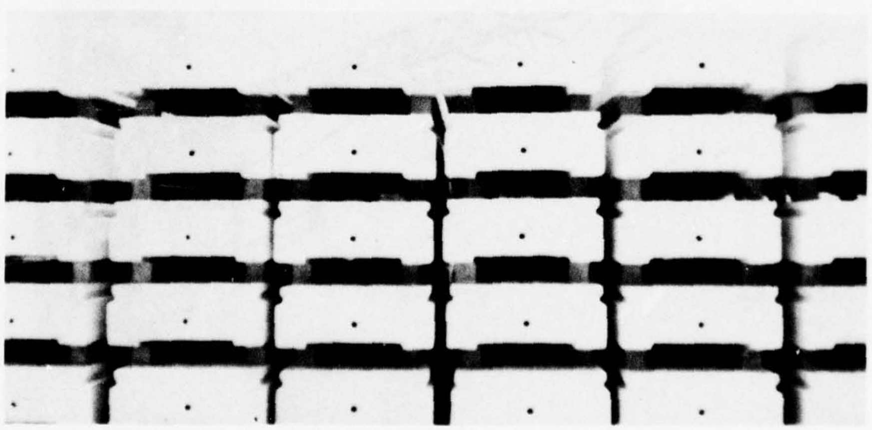


Figure 98. Storage of precast concrete elements

Transportation

149. Moderate-size precast concrete units can be transported by truck. Rail may be used for long-distance shipments and for over-length segments but often requires supplemental transportation to the actual jobsite. Barge transportation is very economical and practicable to water sites and can be used to transport heavy and oversize units.[6]

150. During transport, precast concrete units should be supported as they were in the storage yard, with added bracing to assure that they remain in this loaded position without shifting or overturning. Adequate padding must be inserted between chains, cables, or ropes and the precast concrete units to prevent clipping or other damage, a precaution especially important on edges and corners. This padding can consist of timber blocks or logging, rope mats, or plastic pads.

151. Lateral trussing or bracing might be necessary to prevent flexing of long slender units. A method that has been used successfully on long slender Tee- or I-girders is to attach short lengths of steel angle in both sides of the stem near the ends of the girder and a structural strut on each side at the midspan, with one or two stressing strands stressed between the angles and over the strut on each side[59] (Figure 99). For long members, pole trailers (Figure 100) are often

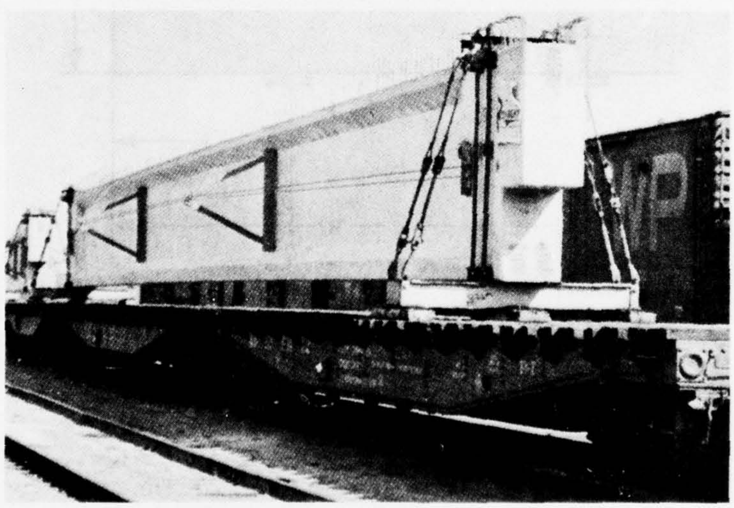


Figure 99. Long girder transported by rail cars (courtesy of American Concrete Institute[59])

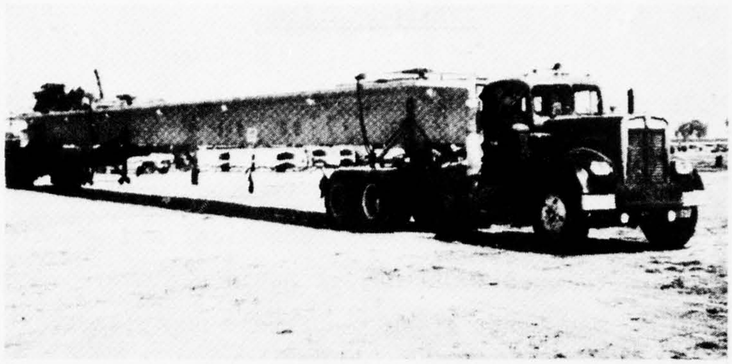


Figure 100. Pole trailer (courtesy of American Concrete Institute[59])

used, with the precast unit serving as the "pole" connection between truck and trailer.

152. Trucks with double bolsters are generally satisfactory provided the precast units are fully seated in the outer bolsters at not more than 3 ft or the depth of the number from the end, and the inner bolster is not more than 8 ft from the end of the unit (Figure 101).

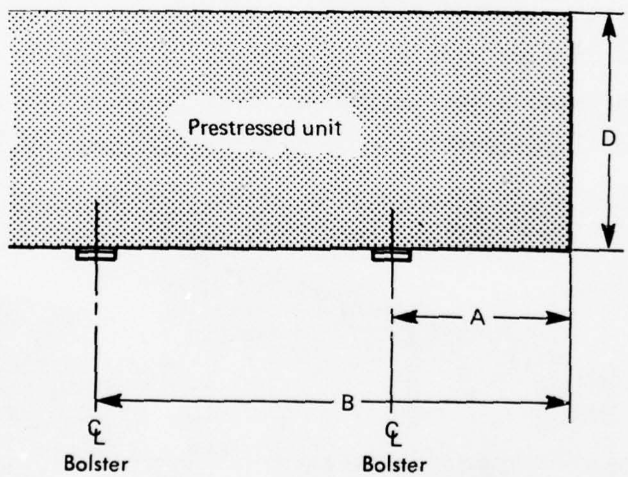


Figure 101. The distance from the center line of the rear bolster on a double-bolster dolly to the end of the prestressed member (distance A) should not exceed "D" or 3 ft, whichever is smaller. Distance "B" from center line of inner bolster to end of girder should not be more than 8 ft (courtesy of American Concrete Institute[59])

153. Upon arrival of the vehicle at the jobsite, the first operation is to remove all load binders, chains, and ropes confining the precast members. Then the exposed packing and padding are removed. Care should be taken to avoid damaging the concrete. Only one unit should be removed at a time except for small units that might be grouped on pallets. Units should be removed from alternate sides of the vehicle to avoid unbalancing the load, and the remaining units should be braced to prevent slipping or tipping. Units on the outside or top of the load should be unloaded first. Never try to slide a member out from the center of the load.

Connections

154. The connections between precast members should be designed in such a manner that they are capable of withstanding the ultimate vertical and horizontal loads for which the structure is proportioned, without failure, excessive deformation, or rotation. The recommendation of ACI-ASCE Committee 512[60] should be followed. The following paragraphs from Reference 60 are pertinent to the present discussion.

General considerations

155. It is recommended that joints and connections occur at logical locations in the structure and, when practical, at points that may be most readily analyzed and easily reinforced. Precautions should be made to avoid connection and joint details that would result in stress concentrations and the resulting spalling or splitting of members at contact surfaces. Liberal chamfers, steel-edged corners, adequate reinforcement, and cushioning materials are a few of the means by which such stress concentrations may be avoided or provided for.

156. The strength of a partially completed or completed structure should be governed by the strength of the connections; the connection should not be the weak link in the structure.

Loading conditions

157. Loading conditions to be considered in the design of joints and connections are service loads including wind and earthquake forces;

volume changes due to shrinkage, creep, and temperature change; erection loads; and loading encountered in stripping forms, shoring and removal of shores, storage, and transportation of members. Proper attention should be given to loads and the resulting stress peculiar to the sequence of erection. Typical examples of construction in which the sequence and manner of erection affect the loading and stresses in the member are possible eccentric loading due to the erection of members on one side only of a member, installation of composite concrete toppings on shored or unshored slabs or beams, and continuity moment connections over supports. All significant combinations of loading should be investigated, and the joints and connections should be designed for loadings consistent with these possible combinations of loading.

158. If it is not practical to provide for all possible temporary loading conditions that could occur during erection, special erection procedures may be warranted. If so, complete erection instructions should be included in the plans and specifications that become part of the erection contract documents. Loading sequences, connection sequences, and if necessary shoring or guying schedules should be clearly outlined. The disposition and strength of shoring should be stated and approved prior to construction.

Erection

159. The erection methods are determined by the span, height, and type of the structure, its location, the topography, the weight, size, and configuration of the precast elements, the method of connection, and the erection equipment available. In general, however, the majority of erection methods and techniques that have been developed and employed for precast concrete bridge construction fall into the following classes.[6]

Crane erection

160. This includes erection by land-operating cranes, by derricks on water, and by cranes or derricks mounted on the structure itself.

161. When using inclined slings, the temporary buckling stresses

due to increased compression in the top flanges of the girder must be considered, as well as the increased forces on the lifting loops or devices. Angles of force should be considered for each position during the lift. Lifting loops must be suitable for all angles of lift to prevent localized crushing or overstress.

162. Land cranes must have firm undersupport, adequate for the concentrated temporary loads under their tracks, wheels, or outriggers. The position of the crane, angles of lift, and working radii must be plotted on working drawings and accurately laid out and enforced in the field.

163. When two cranes are used to erect a single member, each should have sufficient capacity to take at least 66 percent of the total load, and precautions should be taken to prevent undue swinging and side-pull on the booms and to ensure that the girder does not hit one of the booms during the successive steps of rotation of the booms.

164. Derricks or cranes mounted on the structure must be properly secured, and the temporary loadings imposed on the structure, including torsion, must be checked.

165. Care should be taken to prevent either the unit being lifted or another part of the structure from hitting the boom as this may cause the boom to buckle.

166. Waterborne derrick barges should be checked for capacity during all stages of lift and placement, with due allowance for list due to load and wave action. The list of a waterborne derrick or crane tends to surge it out of position laterally, putting an added strain on anchor lines. Also, the rotation of the revolving crane or derrick while listing puts added strain on the barge, the derrick base and roller path, and the swing engines and also produces torsion in the boom. Furthermore, the list increases the actual picking radius as the load drifts outward and, thus, may overload the crane. Before picking near-capacity loads, therefore, a thorough engineering check must be made of all phases of the pick.

Floating-in

167. Either entire spans or major portions thereof may be built

or assembled on scaffolding on a barge, then towed to the site, moored in exact position, and lowered onto the bearings.

168. Large single barges may be used, or multiple barges may be joined with trussing. How the differential movement, due to waves, affects the precast span or element must be investigated. Wind forces on the barges and spans also must be taken into consideration.

169. Lowering may be accomplished by using the tides, flooding compartments in the barges, or jacks. In flooding, the effect of the free surface on stability must be considered. This usually requires that the barges or pontoons be compartmentalized.

170. Stability must also be carefully calculated during transport on the barges because of the great weights involved and the height of center of gravity.

171. With substructure elements, buoyancy may be provided within the element itself, and sinking accomplished by adding ballast, such as gravel, iron ore, concrete, or sand in compartments, or by flooding isolated compartments. Alternatively, positive buoyancy may be maintained and the element submerged by pulling or jacking against pile anchors.

172. Substructure units may also be transported under a barge or pontoons. In such a case, the unit may be constructed in a dry dock or basin, which is then flooded, thus allowing the barge to float in over it, pick it up, and carry it underneath itself until in position. This method takes advantage of the reduction in deadweight due to submergence, shows inherent stability, and all lifts and lowerings are direct.

Erection in falsework

173. A steel or aluminum truss is placed in position, and the elements are lifted one by one, for example, by crane, onto the falsework. When an entire span unit is erected, the precast units are jacked and shimmed to the exact profile, then jointed and stressed. This method is especially adapted to the case of parallel girders, because after one girder is erected and stressed, the stressing automatically decentering the falsework, the falsework span may be moved sidewise for the next parallel girder. Alternatively, the falsework truss span may

be above the final girder location, the precast units being raised from barges into position by hoists, and held until jointed and stressed.

Launching gantry

174. This method involves the use of a special erection or launching gantry, which may include means for moving itself forward as portions of the bridge are completed.

175. Under one system precast segments are moved forward at deck level from one abutment, out over the completed superstructure. The segment is then picked up by the launching gantry and carried forward. To enable it to pass through the supporting legs, it is usually rotated at right angles to its final position during movement, then turned back and set in its final position. The individual precast segments are usually jointed and stressed before the next segment is launched.

176. When using a launching gantry to erect prestressed girders, provision must be made for lateral transfer of the girders after they have been moved into their span. Rollers, wheels on tracks, skidding with jacks, etc., are often employed to accomplish this lateral transfer. Positive stops must be provided to prevent the girder being moved beyond the end of the cap through accident.

177. Launching gantries are major steel bridges in themselves, subject to reversal of stress conditions as they are moved and to impact as they handle the precast segments. Since the connections are usually field bolted, it is important that provision be made for frequent inspection of all joints and repairing or strengthening of any members accidentally damaged. If high-strength bolts are used, a clear identification marking must be placed on them to prevent careless replacement by a conventional bolt.

178. Safe walkways and, where applicable, moveable safety nets or platforms should be provided as an integral part of the launching gantry.

Direct launching

179. This scheme has been employed to move precast girders lengthwise from a completed portion of the superstructure to their span location. A light steel or aluminum launching nose is overbalanced by a counterweight or heavy rearward extension. Movement forward may be

accomplished by jacking, rolling, tracked carriages, or cranes. The girder must be analyzed for temporary stress conditions as it is cantilevered forward and, if necessary, strengthened by external trussing or internal reinforcement. This method is particularly suitable for a single span in remote locations.

180. The same principle has been used in Venezuela, Germany, France, and the U. S. S. R. to launch an entire series of spans of prestressed concrete, the girders being approximately uniformly stressed to take care of moment reversal until they are in final location. Then the tendons are deflected up and down to their permanent profile, or additional curved tendons added. Special "frictionless" bearings of teflon on chrome-nickel steel plates are used on top of the piers. The piers may require temporary guys or stays during the launching operations.

Cantilever-suspended span

181. The precast hammerhead section may be floated or lifted in, supported by barges or cranes at each end, and set on the pier. Temporary stresses as a simple span must be countered by external or internal reinforcement.

182. Since this is the section subject to maximum negative moment, its required final prestress force will generally be very high. During this stage, before the adjoining suspended spans are set, the tensile stresses in the bottom may exceed allowable limits. Stage stressing may be employed, or additional internal reinforcement provided in the bottom of the girders, or external structural steel beams bound to the segment.

183. Smaller hammerhead girders may be hoisted by one crane lifting at the center.

184. Stability may be provided by stressing temporarily or permanently to the pier shaft, by an inclined leg support from the pier base, or by falsework towers at one or both ends.

185. Precast girders are particularly adaptable to suspended spans. They may be lifted in with one or two cranes working from below or from the cantilevered ends of the superstructure, or they may be moved forward on a falsework truss or by launching gantry. Suspended

spans may be assembled from precast segments on barges and floated or lifted into place.

Progressive cantilevering

186. This is an extremely useful method for construction of concrete bridges with precast or cast-in-place segments. As each segment is placed, it is jointed and stressed back to the completed portion of the superstructure. The sequence of erection is chosen to keep the partially completed superstructure balanced about a pier, in double cantilever.

187. To facilitate setting of a precast segment, a step or ledge may be provided on the previous segment so that the new segment can be readily set into exact position. Erection bolts should be provided so the segment can be pulled into exact position and held.

188. Dry joints and epoxy joints are particularly adaptable to use with progressive cantilevering as they enable each segment to be jointed and stressed as one continuous operation, usually in one day. Other types of joints may be employed with accelerated curing so as to minimize delays between successive segments.

189. Temporary suspension of the cantilevered segments may be provided by external tendons, e.g., cables running up to a temporary tower above the pier. Stability during erection of the cantilevered arms may be provided by temporary vertical stressing down to the pier, by inclined legs, or by falsework towers.

Sliding of segments

190. Precast segments may be slid forward to their position in the span on skids, rails, or rollers over falsework trusses or falsework girders. Similarly, they may be slid along temporary or permanent wire rope cables to their correct position in the span.

Erection by helicopters

191. The precast concrete elements may be lifted into position by helicopters. The Army has used the helicopter to lift and move heavy construction materials, especially in areas where surface transport is limited or restricted, quite extensively. The lifting capacity of present helicopters is about 10 tons. Development of a heavy-lift

helicopter (25 tons) is now being undertaken. Several problems (e.g., relatively low-maximum loads, requirement for preslinging, lack of pilot training for construction operations, lack of efficient communication between pilots and surface crews, etc.) exist when using current inventory helicopters for erection of precast concrete elements. However, since most of these problems can be corrected with new equipment and proper training, it is reasonable to assume that helicopter operations may become much more important in precast concrete construction in the TO.

PART IX: SUMMARY AND RECOMMENDATIONS

Summary

192. The literature survey on the prefabricated concrete elements for structures revealed that precast concrete construction provides a rapid and economical method for erecting new structures and for the repair or replacement of existing structures. This is possible because precast construction eliminates most falsework and shoring at the construction site and requires only a small erection crew. Precast construction is particularly advantageous in isolated places where labor and materials are not readily available.

193. From the many precast concrete bridge structures evaluated, it appears that the precast channel girders developed by the State Aid Division of MSHD are most suitable for use in the TO. Designs for two modified precast concrete channel girder bridges capable of supporting military Heavy Equipment Transporters (HET's)[61] are developed in Appendix D. It is believed that the construction of these precast channel girder bridges is within the normal capabilities of Army engineer troops.

194. Precast, prestressed concrete piles have proven to be the most economical solution for a wide range of piling installations, especially when durability is important, when high axial load and moment capacities are required, and when the total volume in a geographical area is sufficient to justify a proper manufacturing setup and mobilization of proper driving equipment.

195. Precast concrete is well adapted for floating structures of all types. Precast concrete container pier modules that are mass produced ashore, constructed in modules, launched, towed to the site, and jacked to the required elevation are envisioned as a means for providing expedient military ports.

196. Precast concrete field fortifications have been widely used by United States troops during combat operations. Precast concrete security bunkers, quarters shelters, command and control shelters, and equipment and supplies shelters provide excellent protections.

197. Many of the technical advantages that may be gained by using precast instead of cast-in-place concrete depend on the fabrication, handling, and erection methods. Engineering guidance on the fabrication, handling, storage, transportation, connection, and erection of precast concrete structural members is given in Part VIII of this report.

Recommendations

198. The following recommendations are made based on the information survey reported herein:

- a. Fabricate, erect, and test a prototype concrete channel girder bridge to validate the design and refine construction techniques.
- b. Adopt the precast concrete channel girder bridge presented in Appendix D as a standard military bridge.
- c. Either incorporate the results of this study into appropriate existing manuals[2,3,36] or, preferably, develop a new manual devoted to precast concrete.
- d. Develop and evaluate designs for prefabricated concrete barges suitable for use as container pier modules, floating breakwaters, fuel transport and storage facilities, etc., as necessary in expedient TO military ports.
- e. Evaluate the effectiveness of precast concrete in creating expedient barriers and obstacles. An evaluation of thermic methods to neutralize enemy protective structures and barriers of concrete should be included in such an investigation.
- f. The following studies should be performed prior to the use of precast concrete elements in the TO: (1) the casting site be investigated to see if adequate materials (e.g. aggregate) for concrete are available); (2) the importance of the time factor for fabrication of the precast element be considered if the mission is urgent and the need is immediate; (3) the relocatability of the precast concrete elements versus structural steel; and (4) the economics of using precast concrete elements versus wood, steel, or cast-in-place concrete.

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Table 1

Commercially Stocked Concrete Pipe

Inside Diameter in.	Type of Pipe
4 to 24	Nonreinforced concrete drain tile
4 to 36	Nonreinforced concrete sewer, storm drain, and culvert
12 to 108*	Reinforced concrete culvert, storm drain, and sewer pipe
15 to 108*,**	Reinforced concrete arch culvert, storm drain, and sewer pipe
18 to 108*,**	Reinforced concrete elliptical culvert, storm drain, and sewer pipe
4 to 24	Nonreinforced concrete pipe for irrigation or drainage
6 to 24	Nonreinforced concrete irrigation pipe with rubber gasket joints
12 to 108	Reinforced concrete low-head pressure pipe
4 to 24	Perforated concrete pipe
20 to 96	Reinforced concrete water pipe--steel cylinder type, not prestressed
16 to 96	Reinforced concrete water pipe--steel cylinder type, prestressed
12 to 96	Reinforced concrete water pipe--noncylinder type, not prestressed
48 by 48 to 90 by 90	Flat base pipe

* Available in larger sizes on order.
** Equivalent circular sizes.

APPENDIX A: RESPONSE TO QUESTIONNAIRE SENT TO ENGINEER CONSTRUCTION GROUPS AND BATTALIONS

1. As a starting point from which to gather information from the field, a brief questionnaire (Figure A1) was prepared to determine the interests and/or experiences of various Engineer troop units regarding precast concrete elements. Figure A2 is the list of the Engineer Construction Groups and Battalions furnished this questionnaire on 10 December 1974. The first four addresses (Construction Groups) were furnished questions 1-5 on the questionnaire; others (Construction Battalions) were sent questions 1-6. Of the 18 units contacted, 10 responded. Their responses are presented in detail in Figure A3 and then summarized in Table A1.

2. The general consensus was that concrete precasting operations do have a place in Army Engineer TOE units. However, less than 40 percent of the units responding indicated any prior experience with either fabrication or erection of precast concrete elements. All comments were considered in developing the direction and depth of the study, and most are addressed within the report.

Table A1: Summary of Response to Request for Information

	24th Engineer Gp (Const)	?? Engineer Gp (Const)	79th Engineer Bn (Const)	84th Engineer Bn (Const)	864th Engineer Bn (Const)	548th Engineer Bn (Const)	802d Engineer Bn (Const)	293d Engineer Bn (Const)	43d Engineer Bn (Const)	249th Engineer Bn (Const)
1. Do concrete precasting operations have a place in Army Engineer TOE units?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
2. Should the proposed precasting facility include a prestressing capability?	Yes	No	Yes	Yes	No	No	No	No	Yes	Yes
3. Indicate those elements which should be included in the capabilities of a TOE precast facility:										
Types I & II AASHO I-Beams	x		x	x	x				x	x
Tee Beams (Single/Double)	x	x	x	x	x					x
Box Beams			x	x			x			
Channel Beams			x	x	x		x			
Slabs		x	x	x			x	x		
Wall Panels	x	x	x	x	x		x			x
Piling			x	x					x	x
Box Culverts		x	x	x	x		x	x		x
Pipe			x	x		x			x	x
Other			x*			x**	x†	x††		
4. Indicate those theatre of operations type structures most suited to precast concrete construction:										
Administrative Buildings		x	x		x		x			
Barracks-Type Buildings		x	x				x			
Bathhouse and Latrine Facilities			x		x		x			
Medical and Dental Facilities			x	x						
Communications Facilities			x	x	x				x	
Maintenance Facilities			x	x			x			x
Mess Facilities			x							
Protective Structures (Bunkers, Revetments, etc.)	x		x	x	x	x			x	x
Bridges	x		x	x	x	x			x	x
Others			x‡							x‡‡
5. In what organization should the precast facility be located?										
Engineer Construction Battalion TOE-5-115		x	x		x		x			
Engineer Construction Support Company TOE-5-114	x			x	x		x		x	
Engineer Concrete Mixing and Paving Team, TOE 5-590T	x					x				x
Other										
6. Has your Battalion had any experience with:										
Concrete Precasting	--	--	Yes	No	No	No	Yes	No	No	Yes
Prestressing	--	--	No	No	No	No	No	No	No	No
Erection of Commercial Precast Elements	--	--	Yes	No	No	No	Yes	Yes	No	No

* Culvert Headwalls, Refuse Sumps/Tanks, Fence and Utility Poles, Embankment Cribbing, Curbstones, Vehicle Barriers

** Drop Inlets, Members for Crib Walls

† Manholes, Catch Basins

†† Bridge Decking

‡ Warehouse Facilities

‡‡ POL Separators, Sewerage Structures

1. Do concrete precasting operations have a place in Army Engineer TOE units?

Yes______ No______

Comments:

2. Should the proposed precasting facility include a prestressing capability?

Yes______ No______

Comments:

Figure A1. Questionnaire (sheet 1 of 3)

3. Indicate those elements which should be included in the capabilities of a TOE precast facility:

_____ Types I and II AASHO I-Beams

_____ Tee Beams (Single or Double)

_____ Box Beams

_____ Channel Beams

_____ Slabs

_____ Wall Panels

_____ Piling

_____ Box Culverts

_____ Pipe

Other:

4. Indicate those theatre of operations type structures most suited to precast concrete construction:

_____ Administrative Buildings

_____ Barracks Type Buildings

_____ Bathhouse and Latrine Facilities

_____ Medical and Dental Facilities

_____ Communications Facilities

_____ Maintenance Facilities

_____ Mess Facilities

_____ Protective Structures (Bunkers, Revetments, etc.)

_____ Bridges

Others:

Figure A1 (sheet 2 of 3)

5. In what organization should the precast facility be located?

_____ Engineer Construction Battalion, TOE 5-115

_____ Engineer Construction Support Company, TOE 5-114

_____ Engineer Concrete Mixing and Paving Team, TOE 5-590T

Other:

6. Has your Battalion had any experience with:

_____ Concrete Precasting

_____ Prestressing

_____ Erection of commercial precast elements

If so, please provide synopsis of work

Figure A1 (sheet 3 of 3)

Commander
138th Engineer Construction Group
Fort Riley, KS 66442

Commander
24th Engineer Construction Group
APO New York 09227

Commander
2d Engineer Construction Group
APO San Francisco 96301

Commander
35th Engineer Construction Group
Fort Bragg, NC 28307

Commander
293d Engineer Bn (Construction)
APO New York 09034

Commander
94th Engineer Bn (Construction)
APO New York 09175

Commander
79th Engineer Bn (Construction)
APO New York 09360

Commander
249th Engineer Bn (Construction)
APO New York 09360

Commander
84th Engineer Bn (Construction)
APO San Francisco 96225

Commander
52d Engineer Bn (Construction)
Fort Carson, CO 80913

Commander
864th Engineer Bn (Construction)
Fort Lewis, WA 98433

Commander
92d Engineer Bn (Construction)
Fort Stewart, GA 31313

Commander
43d Engineer Bn (Construction)
Fort Benning, GA 31905

Commander
23d Engineer Bn (Construction)
APO Seattle 98749

Commander
802d Engineer Bn (Construction)
APO San Francisco 96271

Commander
548th Engineer Bn (Construction)
Fort Bragg, NC 28307

Commander
44th Engineer Bn (Construction)
APO San Francisco 96259

Commander
46th Engineer Bn (Construction)
Fort Rucker, AL 36360

Figure A2. Distribution list for the questionnaire

1. Do concrete precasting operations have a place in Army Engineer TOE units?

Yes 9   No 1

Comments:

Precasting operations can certainly result in great time and manpower savings when properly utilized. 24th Engineer Group has, however, had no good applications for precasting during recent peace time construction experience. For this reason, it would not be cost-effective to provide any of the units of this group a peace time precasting capability. A TO&E augmentation should, however, be developed to provide this capability in time of war.

Probably only in a fairly static Theater of OPNS environment.

Not necessary in a CONUS application; cheaper to commercially procure.

Not necessary in a rapid TO situation; lines move too fast for application.

Significant savings in forming material can be made; dependence on weather for construction can be reduced and control of curing conditions can be obtained by working indoors; manpower can be concentrated and used more economically by using a casting crew and a placement crew; and centralization of material operation can again economize on personnel and make quality monitoring more effective.

However, before implementation, consideration must be given to the cost effectiveness of obtaining the equipment vs. the type of construction projects units are presently allowed to do in a peace time training situation. Presently construction projects requiring precast and prestressed concrete are not being constructed by troop units. Therefore, this capability should not be added to the TOE's until needed in war or a change is made in the type of projects given to troop units.

Situations which call for precast building materials to be used could arise frequently enough to warrant a precasting capability in an Engineer Battalion. Such situations include structural members of fixed bridges and construction of field fortification and obtacles.

A precasting capability could have limited use in TOE units. However, most construction projects assigned to CONUS units would not merit precasting techniques. This unit has not been tasked with any

Figure A3. Detailed responses to the questionnaire (sheet 1 of 5) project during the past 12 months nor are any projects under design which would merit establishing a precast operation.

We use precasting as much as possible now, particularly in the winter where we can construct the member inside a heated tent or shelter.

Experience and forecasted construction operations indicate that TOE units would do little precasting, and that which might be required would likely be tailored to a specific job.

Tailoring members most attractive. Availability of heavy timbers; steel sometimes limited. This is a good concept.

Current practices in Germany dictate that the larger more complex projects be assigned to civilian construction firms. We have precast some POL separator (3m × 4m) covers and similar structural elements. While engineer construction units in Europe have not, thus far, encountered a significant need for precast concrete, Theater of Operations facilities may lend themselves to use of precast concrete in the construction of walls, bridge slabs, liners for open ditches, and other areas. In the 79th Engineer Group in RVN we preferred to cast our reinforced concrete structures (such as bridge beams and slabs) in place. Nevertheless, the benefit-to-cost ratio for such uses should be investigated.

2. Should the proposed precasting facility include a prestressing capability?

Yes 5 No 5

Comments:

Without a prestressing capability, the facility would be very limited in application for bridge beams.

Precasting is on the verge of feasibility; prestressing too complicated for normal situations.

This operation is simple enough in practice to be easily incorporated and greatly expands mission capability.

Although precasting applications do arise, situations requiring prestressing at unit level are not as frequent to warrant a prestressing capability. In such instances it would probably be simpler to order the prestressed item as one would order a similar steel section.

Prestressing would require a very high level of engineering experience which would be extremely difficult to maintain in a TOE unit and is not recommended.

The design criteria used on a prestressed structure are close in so far as safety factors are concerned. I'm afraid our quality control isn't good enough (at troop unit level) to be absolutely sure we meet the specs of a prestressed member. You can see the trouble we would have by a structural failure traced to an ill-constructed

Figure A3 (sheet 2 of 5)

prestressed member. I know we preach quality control, and everyone honestly tries, but I'm just afraid this would go beyond what we are actually capable of doing in real life.

Casting prestressed concrete elements requires a higher degree of individual and unit technical expertise than will be found in TOE units.

A centralized facility is required. I would recommend this be in the Const. Spt. Company. With the proposed change of Const Bn to Combat Bn (Heavy), more rapid moves are anticipated. A prestressing facility must have more stability (i.e., fixed location, quality control).

If the precast facility is added, prestress capability should be included to make the facility as versatile and useful as possible.

3. Indicate those elements which should be included in the capabilities of a TOE precast facility:

   6 Types I and II AASHO I-Beams

   6 Tee Beams (Single or Double)

   3 Box Beams

   4 Channel Beams

   5 Slabs

   7 Wall Panels

   4 Piling

   7 Box Culverts

   5 Pipe

   4 Other: (Culvert Headwalls, Refuse Sumps/Tanks, Fence and Poles, Embankment Cribbing, Curbstones, Vehicle Barriers, Drop Inlets, Members for Crib Walls, Manholes, Catch Basins, Bridge Decking)

   Comments:

   The elements checked, being simplest, would most likely be employed in precasting operations if any.

4. Indicate those Theater of Operations type structures most suited to precast concrete construction:

   4 Administrative Buildings

   3 Barracks Type Buildings

   3 Bathhouse and Latrine Facilities

   2 Medical and Dental Facilities

Figure A3 (sheet 3 of 5)

__4__ Communications Facilities

__4__ Maintenance Facilities

__1__ Mess Facilities

__7__ Protective Structures (Bunkers, Revetments, etc.)

__7__ Bridges

__2__ Others: (Warehouse Facilities, POL Separators, Sewerage Structures)

Comments:

Although theater construction depends upon location, materials available, size of structure and permanence desired, those structures most suited to precast concrete would include hardened protective structure bridges, and some structures of a large size.

Those checked are usually "standard design." The others are dern near always a case-by-case, especially designed facility where we wouldn't gain that much by standard precasting.

Exact type depends on investment for forms. All of the above o.k. but X-marked probably most used.

5. In what organization should the precast facility be located?

__4__ Engineer Construction Battalion, TOE 5-115

__5__ Engineer Construction Support Company, TOE 5-114

__3__ Engineer Concrete Mixing and Paving Team, TOE 5-590T

_____ Other: The facility should be included as a non-active augmentation to both TO&E 5-114 and TO&E 5-590T

Comment:

Even if you come up with a requirement for precasting capability in the present environment it will be hard to train and develop experience in the CONUS Const. Bns. because of laws, regulations, and opportunity for construction.

In the long run if we need to use such a capability in a TO that is fairly static we would probably be better off to develop it then rather than to work it into our TO&E units now. I've never seen the Mixing and Paving Team except in FM's. Are they for real?

6. Has your Battalion had any experience with:

Yes __3__ No __5__ Concrete Precasting

Yes __0__ No __8__ Prestressing

Yes __3__ No __5__ Erection of commercial precast elements

Figure A3 (sheet 4 of 5)

If so, please provide synoposis of work.

Comments:

Precast lintels, small slabs, curbing, and vehicle bumpers have been used on several projects. On a large MCA project headwalls, stairs, lintels, large curbstones, vehicle bumpers were precast. An entire administrative office area with offices, storage and latrines would have been precast but the weight of sections required to be cast was too high due to restriction imposed by lifting equipment. 20T crane is heaviest organic equipment available. This is a critical consideration. Precast POL separators were also placed on this project. A contractor did the placing with the assistance of the troops; however, site preparation included a concrete "leveling course" that was placed by the troops. Troops could have performed the entire operation. In several places, concrete leveling pieces were precast and placed in areas where groundwater level was too high, thereby preventing compaction. Restriction here, of course, was that no heavy loads be used but some settlement be permitted.

We've done our own precasting on every barracks/maintenance facility we've built in Korea. Major parts have been lintels, window casings, bond beams, and segments of ring foundations. We've used commercially produced, prestressed stringers to repair a bridge.

As I'm sure you are aware, we do as much precasting as we can right now. As part of your study you mentioned preparing standard designs for precast members. I think this would be particularly useful to our situation. We could have precast wall sections had we really had a feel for reinforcing requirements.

We have few masons in the Bn and precast members would certainly help out in the skilled manpower (or lack thereof).

If possible, it would be helpful if you could run a cost analysis as part of your survey comparing precasts with similar members, walls, etc., not precast.

Small roof slabs (-1 × 2m). 577th Engr Bn (Const) precast a concrete bridge deck for the Ban Thech bridge, 990 ft long in RVN, 1968.

Figure A3 (sheet 5 of 5)

APPENDIX B: AASHO HIGHWAY LOADINGS

1. AASHO[8]* uses five standard truck loadings according to type of truck:

a. Two axle trucks--H20-44, H15-44, and H10-44.

b. Two axle trucks with semitrailers--HS20-44 and HS15-44. Figure B1 illustrates this loading system.

2. The uniformly distributed lane loading (Figure B2) is used when it produces the more severe loading condition. For simple spans, it will be found that truck loads are critical for moment for spans under 140 ft and for shear for spans under 120 ft.

3. Table B1 presents the maximum moments, shears, and reactions for standard AASHO loadings.

---

* Raised numbers refer to similarly numbered items in the References at the end of the main text.

Table B1

Maximum Moments, Shears, and Reactions--Simple Spans, One Lane (courtesy of AASHTO[8])

H15-44 Loading

Span	Moment	End shear and end reaction (a)
1	6.0(b)	24.0(b)
2	12.0(b)	24.0(b)
3	18.0(b)	24.0(b)
4	24.0(b)	24.0(b)
5	30.0(b)	24.0(b)
6	36.0(b)	24.0(b)
7	42.0(b)	24.0(b)
8	48.0(b)	24.0(b)
9	54.0(b)	24.0(b)
10	60.0(b)	24.0(b)
11	66.0(b)	24.0(b)
12	72.0(b)	24.0(b)
13	78.0(b)	24.0(b)
14	84.0(b)	24.0(b)
15	90.0(b)	24.0(b)
16	96.0(b)	24.8(b)
17	102.0(b)	25.1(b)
18	108.0(b)	25.3(b)
19	114.0(b)	25.6(b)
20	120.0(b)	25.8(b)
21	126.0(b)	26.0(b)
22	132.0(b)	26.2(b)
23	138.0(b)	26.3(b)
24	144.0(b)	26.5(b)
25	150.0(b)	26.6(b)
26	156.0(b)	26.8(b)
27	162.7(b)	26.9(b)
28	170.1(b)	27.0(b)
29	177.5(b)	27.1(b)
30	185.0(b)	27.2(b)
31	192.4(b)	27.3(b)
32	199.8(b)	27.4(b)
33	207.3(b)	27.5(b)
34	214.7(b)	27.7
35	222.2(b)	27.9
36	229.6(b)	28.1
37	237.1(b)	28.4
38	244.5(b)	28.6
39	252.0(b)	28.9
40	259.5(b)	29.1
42	274.4(b)	29.6
44	289.3(b)	30.1
46	304.3(b)	30.5
48	319.2(b)	31.0
50	334.2(b)	31.5
52	349.1(b)	32.0
54	364.1(b)	32.5
56	379.1(b)	32.9
58	397.6	33.4
60	418.5	33.9
62	439.9	34.4
64	461.8	34.9
66	484.1	35.3
68	506.9	35.8
70	530.3	36.3
75	590.6	37.5
80	654.0	38.7
85	720.4	39.9
90	789.8	41.1
95	862.1	42.3
100	937.5	43.5
110	1,097.3	45.9
120	1,269.0	48.3
130	1,452.8	50.7
140	1,648.5	53.1
150	1,856.3	55.6
160	2,076.0	57.9
170	2,307.8	60.3
180	2,551.5	62.7
190	2,807.3	65.1
200	3,075.0	67.0
220	3,646.5	72.3
240	4,265.0	77.1
260	4,933.5	81.9
280	5,649.0	86.7
300	6,412.5	91.5

(Continued)

Note: Spans in feet; moments in thousands of foot-pounds; shears and reactions in thousands of pounds. These values are subject to specification reduction for loading of multiple lanes. Impact not included.

(a) Concentrated load is considered placed at the support. Loads used are those stipulated for shear.

(b) Maximum value determined by Standard Truck Loadings. Otherwise the Standard Lane Loading governs.

(Sheet 1 of 4)

Table B1 (Continued)

H20-44 Loading

Span	Moment	End shear and end reaction (a)
1	8.0(b)	32.0(b)
2	16.0(b)	32.0(b)
3	24.0(b)	32.0(b)
4	32.0(b)	32.0(b)
5	40.0(b)	32.0(b)
6	48.0(b)	32.0(b)
7	56.0(b)	32.0(b)
8	64.0(b)	32.0(b)
9	72.0(b)	32.0(b)
10	80.0(b)	32.0(b)
11	88.0(b)	32.0(b)
12	96.0(b)	32.0(b)
13	104.0(b)	32.0(b)
14	112.0(b)	32.0(b)
15	120.0(b)	32.5(b)
16	128.0(b)	33.0(b)
17	136.0(b)	33.4(b)
18	144.0(b)	33.8(b)
19	152.0(b)	34.1(b)
20	160.0(b)	34.4(b)
21	168.0(b)	34.7(b)
22	176.0(b)	34.9(b)
23	184.0(b)	35.1(b)
24	192.0(b)	35.3(b)
25	200.0(b)	35.5(b)
26	208.0(b)	35.7(b)
27	216.9(b)	35.9(b)
28	226.8(b)	36.0(b)
29	236.7(b)	36.1(b)
30	246.6(b)	36.3(b)
31	256.5(b)	36.4(b)
32	266.5(b)	36.5(b)
33	276.4(b)	35.6(b)
34	286.3(b)	36.9
35	296.2(b)	37.2
36	306.2(b)	37.5
37	316.1(b)	37.8
38	326.1(b)	38.2
39	336.0(b)	38.5
40	346.0(b)	38.8

Span	Moment	End shear and end reaction (a)
42	365.9(b)	39.4
44	385.8(b)	40.1
46	405.7(b)	40.7
48	425.6(b)	41.4
50	445.6(b)	42.0
52	465.5(b)	42.6
54	485.5(b)	43.3
56	505.4(b)	43.9
58	530.1	44.6
60	558.0	45.2
62	586.5	45.8
64	615.7	46.5
66	645.5	47.1
68	675.9	47.8
70	707.0	48.4
75	787.5	50.0
80	872.0	51.6
85	960.5	53.2
90	1,053.0	54.8
95	1,149.5	56.4
100	1,250.0	58.0
110	1,463.0	61.2
120	1,692.0	64.4
130	1,937.0	67.6
140	2,198.0	70.8
150	2,475.0	74.0
160	2,768.0	77.2
170	3,077.0	80.4
180	3,402.0	83.6
190	3,743.0	86.8
200	4,100.0	90.0
220	4,862.0	96.4
240	5,658.0	102.8
260	6,578.0	109.2
280	7,532.0	115.6
300	8,550.0	122.0

(Continued)

(a) Concentrated load is considered placed at the support. Loads used are those stipulated for shear.

(b) Maximum value determined by Standard Truck Loading. Otherwise the Standard Lane Loading governs.

(Sheet 2 of 4)

Table B1 (Continued)

HS15-44 Loading

Span	Moment	End shear and end reaction (a)
1	6.0(b)	24.0(b)
2	12.0(b)	24.0(b)
3	18.0(b)	24.0(b)
4	24.0(b)	24.0(b)
5	30.0(b)	24.0(b)
6	36.0(b)	24.0(b)
7	42.0(b)	24.0(b)
8	48.0(b)	24.0(b)
9	54.0(b)	24.0(b)
10	60.0(b)	24.0(b)
11	66.0(b)	24.0(b)
12	72.0(b)	24.0(b)
13	78.0(b)	24.0(b)
14	84.0(b)	24.0(b)
15	90.0(b)	25.6(b)
16	96.0(b)	27.0(b)
17	102.0(b)	28.2(b)
18	108.0(b)	29.3(b)
19	114.0(b)	30.3(b)
20	120.0(b)	31.2(b)
21	126.0(b)	32.0(b)
22	132.0(b)	32.7(b)
23	138.0(b)	33.4(b)
24	144.5(b)	34.0(b)
25	155.5(b)	34.6(b)
26	166.6(b)	35.1(b)
27	177.8(b)	35.6(b)
28	189.0(b)	36.0(b)
29	200.3(b)	36.6(b)
30	211.6(b)	37.2(b)
31	223.0(b)	37.7(b)
32	234.4(b)	38.3(b)
33	245.8(b)	38.7(b)
34	257.7(b)	39.2(b)
35	270.9(b)	39.6(b)
36	284.2(b)	40.0(b)
37	297.5(b)	40.4(b)
38	310.7(b)	40.7(b)
39	324.0(b)	41.1(b)
40	337.4(b)	41.4(b)

Span	Moment	End shear and end reaction (a)
42	364.0(b)	42.0(b)
44	390.7(b)	42.5(b)
46	417.4(b)	43.0(b)
48	444.1(b)	43.5(b)
50	470.9(b)	43.9(b)
52	497.7(b)	44.3(b)
54	524.5(b)	44.7(b)
56	551.3(b)	45.0(b)
58	578.1(b)	45.3(b)
60	604.9(b)	45.6(b)
62	631.8(b)	45.9(b)
64	658.6(b)	46.1(b)
66	685.5(b)	46.4(b)
68	712.3(b)	46.6(b)
70	739.2(b)	46.8(b)
75	806.3(b)	47.3(b)
80	873.7(b)	47.7(b)
85	941.0(b)	48.1(b)
90	1,008.3(b)	48.4(b)
95	1,074.9(b)	48.7(b)
100	1,143.0(b)	49.0(b)
110	1,277.7(b)	49.4(b)
120	1,412.5(b)	49.8(b)
130	1,547.3(b)	50.7
140	1,682.1(b)	53.1
150	1,856.3	55.5
160	2,076.0	57.9
170	2,307.8	60.3
180	2,551.5	62.7
190	2,807.3	65.1
200	3,075.0	67.5
220	3,646.5	72.3
240	4,266.0	77.1
260	4,933.5	81.9
280	5,649.0	86.7
300	6,412.5	91.5

(Continued)

(a) Concentrated load is considered placed at the support. Loads used are those stipulated for shear.

(b) Maximum value determined by Standard Truck Loading (one HS truck). Otherwise the Standard Lane Loading governs.

(Sheet 3 of 4)

Table B1 (Concluded)

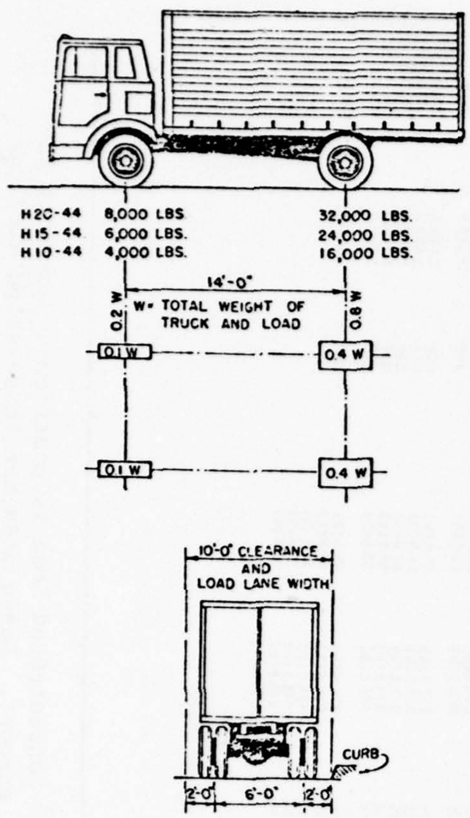
HS20-44 Loading

Span	Moment	End shear and end reaction (a)
1	8.0(b)	32.0(b)
2	16.0(b)	32.0(b)
3	24.0(b)	32.0(b)
4	32.0(b)	32.0(b)
5	40.0(b)	32.0(b)
6	48.0(b)	32.0(b)
7	56.0(b)	32.0(b)
8	64.0(b)	32.0(b)
9	72.0(b)	32.0(b)
10	80.0(b)	32.0(b)
11	88.0(b)	32.0(b)
12	96.0(b)	32.0(b)
13	104.0(b)	32.0(b)
14	112.0(b)	32.0(b)
15	120.0(b)	34.1(b)
16	128.0(b)	36.0(b)
17	136.0(b)	37.7(b)
18	144.0(b)	39.1(b)
19	152.0(b)	40.4(b)
20	160.0(b)	41.6(b)
21	168.0(b)	42.7(b)
22	176.0(b)	43.6(b)
23	184.0(b)	44.5(b)
24	192.7(b)	45.3(b)
25	207.4(b)	46.1(b)
26	222.2(b)	46.8(b)
27	237.0(b)	47.4(b)
28	252.0(b)	48.0(b)
29	267.0(b)	48.8(b)
30	282.1(b)	49.6(b)
31	297.3(b)	50.3(b)
32	312.5(b)	51.0(b)
33	327.8(b)	51.6(b)
34	343.5(b)	52.2(b)
35	361.2(b)	52.8(b)
36	378.9(b)	53.3(b)
37	396.6(b)	53.8(b)
38	414.3(b)	54.3(b)
39	432.1(b)	54.8(b)
40	449.8(b)	55.2(b)
42	485.3(b)	56.0(b)
44	520.9(b)	56.7(b)
46	556.5(b)	57.3(b)
48	592.1(b)	58.0(b)
50	627.9(b)	58.5(b)
52	663.6(b)	59.1(b)
54	699.3(b)	59.6(b)
56	735.1(b)	60.0(b)
58	770.8(b)	60.4(b)
60	806.5(b)	60.8(b)
62	842.4(b)	61.2(b)
64	878.1(b)	61.5(b)
66	914.0(b)	61.9(b)
68	949.7(b)	62.1(b)
70	985.6(b)	62.4(b)
75	1,075.1(b)	63.1(b)
80	1,164.9(b)	63.6(b)
85	1,254.7(b)	64.1(b)
90	1,344.4(b)	64.5(b)
95	1,434.1(b)	64.9(b)
100	1,524.0(b)	65.3(b)
110	1,703.6(b)	65.9(b)
120	1,883.3(b)	66.4(b)
130	2,063.1(b)	67.6
140	2,242.8(b)	70.8
150	2,475.1	74.0
160	2,768.0	77.2
170	3,077.1	80.4
180	3,402.1	83.6
190	3,743.1	86.8
200	4,100.0	90.0
220	4,862.0	96.4
240	5,688.0	102.8
260	6,578.0	109.2
280	7,532.0	115.6
300	8,550.0	122.0

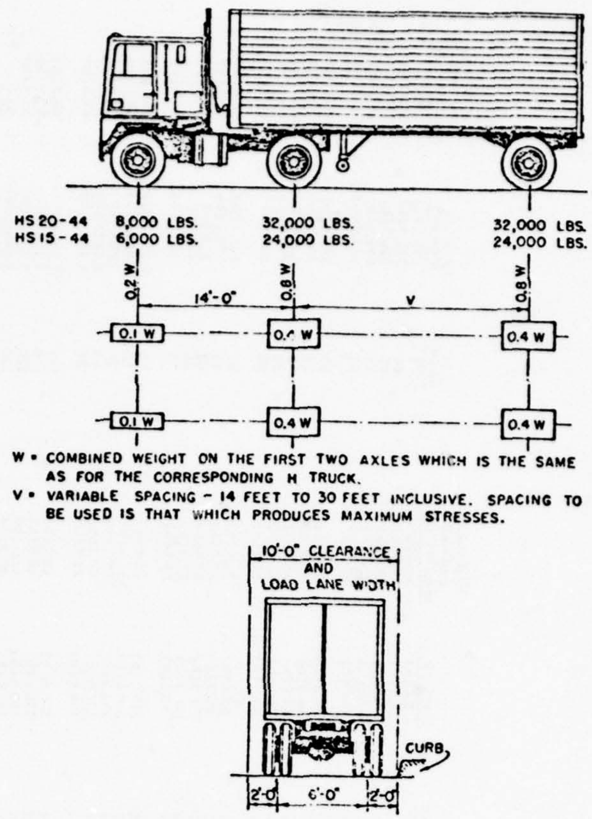
(a) Concentrated load is considered placed at the support. Loads used are those stipulated for shear.

(b) Maximum value determined by Standard Truck Loading (one HS truck). Otherwise the Standard Lane Loading governs.

(Sheet 4 of 4)



a. Standard H trucks



b. Standard HS trucks

Figure B1. Standard truck loadings (courtesy of AASHTO[8])

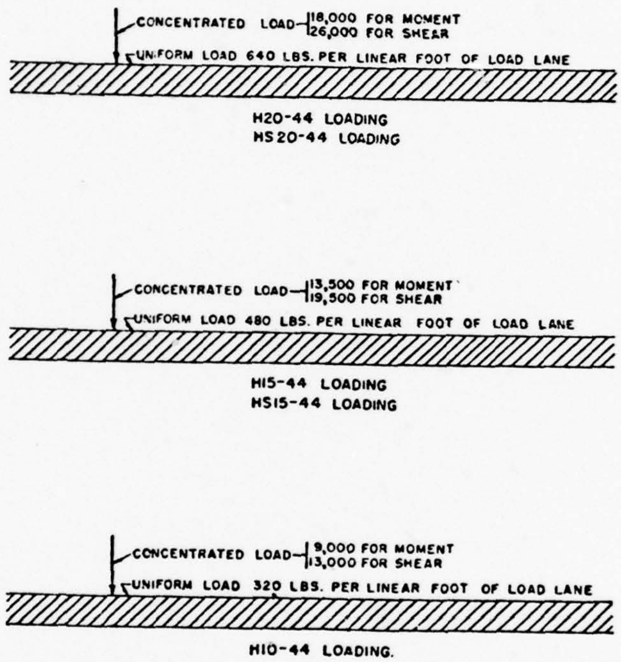


Figure B2. H lane and HS lane loadings (courtesy of AASHTO[8])

APPENDIX C: AREA RAILROAD LOADINGS

1. The standard railroad loading recommended by AREA[29] for fixed spans under 400 ft is Cooper E-72 (Figure C1). This loading represents two locomotives with maximum axial loads of 72 kips, followed by a

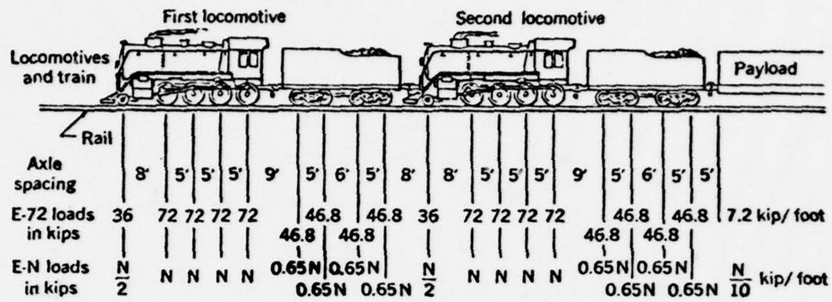


Figure C1. Cooper E-72 railroad loadings

uniformly distributed load of 7.2 kips/ft of track. If E-72 is not a satisfactory representation of the bridge usage, e.g. a bridge on a minor branch line, it is permissible to use another loading with the same axle spacing but with the loads all altered by a constant ratio. For example, E-N would have loads N/72 times those shown in Figure C1 for E-72.

2. Figure C2 illustrates the case of a multitrack bridge in which it is necessary to decide on track loadings. The AREA code does not require all tracks to be fully loaded simultaneously for bridges with three or more tracks.

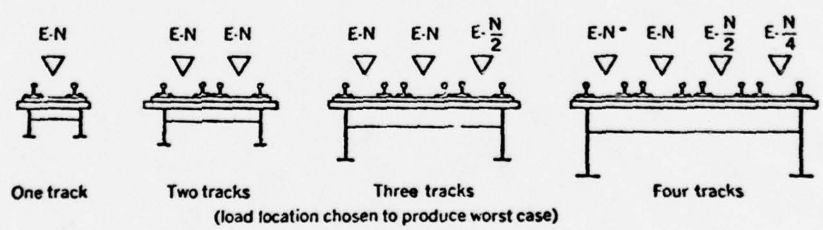


Figure C2. Loads on multitrack rail bridges

APPENDIX D: RECOMMENDED PRECAST CONCRETE MILITARY BRIDGES

1. From the many precast concrete bridge structures surveyed and evaluated (Part III), it appears that the precast channel girder bridges developed by the State Aid Division of MSHD are most suitable for use in the TO.

2. Since these bridges are designed for AASHO[8] H15 loadings, they need to be modified in order to support military HET's[61] (maximum weight = 172,000 lb). The design modification was accomplished by using a computer program (Appendix E) and was based on the following assumptions and criteria:

- a. Precast channel elements will act as one unit. Shear keys and/or transverse tie rods will distribute the loads laterally. Thus, the load carried by each element is less than a full wheel load.
- b. Modified AASHO HS20 loadings having a total weight of 172,000 lb are used.
- c. The allowable stresses used in the design are those specified in the AASHO specification.
- d. The minimum strength of concrete at 28 days is 5000 psi. Minimum concrete strength for removing channel elements is 3000 psi.
- e. Minimum concrete strength before applying initial prestress is 4200 psi.
- f. Stress-steel tendous have a minimum ultimate strength of 160,000 psi and yield strength of 140,000 psi.
- g. All reinforcing bars conform to ASTM A 615.[62]

The design details of the recommended precast concrete channel girder bridges are given in Figures D1-D4.

3. The weights of the interior and exterior units are approximately 13,300 and 14,600 lb, respectively, for 19-ft span bridge and 20,000 and 30,000 lb, respectively, for 31-ft span bridge. Two exterior curb units and six interior units are required to obtain a 26-ft-6-in. clear roadway.

4. The recommended erection sequence for the precast concrete channel girder bridges is as follows:

- a. Install precast concrete piles per TM 5-258.[36]
- b. Place precast concrete pile cap on top of precast concrete piles and connect to the piles with dowel pins inserted

through holes in the pile cap into the precast holes (or holes drilled after driving) at the top of the piles. Grout all dowel holes.

c. Position channel girders on the pile cap, and after proper alignment has been obtained, pins are placed in the dowel holes and all holes in the girders and caps are grouted.

d. The girders are tied transversely by bolting the legs of adjacent channels together. Longitudinally, all channel ends are also bolted together.

e. After bolting, all keys are grouted before traffic use; no leveling or wearing course is required.

5. Photos D1 through D26 illustrate a typical fabrication, transportation, and erection sequence for a 19-ft span precast channel girder bridge supported on timber piles.

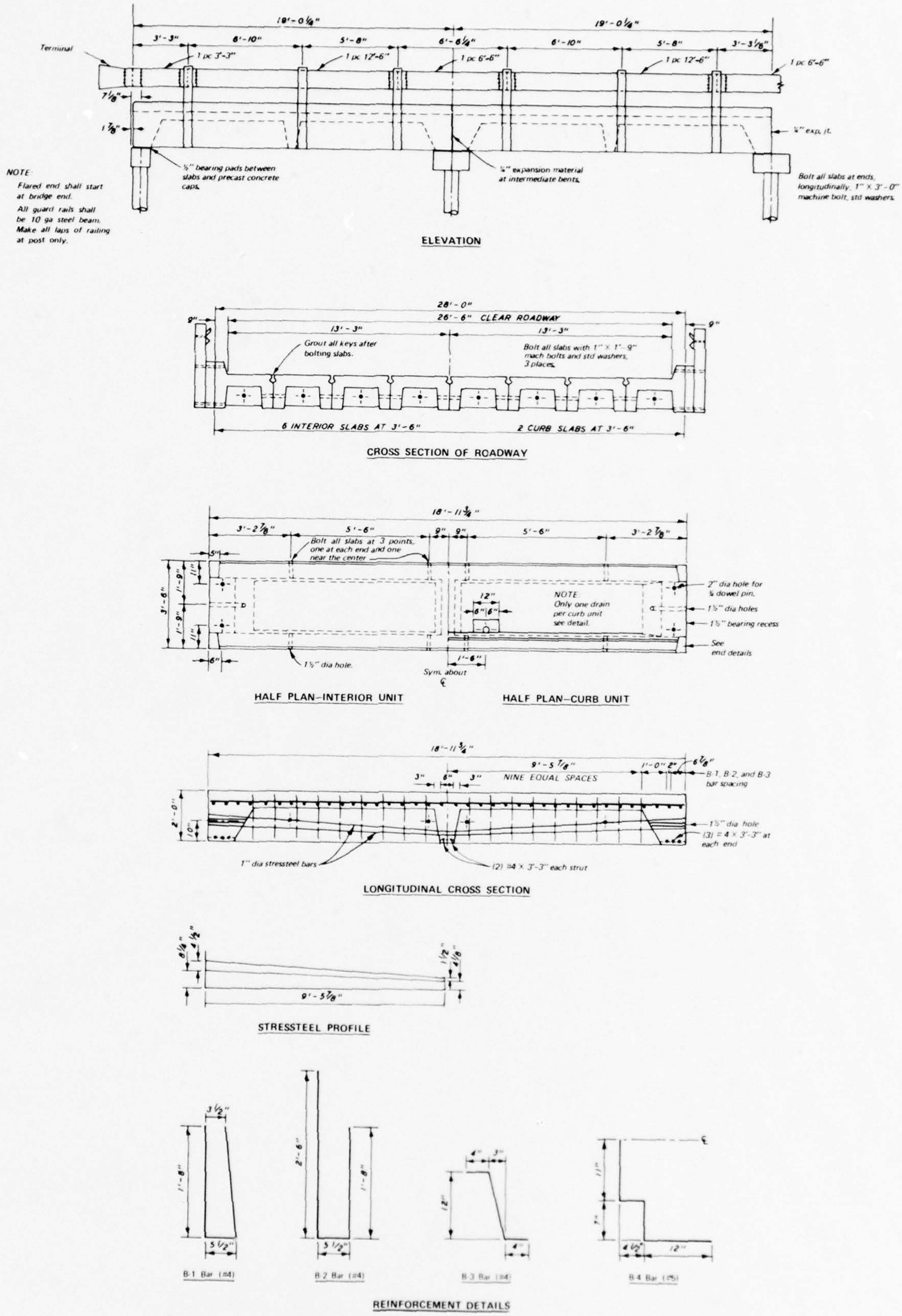
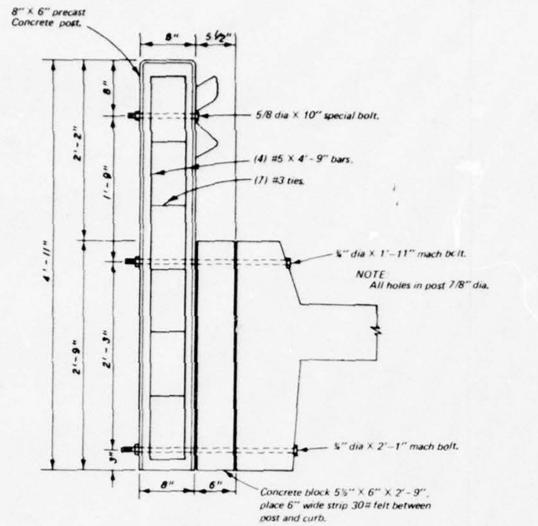
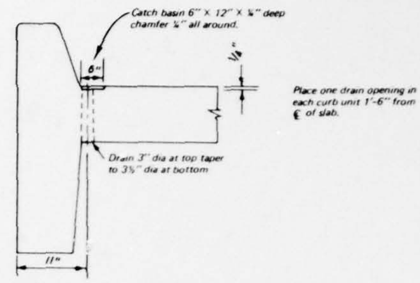


Figure D1. Precast, prestressed concrete

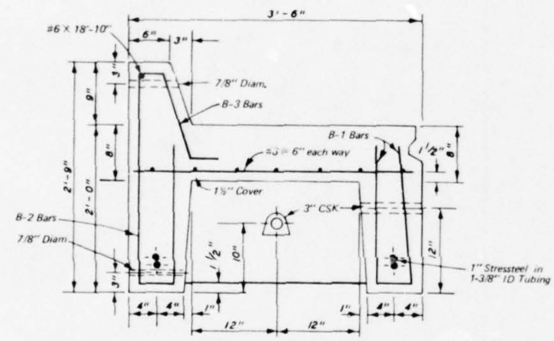
slabs at ends.
dinally, 1" X 3'-0"
bolt, std washers.



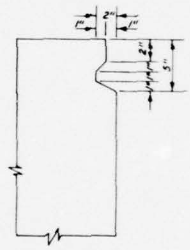
PRECAST POST DETAIL



SECTION AT DRAIN



CURB UNIT CROSS-SECTION
NEAR CENTER LINE



KEY DETAIL

GENERAL NOTES

Concrete:

All concrete shall have a minimum strength of 5,000 psi at 28 days.

Maximum size of concrete aggregate shall be 1".

Minimum concrete strength for removing these slabs from their forms shall be 3,000 psi.

Minimum concrete strength before applying initial prestress shall be 4,200 psi.

All exposed concrete corners shall be chamfered 3/4" unless otherwise noted.

Prestressing Steel:

Stressteel tendons shall have a minimum ultimate strength of 160,000 psi, f_{sy} = 140,000 psi ASTM A322 and A29. All tendons shall be grouted.

Prestressing Stressteel Bars:

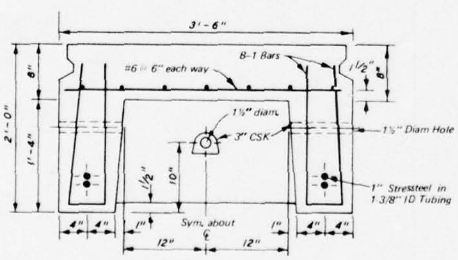
After concrete has reached a minimum strength of 3,000 psi, handling stresses of 60,000 pounds may be applied to the two top tendons only and the slabs removed from the forms. After concrete has minimum strength of 1,200 psi, the total initial prestressing force of 90,700 pounds shall be applied to each of the 1" tendons. When tensioning the tendons, corresponding tendons in each leg shall be jacked simultaneously. The tendons shall be jacked from one end.

Hardware:

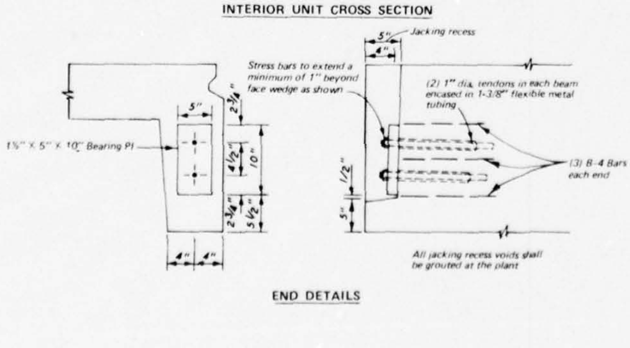
All machine and special bolts shall be galvanized steel ASTM A307, galvanized ASTM A153.

Reinforcing Bars:

All reinforcing bars shall conform to ASTM A615.



INTERIOR UNIT CROSS SECTION



END DETAILS

estressed concrete bridge slab details for 19-ft spans

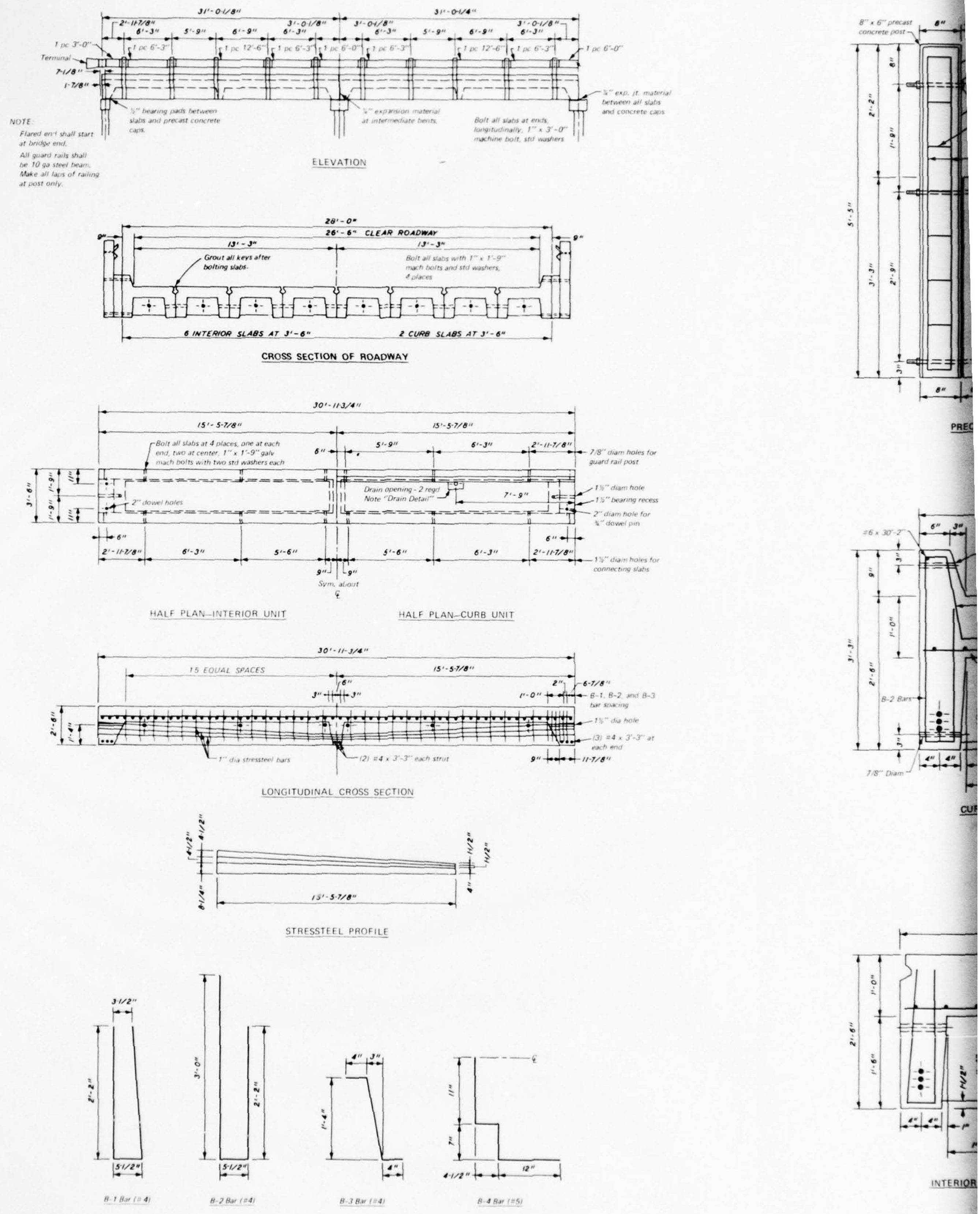
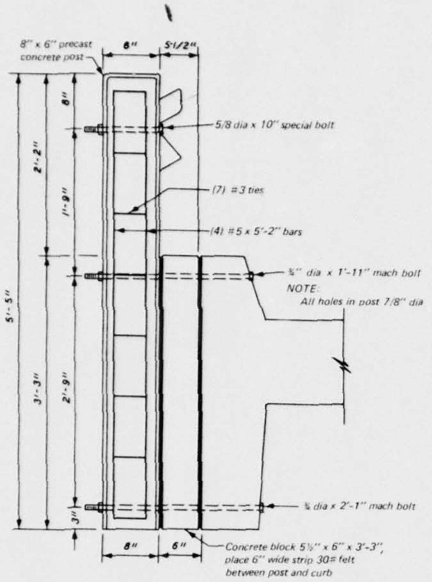
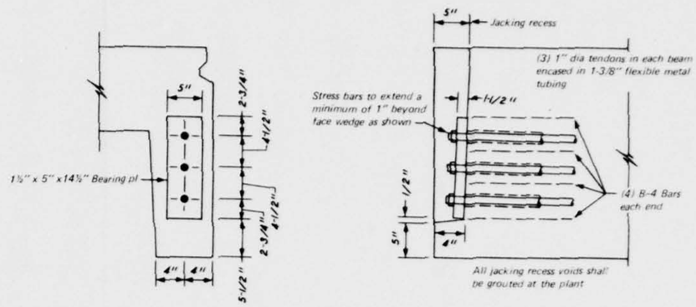


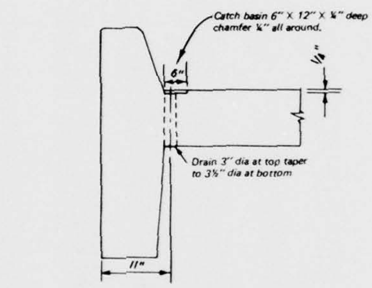
Figure D2. Precast, prestressed concrete br



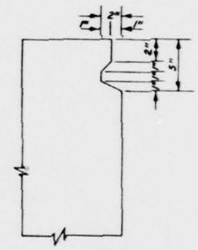
PRECAST POST DETAIL



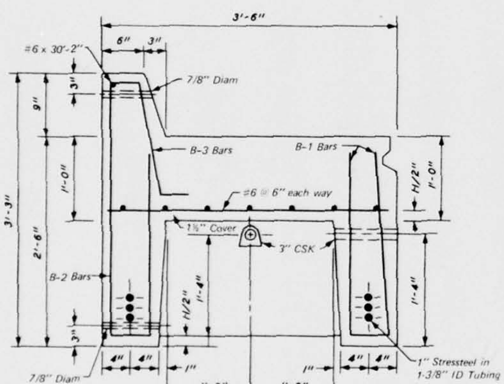
END DETAILS



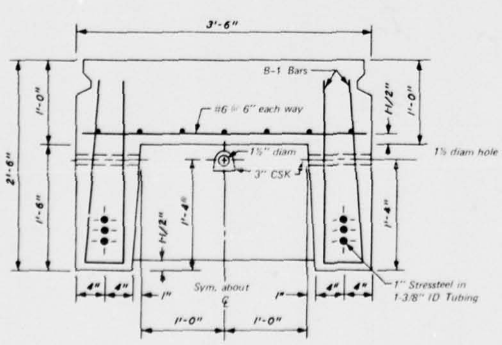
SECTION AT DRAIN



KEY DETAIL



CURB UNIT CROSS-SECTION
NEAR CENTER LINE



INTERIOR UNIT CROSS SECTION

GENERAL NOTES

Concrete:

All concrete shall have a minimum strength of 5,000 psi at 28 days.

Maximum size of concrete aggregate shall be 1".

Minimum concrete strength for removing these slabs from their forms shall be 3,000 psi.

Minimum concrete strength before applying initial prestress shall be 4,200 psi.

All exposed concrete corners shall be chamfered 3/4" unless otherwise noted.

Prestressing Steel:

Stressteel tendons shall have a minimum ultimate strength of 160,000 psi, f_{sy} = 140,000 psi ASTM A322 and A29. All tendons shall be grouted.

Prestressing Stressteel Bars:

After concrete has reached a minimum strength of 3,000 psi, handling stresses of 60,000 pounds may be applied to the two top tendons only and the slabs removed from the forms. After concrete has minimum strength of 4,200 psi, the total initial prestressing force of 90,700 pounds shall be applied to each of the 1" tendons. When tensioning the tendons, corresponding tendons in each leg shall be jacked simultaneously. The tendons shall be jacked from one end.

Hardware:

All machine and special bolts shall be galvanized steel ASTM A307, galvanized ASTM A153.

Reinforcing Bars:

All reinforcing bars shall conform to ASTM A615.

stressed concrete bridge slab details for 31-ft spans

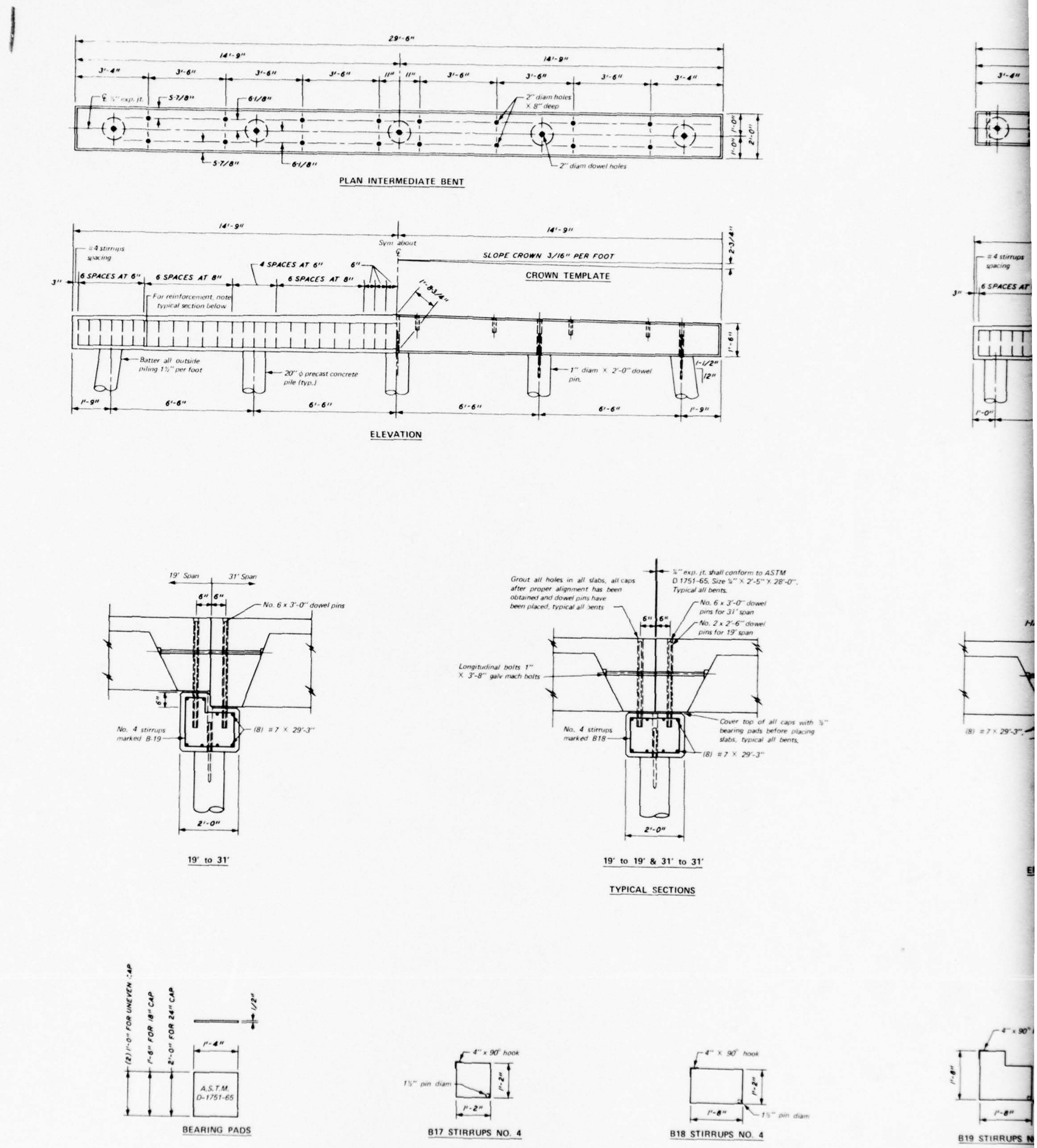
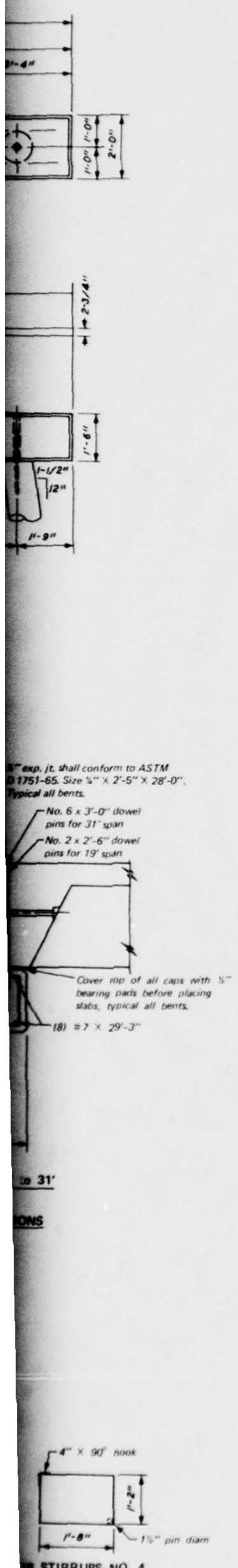
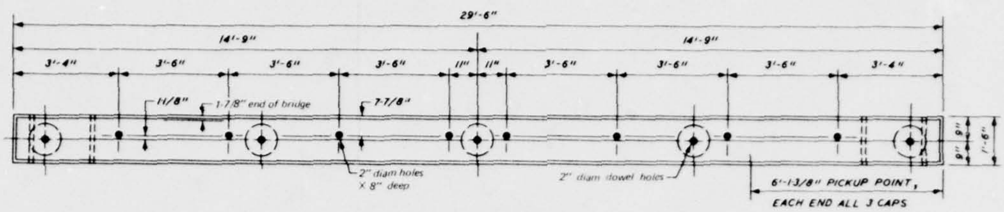
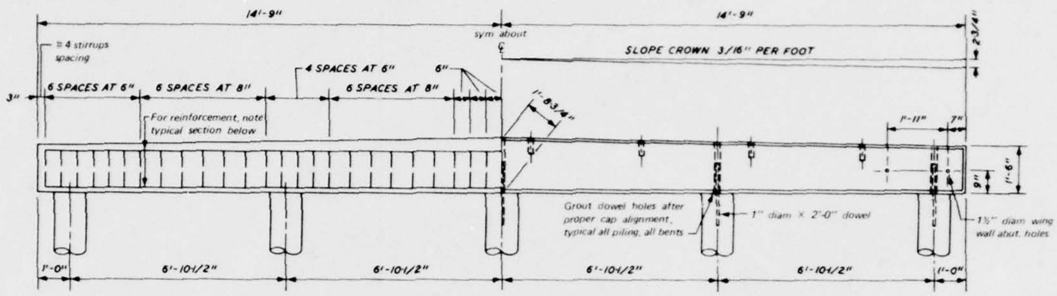


Figure D3. Precast concrete caps

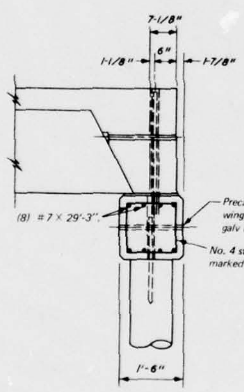




PLAN END BENT



ELEVATION END BENT



END SECTION

GENERAL NOTES

Concrete:

All concrete shall have a minimum ultimate compressive strength of 3,000 psi at 28 days.

Concrete shall reach a strength of 2,500 psi before caps may be lifted from forms.

All exposed edges shall be chamfered 3/4" × 45° unless otherwise noted.

Reinforcing:

All reinforcing steel shall be accurately located in the forms and firmly held in place by steel wire supports.

Reinforcing steel shall be deformed bars conforming to ASTM A615.

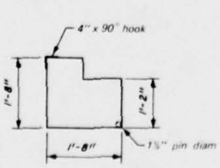
Reinforcing dimensions are to the ℄'s of bars unless otherwise noted.

Piling:

All piling shall meet AASHO specifications. Drive all piling to a minimum of 35 tons.

Hardware:

Hardware shall be either black mild steel or wrought iron.



B19 STIRRUPS NO. 4

Figure D3. Precast concrete caps

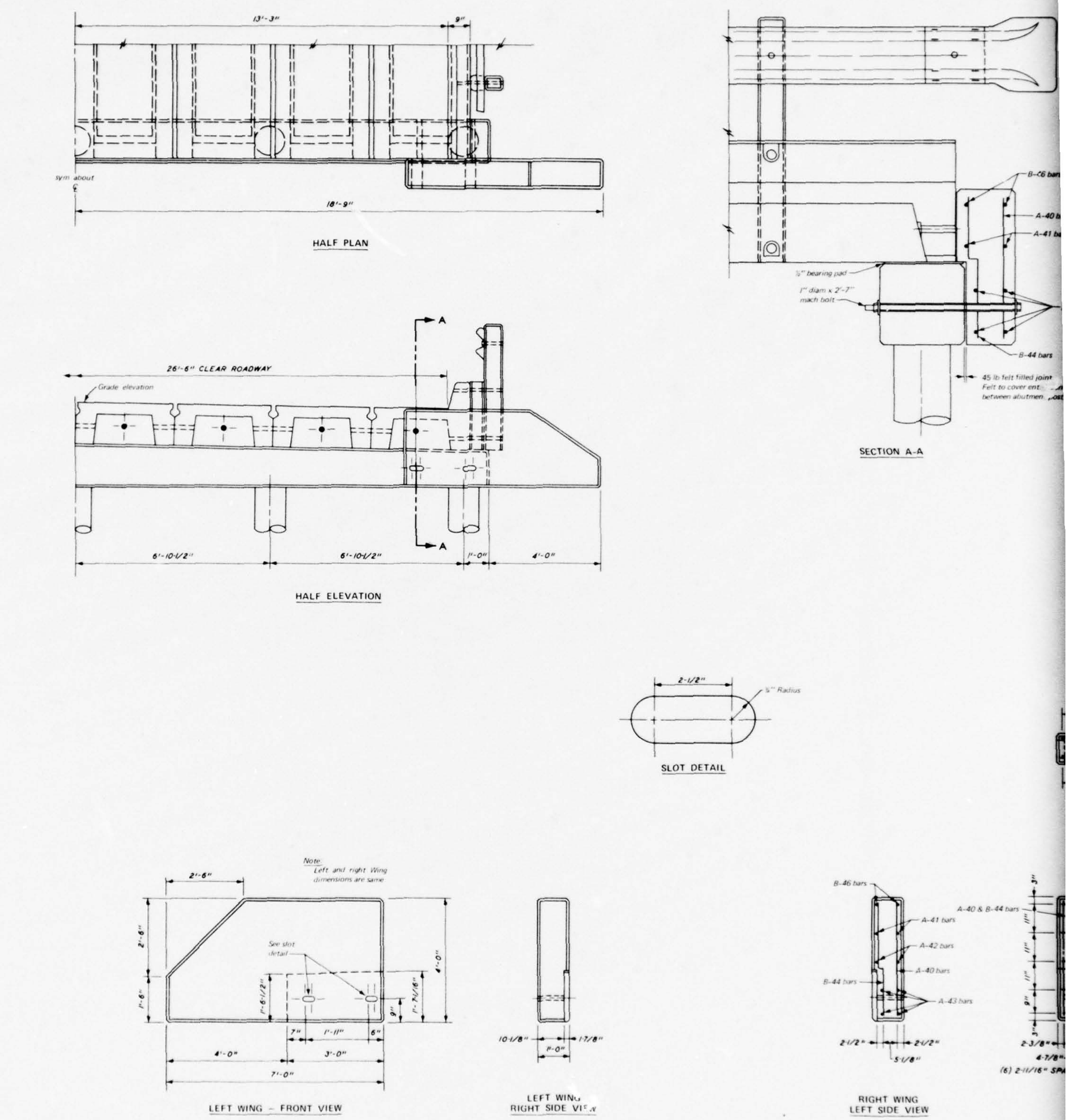
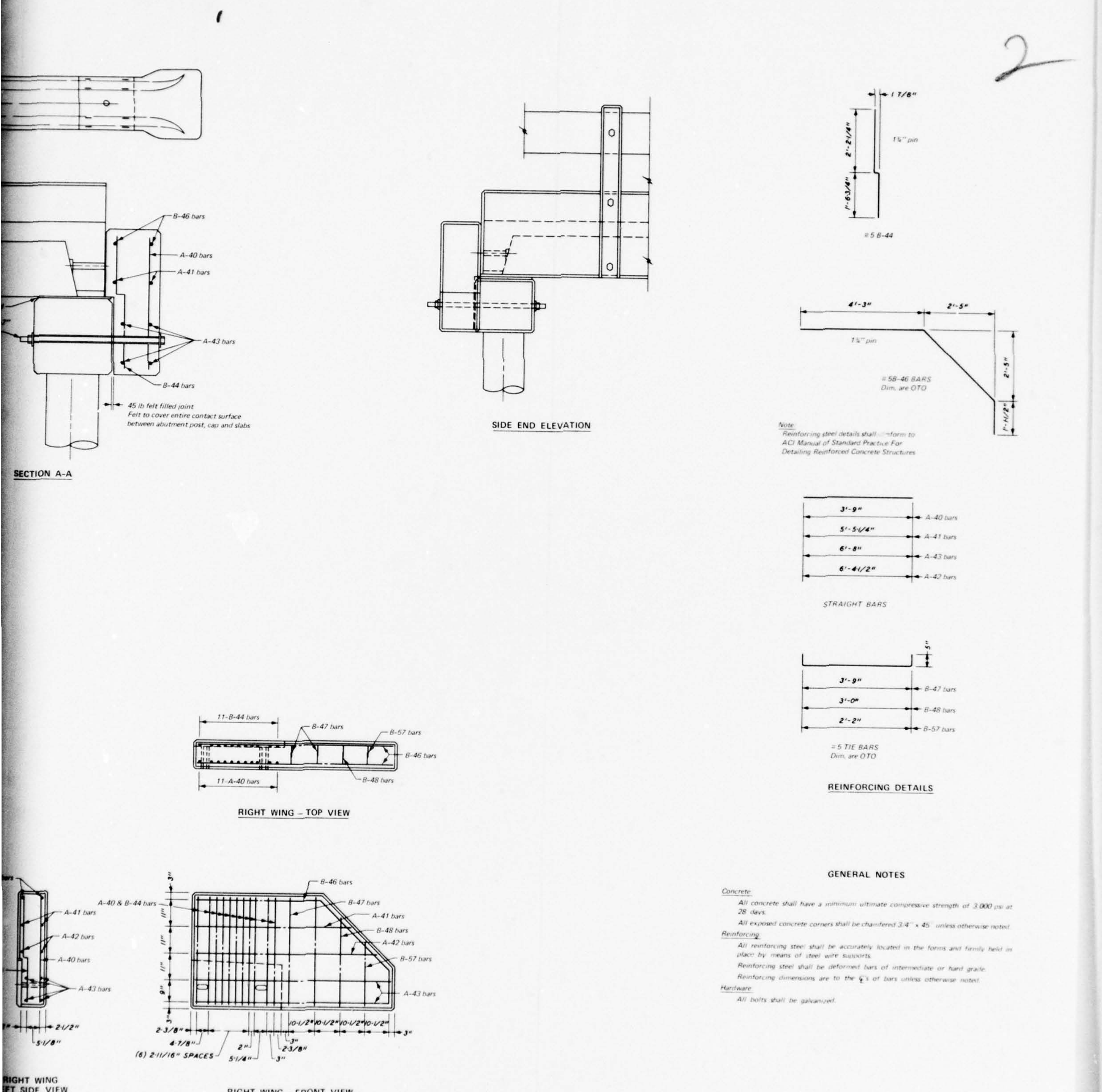


Figure D4. Precast concrete



• Precast concrete abutment wings

Photo D1. A minimal concrete production facility

Photo D2. Reinforcement storage

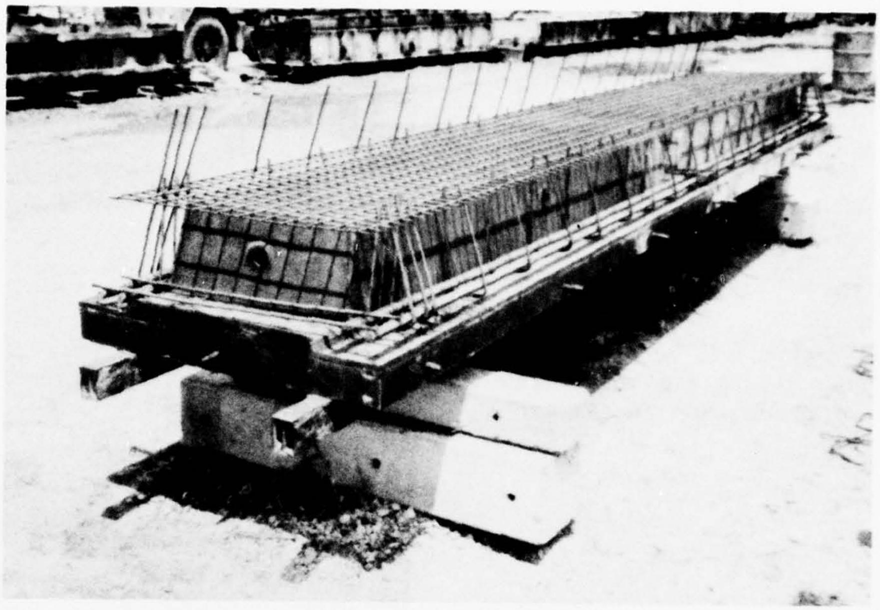


Photo D3. Base of exterior girder form with reinforcing positioned

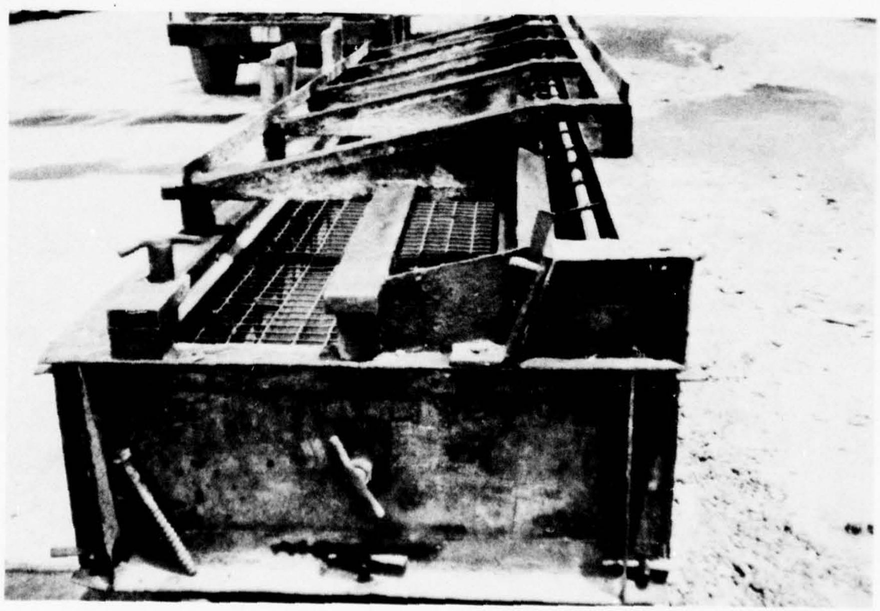


Photo D4. Exterior reinforced concrete girder immediately prior to casting

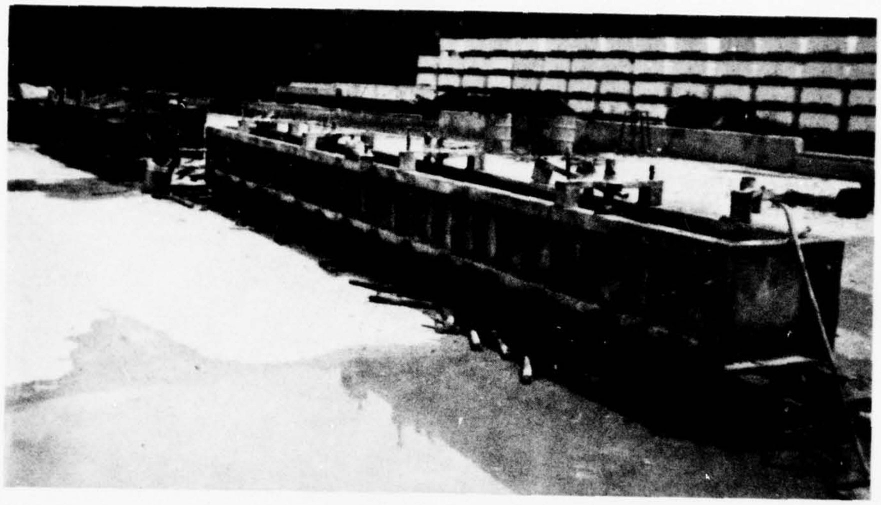


Photo D5. Pile cap form

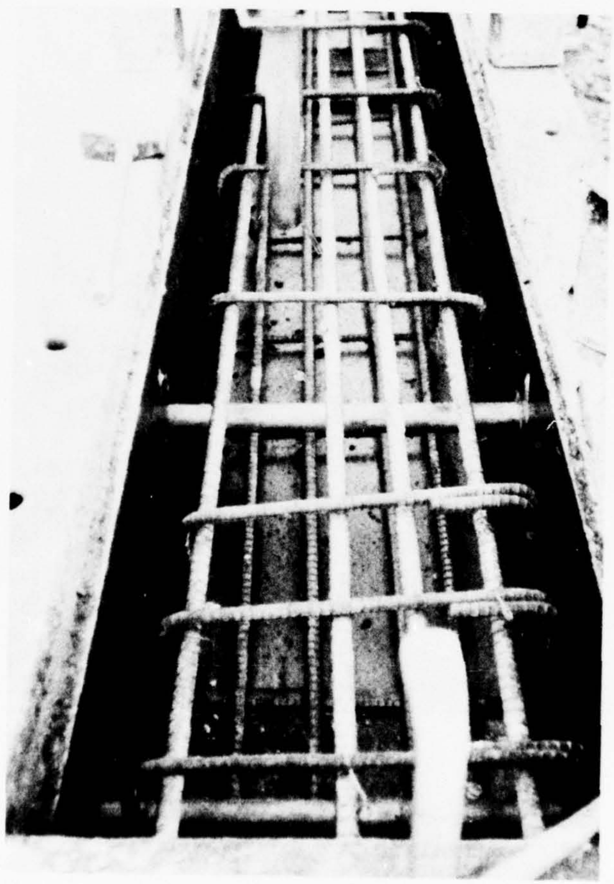
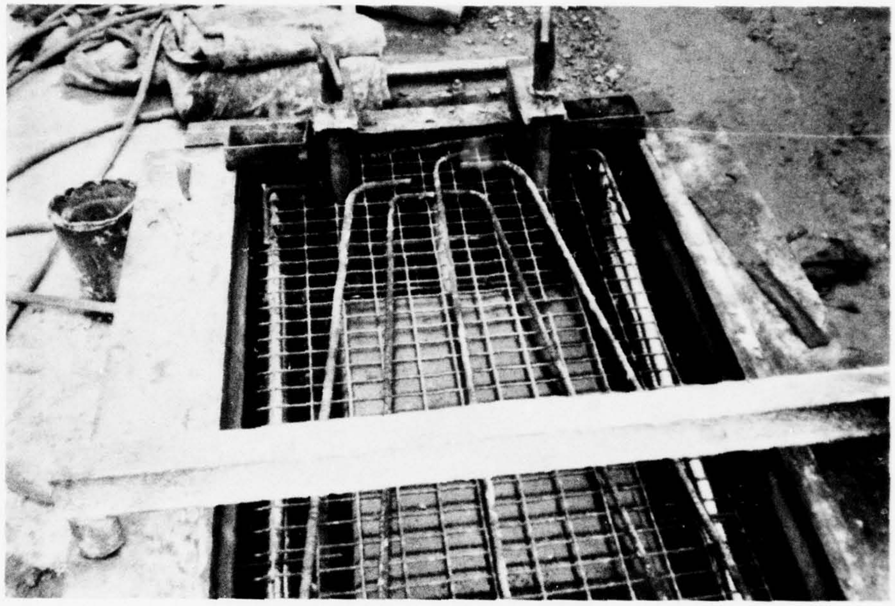
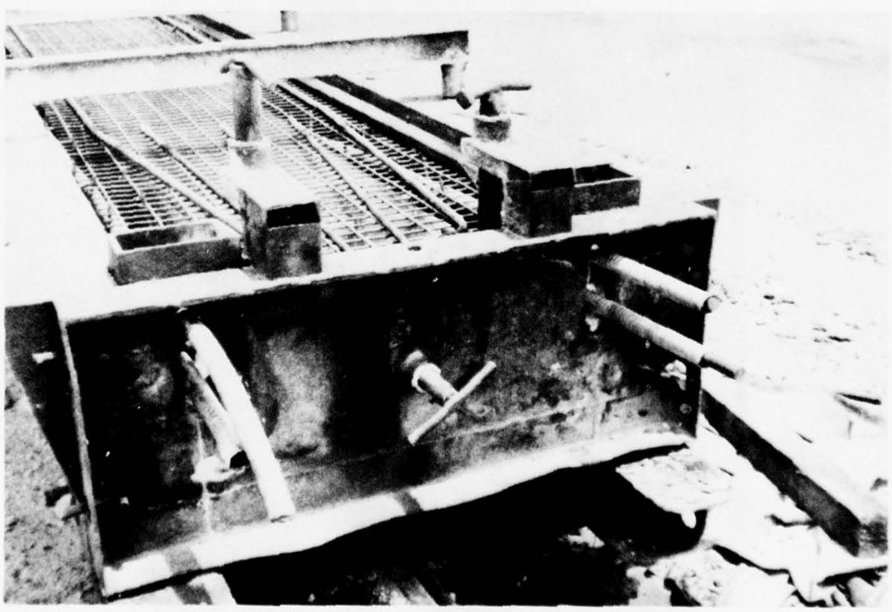


Photo D6. Pile cap reinforcing

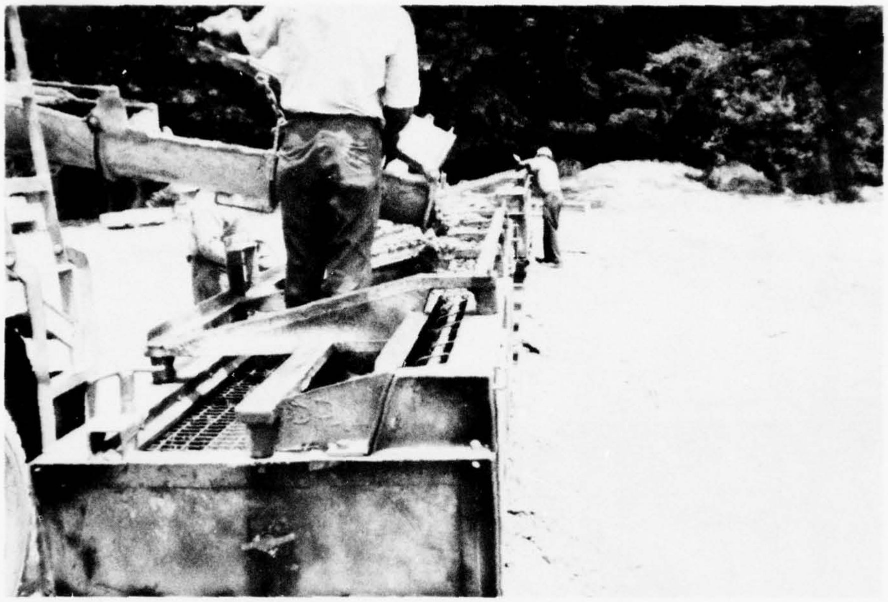


a. Top view

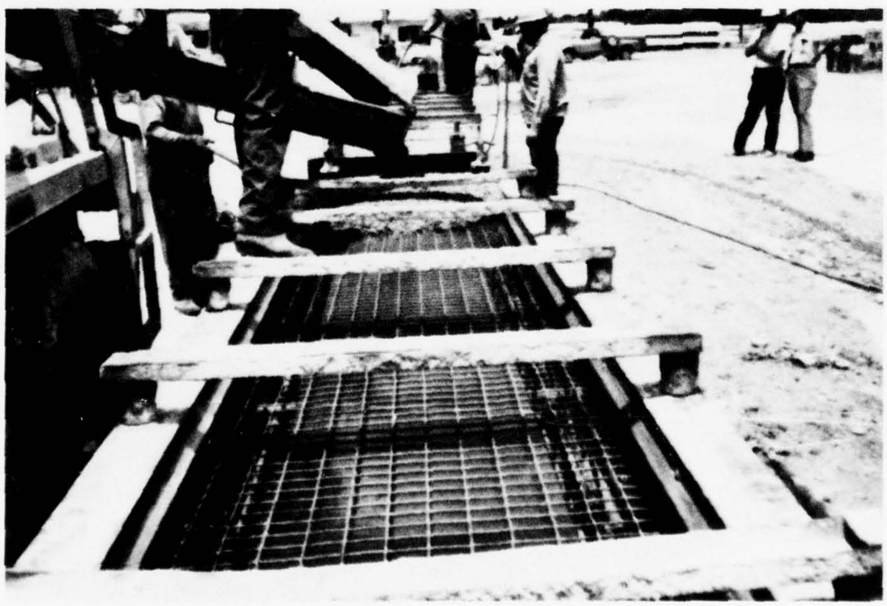


b. End view

Photo D7. Interior posttensioned concrete girder immediately prior to casting



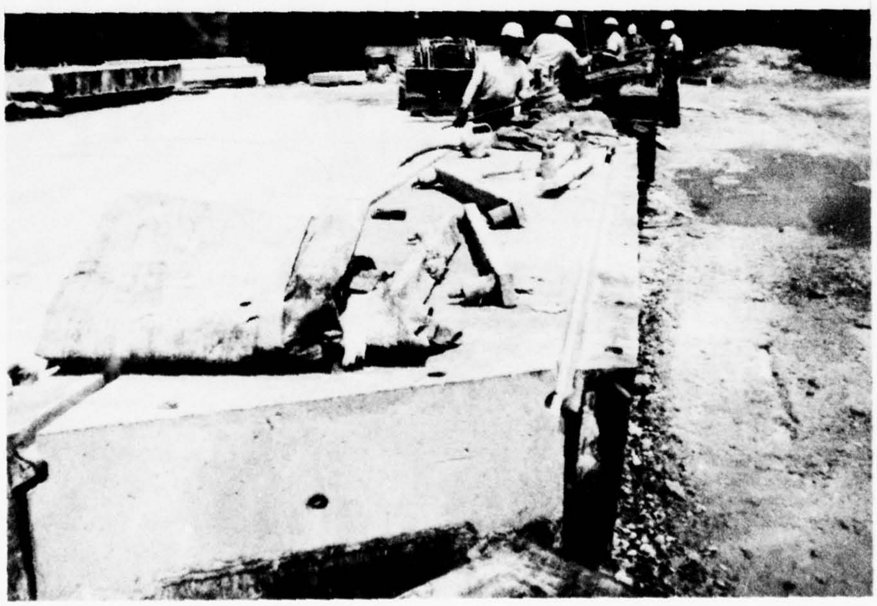
a. Exterior girder



b. Interior girder

Photo D8. Placing, consolidation, and finishing of concrete channel girders

a. Conventional interior girder



b. Skewed-end girder

Photo D9. Form stripping operations

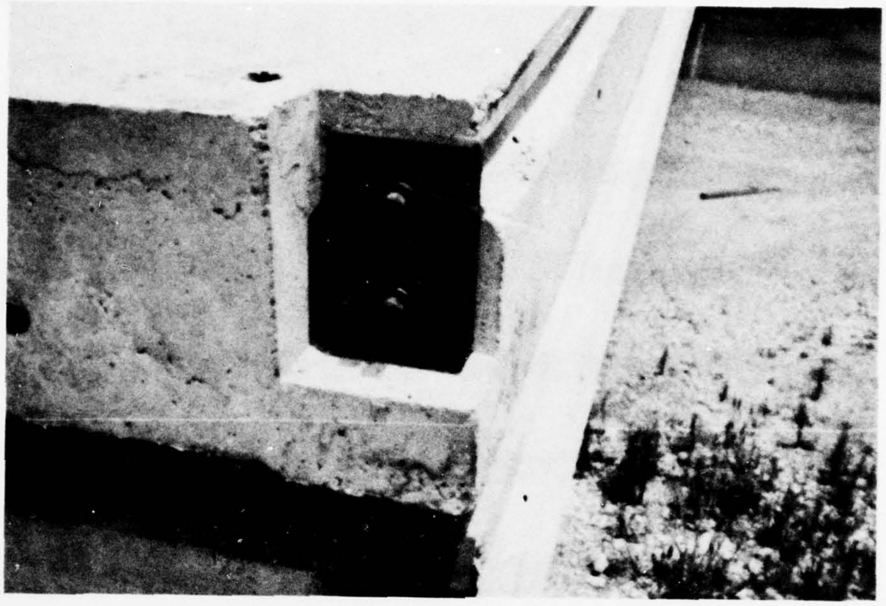


Photo D10. Channel girder after posttensioning and removal of excess tendon

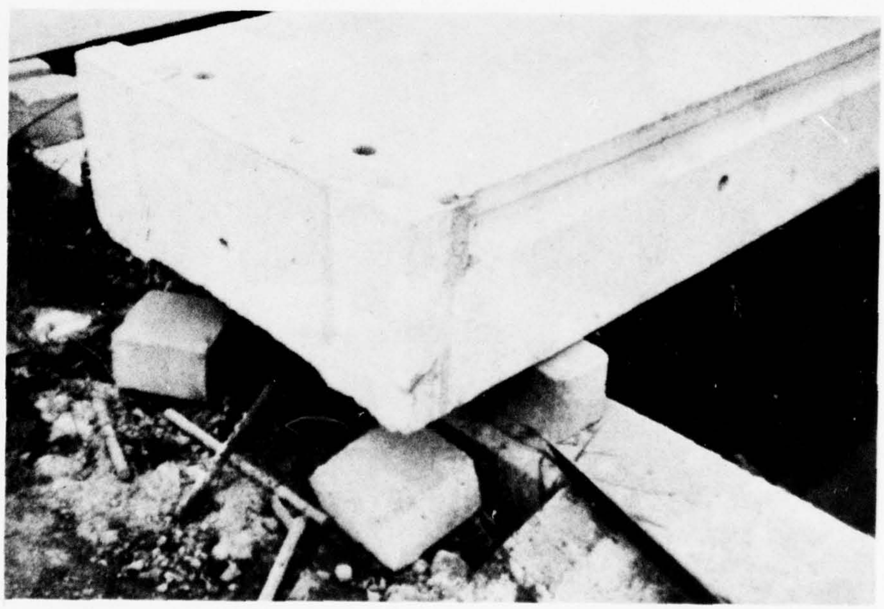


Photo D11. After grouting of stress-steel tendon, end anchorage protection is applied

Photo D12. Storage at precast plant

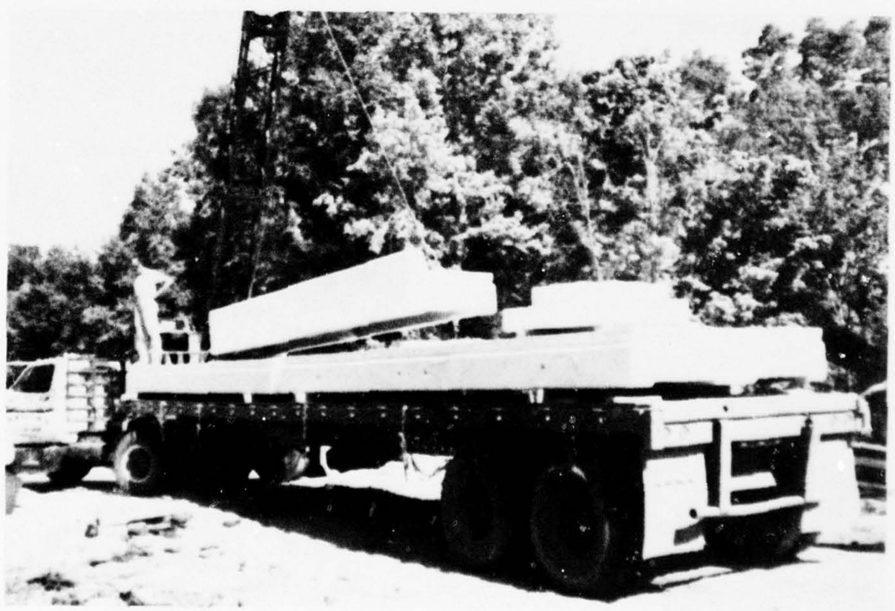


Photo D13. Typical transportation, precast plant to erection site

Photo D14. Pile driving equipment

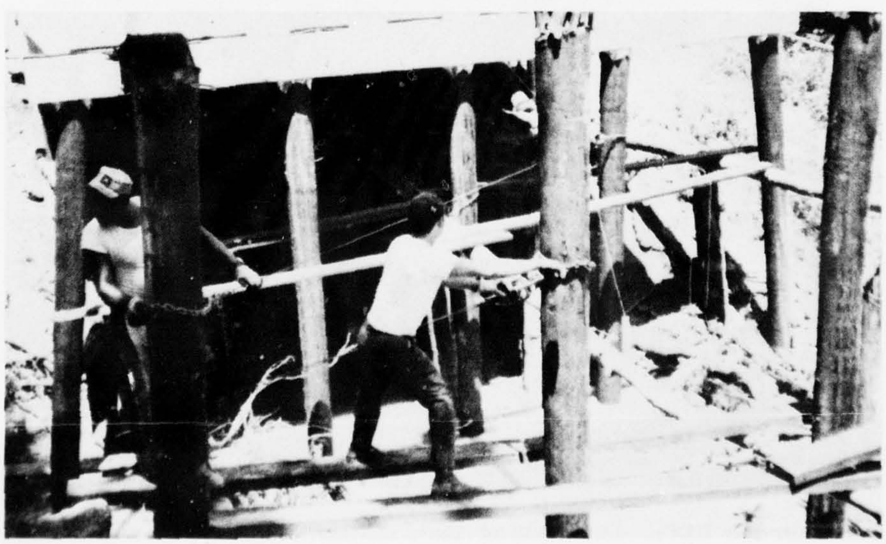


Photo D15. Using hand winches to obtain proper alignment of piles

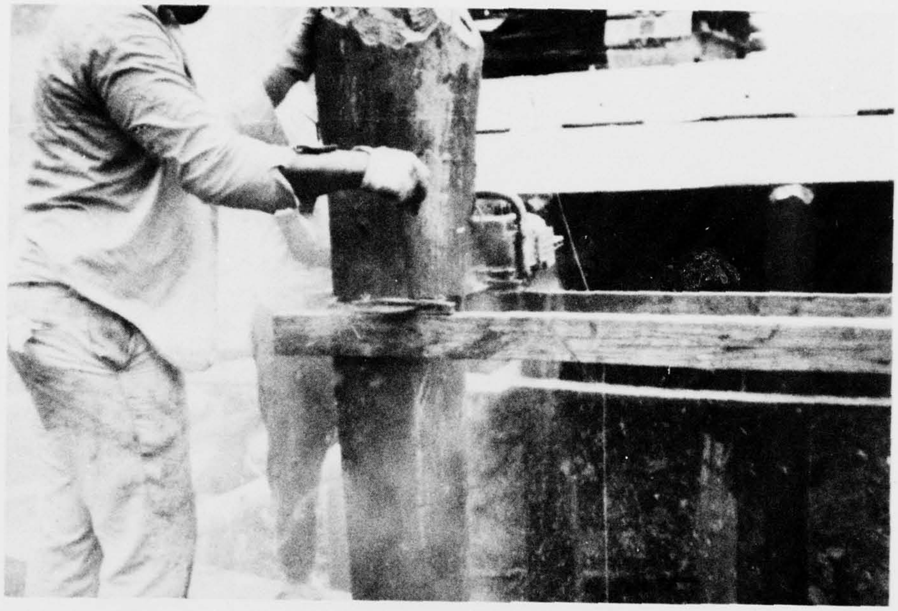


Photo D16. Cutting piles at desired elevation

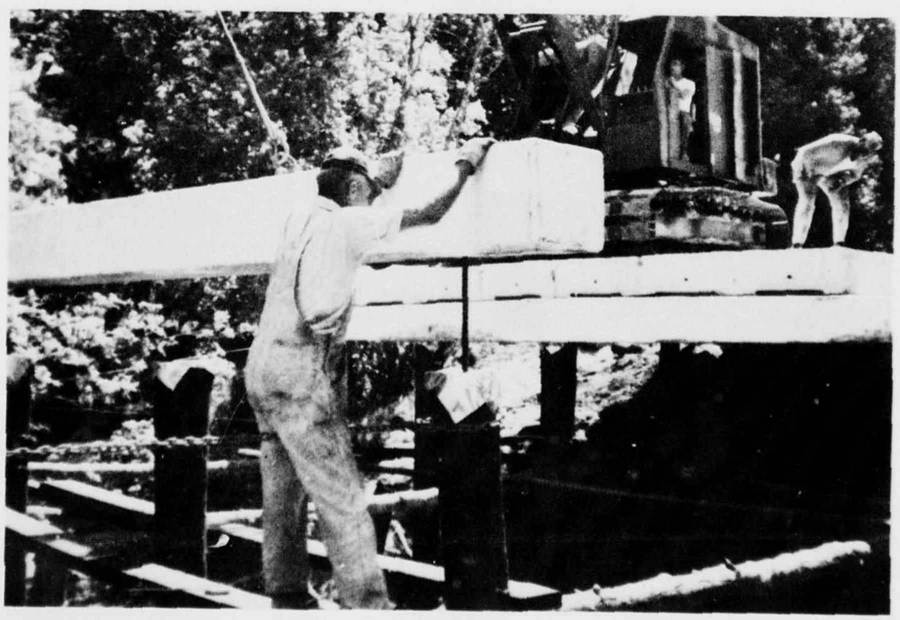


Photo D17. Installing precast concrete pile cap

Photo D18. Driving dowel pins through the pile cap

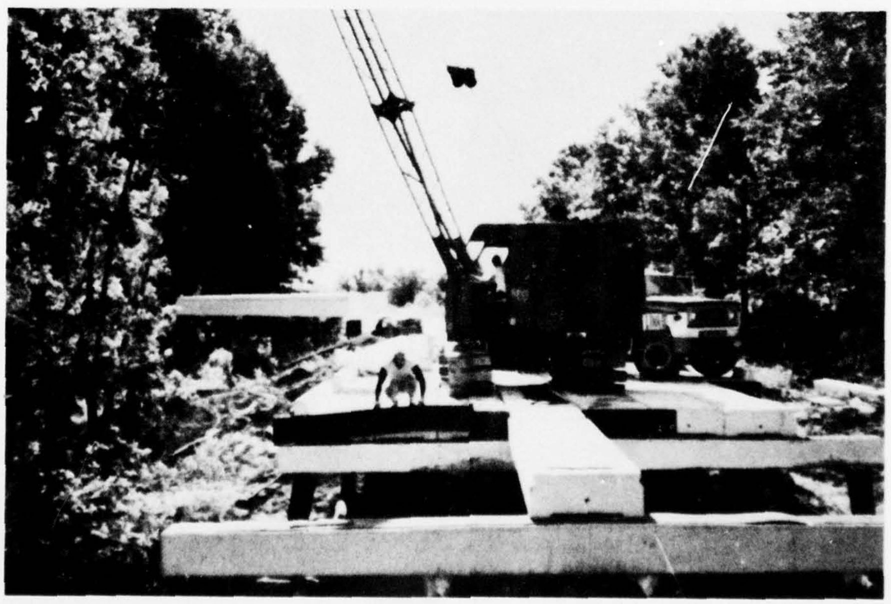
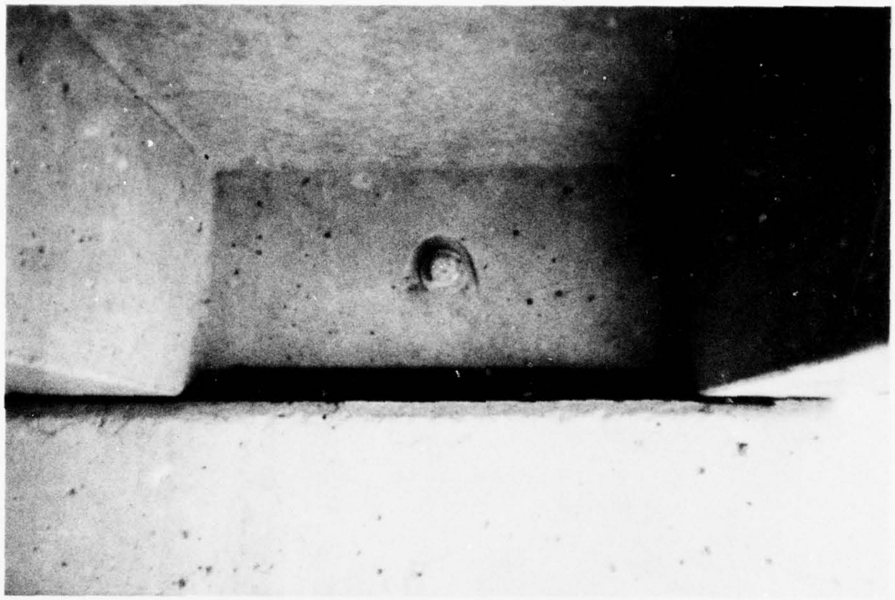


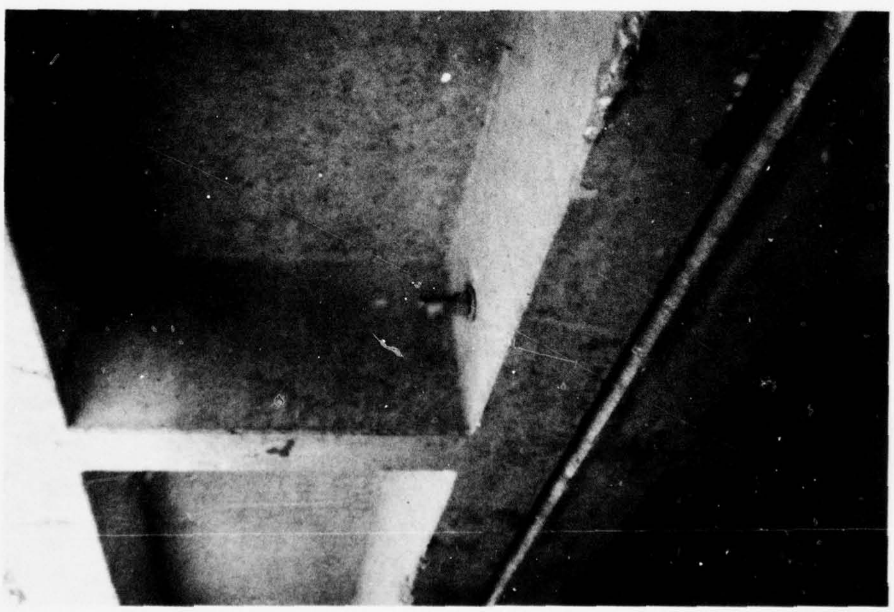
Photo D19. Positioning interior channel girders

Photo D20. Inserting dowel pins through channel girder into pile cap

Photo D21. Positioning exterior channel girder



a. Longitudinal connection



b. Transverse connection

Photo D22. Bolted connections of adjacent channel girders

Photo D23. Upon completion of a bent, the crane is moved forward and the next bent is constructed using the same procedure

Photo D24. Installing precast abutment wing

Photo D25. Installing precast guard rail posts

Photo D26. Concreting keyways and dowels

APPENDIX E: COMPUTER PROGRAM OF THE ANALYSIS AND DESIGN OF SIMPLE-SPAN, PRECAST-PRESTRESSED HIGHWAY OR RAILWAY BRIDGES

Description of Program

1. The program performs the analysis and design of simple-span, precast-prestressed highway or railway bridges. The program will accommodate the composite and noncomposite sections included in Figure E1

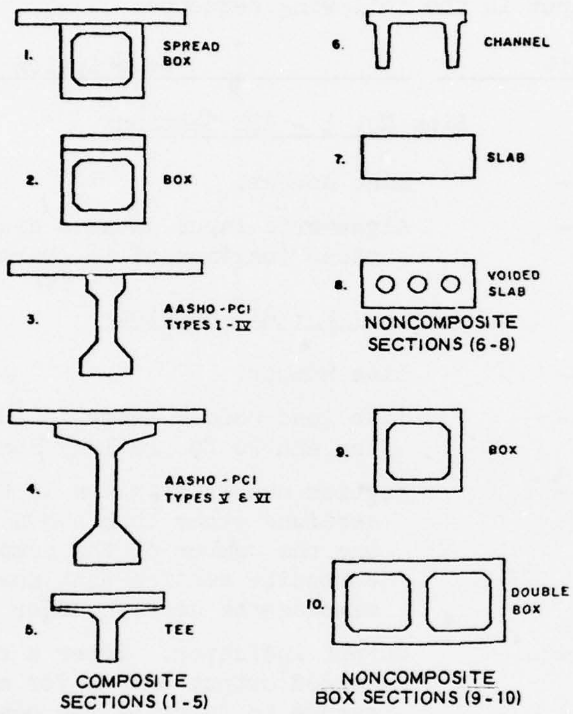


Figure E1. Composite and noncomposite sections

and will compute the following: section properties, dead- and live-load shears and moments, stresses for various loading conditions, ultimate design moments and resisting moments, spacing of shear reinforcement, horizontal shear stress between the composite slab and precast member, midspan elastic deflections for various loading conditions, and the number and center of gravity of prestressing strands required.

Input Data

2. Data may be input interactively through the question/response option of the program or read directly into the program from an input file. As the program uses a variable field format to read input, a comma or blank(s) is required to separate each input value of a line of data. Data is input in the following sequence:

Symbol	Unit	Description
		Line No. 1 - All Sections
LN	--	Line number.
TITLE	--	Alphameric input data to describe computations (maximum of 66 characters).
		Line No. 2 - All Sections
LN	--	Line number.
IDLD	--	Live load code. Enter 10 for highway loading and 20 for railway loading.
IDSEC	--	Section number as given in Figure E1. For sections other than shown in this figure, use the number of the composite or noncomposite section that most closely resembles the section under design.
IOTPT	--	Output indicator. Enter a blank for extended output and -1 for minimum output needed to describe the design.
IDPST	--	Indicator for geometry of prestressing strands. Enter 1 for straight parallel strands, 2 for depressed strands, and 3 for parabolic posttensioned strands.
FLOAD	--	Magnitude of live-load code.

Highway Loading

Enter	AASHO Loading
20	H10-44
30	H15-44
40	H20-44
54	HS15-44
72	HS20-44
90	HS25-44

FLOAD (Cont'd)

Railroad Loading	
Enter	Cooper Loading
60	E-60
72	E-72
80	E-80

SPAN	ft	Span length (distance center to center of bearings).
SDL	kips per linear ft	Dead load to be applied to the noncomposite section, exclusive of beam weight.
CDL	kips per linear ft	Dead load to be applied to the composite section, exclusive of beam weight and SDL. Enter a blank for noncomposite sections.
ALLFR	--	Fraction of a truck load or track load to be applied to the section. Enter 1.0 for one truck load per beam (two lines of wheels), 0.5 for one-half truck load per beam, etc.
FIMP	--	Impact fraction to be used for railroad loading. Enter as a decimal fraction, i.e. 0.30 for 30 percent. As the highway loading impact fraction is computed by the program, enter a blank for highway loading.
FLL	--	Fraction of ALLFR to account for eccentricity and centrifugal force.

Line No. 3 - All Sections Other Than Noncomposite Box Sections

LN	--	Line number.
DSECT	in.	Depth of precast section.
ASECT	sq in.	Area of precast section.
SECTI	$in.^4$	Moment of inertia of precast section.
YT	in.	Distance from neutral axis of precast section to the top of the section.
YB	in.	Distance from neutral axis of precast section to the bottom of the section.
WTS	in.	Width of top slab or flange of precast section.
TTS	in.	Minimum thickness of top slab or flange of precast section.
BB	in.	Minimum width of web of precast section. Enter a blank if slab section (7).

Line No. 3A - Noncomposite Box Sections Only

LN	--	Line number.
WB	ft	Total width of box beam.
DB	ft	Total depth of box beam. (When top surface is sloped, use depth at lower edge.)
TTS	in.	Minimum thickness of top slab of box beam (at lower edge).
TBS	in.	Thickness of bottom slab of box beam.
TSW	in.	Thickness of sidewalls of box beam.
TMW	in.	Thickness of center wall of double-cell box beam. Enter a blank for single-cell box designs.
DH	in.	Depth and width of fillet.
DELTA	in.	Increase in thickness of top slab at higher edge due to sloping.

Line No. 4 - All Sections

LN	--	Line number.
DILOC	--	Diaphragm location expressed as fraction of span length, i.e., for diaphragms at third points, enter 0.33. If no diaphragms are used, enter 0.5.
DIAPH	kips	Weight per diaphragm.
HDPT	ft	Hold-down point for type 2 prestressing (maximum of 2 points). This distance is measured from midspan.
AS	$in.^2$	Area of a single prestressing strand or cable.
FSULT	kips per sq in.	Ultimate strength of prestressing steel.
RS	--	Ratio of steel stress at time of strand release or anchorage to ultimate prestressing steel strength.
R	--	Ratio of steel stress after loss of prestress to steel stress at anchorage.
EMIN	in.	Minimum feasible eccentricity of center of gravity of prestressing tendons from bottom of beam. See Table E1 for approximate values.

ESR	--	A factor to allow for strand relaxation and member shortening prior to computing stage 1 stresses. See Table E1 for approximate values.

<u>Line No. 5 - All Sections</u>

LN	--	Line number.
FCULT	kips per sq in.	Compressive strength of concrete in the prestressed member at 28 days.
FCI	kips per sq in.	Compressive strength of concrete in the prestressed member at time of anchorage or strand release.
FCPC	kips per sq in.	Compressive strength of concrete in the composite deck slab. Enter a blank if noncomposite.
FTENT	kips per sq in.	Allowable tensile stress in top fibers of the prestressed member.
FTENB	kips per sq in.	Allowable tensile stress in bottom fibers of the prestressed member.
FNPS	kips per sq in.	Allowable steel stress of nonprestressed reinforcement.
FV	kips per sq in.	Ultimate steel stress of stirrup reinforcement.
AV	sq in.	Area of all legs of stirrups at one section in the member.

<u>Line No. 6 - All Sections</u>

LN	--	Line number.
NSEC	--	Number of sections at which beam is to be analyzed for moment (maximum of 4).
NETRL	--	Enter 1 if number and location of prestressing strands are to be input; otherwise, enter -1.
DIST	--	For each desired section (maximum of 4) enter the distance as a fraction of the span, i.e., for midspan enter DIST as 0.5, and for the support enter DIST as 0.0. <u>DIST (1) must be at midspan.</u>

BMLL	ft-kips	Live-load moments for railroad loading at points corresponding to DIST values. The moments for Cooper's E-1 loading may be entered with appropriate FLOAD and ALLFR values, or 1 may be entered for FLOAD and ALLFR with the BMLL values entered as the actual moments to be applied to the section. The program computes the live-load moments for highway loading for each DIST value using the given FLOAD and ALLFR values.

Line No. 7 - Composite Sections Only

LN	--	Line number.
WCS	in.	Width of the composite deck slab.
TCS	in.	Thickness of the composite deck slab.
XNCS	in.	Ratio of the modulus of elasticity of the composite deck slab to the modulus of elasticity of the precast member.

Line No. 8 - Any Section with the Number and Location of Prestress Strands Included as Input

LN	--	Line number.
IDC	--	A number to identify the case.
STRNS	--	Number of prestressing strands.
YM	in.	Distance from the bottom of the beam to the centroid of the prestressing strands at midspan.
YE	in.	Distance from the bottom of the beam to the centroid of the prestressing strands at the end of the beam.

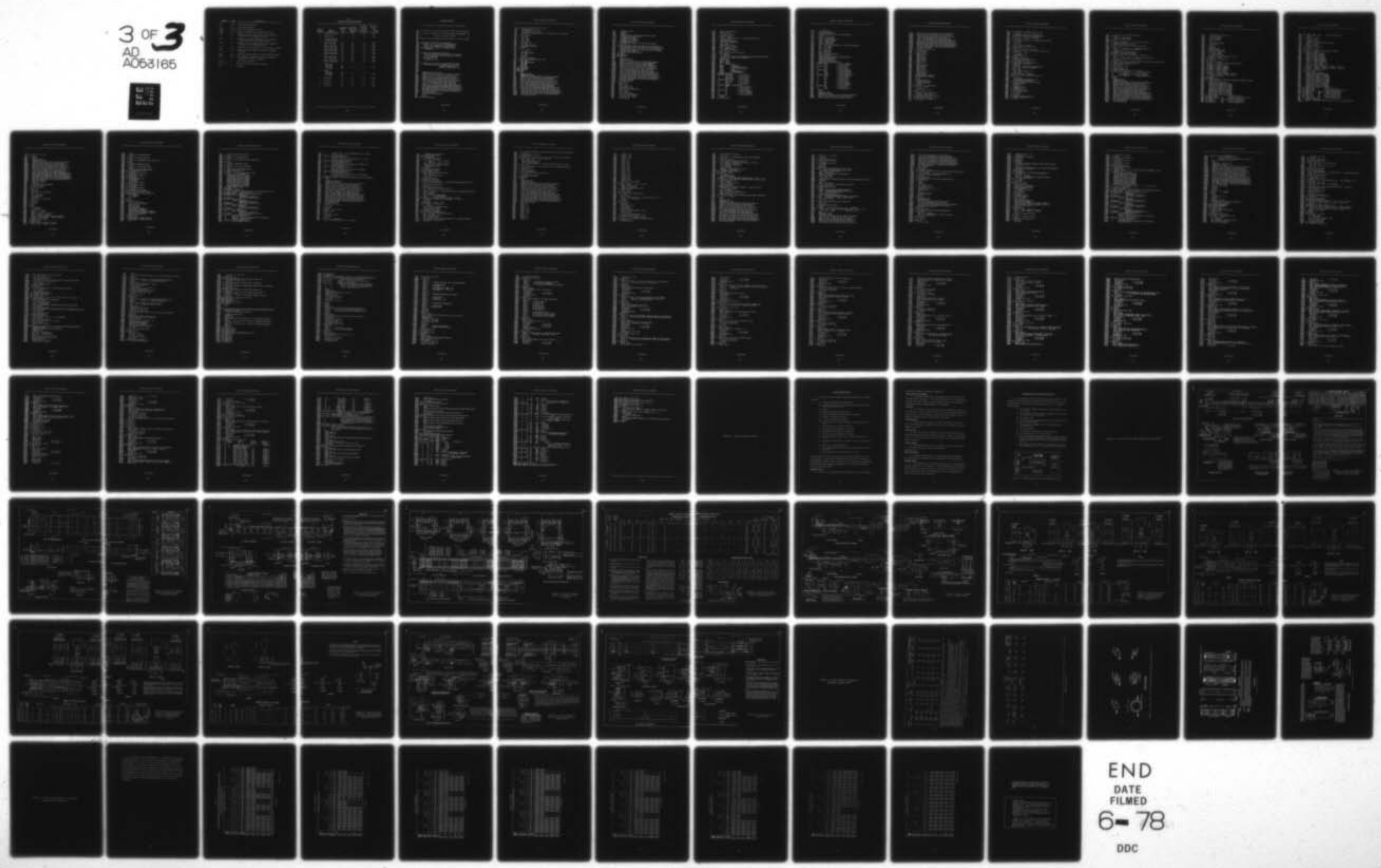
Description of Output

3. The output is generally self-explanatory. However, a few abbreviations or symbols are used. Those output symbols not described in the previous section on input data are defined as follows:

AD-A053 165 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/2
PRECAST CONCRETE ELEMENTS FOR STRUCTURES IN SELECTED THEATERS O--ETC(U)
FEB 78 J E MCDONALD, T C LIU

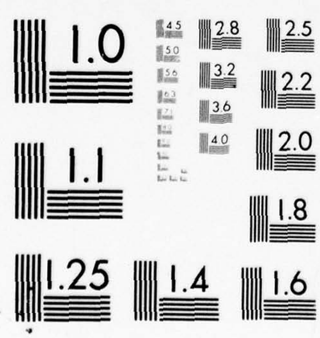
UNCLASSIFIED WES-TR-C-78-1 NL

3 OF 3
AD
A053165



END
DATE
FILMED
6-78
DDC

05316



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Symbol	Unit	Description
SB	$in.^3$	Bottom section modulus.
ST	$in.^3$	Top section modulus.
ACMP	sq in.	Area of the composite section.
CMPI	$in.^4$	Moment of inertia of the composite section.
YTC	in.	Distance from the neutral axis of the composite section to top of precast section.
YBC	in.	Distance from the neutral axis of the composite section to bottom of precast section.
YTSC	in.	Distance from the neutral axis of the composite section to top of composite slab.
STC	$in.^3$	Composite section modulus at top of precast section.
SBC	$in.^3$	Composite section modulus at bottom of precast section.
STSC	$in.^3$	Composite section modulus at top of composite slab.
QTSC	$in.^3$	First moment of composite slab about composite neutral axis ($QTSC = A_{slab} XY_c$).
LL + I	--	Live-load plus impact.
DL + LL + I	--	Dead-load plus live-load plus impact.
ULT	--	Ultimate.

Table E1

Approximate Values for EMIN and ESR

Section Number in Figure E1	Type of Section	Approximate Value for EMIN in.	1 Approximate Elastic Shortening Loss percent	2 Approximate Strand Relaxation Loss @ 48 hr percent	Approximate Value of ESR $1.0 - \frac{(1 + 2)}{100}$
1	Composite spread box	2.0	5.0	2.5	0.925
2	Composite box	2.0	5.0	2.5	0.925
3	Composite AASHO-PCI standard sections				
	Type I 30-ft span	2.0	6.0	2.5	0.915
	Type I 45-ft span	3.0	9.5	2.5	0.88
	Type II 40-ft span	2.5	6.0	2.5	0.915
	Type II 60-ft span	3.5	9.5	2.5	0.88
	Type III 55-ft span	3.5	6.0	2.5	0.915
	Type III 80-ft span	4.0	9.5	2.5	0.88
	Type IV 70-ft span	3.5	6.0	2.5	0.915
	Type IV 100-ft span	4.5	9.5	2.5	0.88
4	Type V 90-ft span	4.5	7.0	2.5	0.905
	Type V 120-ft span	5.0	9.5	2.5	0.88
	Type VI 110-ft span	5.0	7.0	2.5	0.905
	Type VI 140-ft span	5.5	9.5	2.5	0.88
5	Composite tee				
	40-ft span	4.5			
	50-ft span	5.0	7.0	2.5	0.905
	60-ft span	6.0			
6	Channel				
	20-ft span	3.0			
	30-ft span	4.0	7.0	2.5	0.905
	40-ft span	5.0			
7	Solid slab	2.0	4.0	2.5	0.935
8	Voided slab	2.0	4.5	2.5	0.93
9	Single box	2.0	5.0	2.5	0.925
10	Double box	2.0	5.0	2.5	0.925

Fortran Listing

4. A listing of the computer program is given below.

```
C ***********************************************************************
C *                                                                     *
C *   ANALYSIS AND DESIGN OF SIMPLE-SPAN PRECAST-PRESTRESSED            *
C *                                                                     *
C *                   HIGHWAY OR RAILWAY BRIDGES                        *
C *                                                                     *
C ***********************************************************************
C
C
C  ****WRITTEN BY CLIFFORD L FREYERMUTH,PCA
C  ****ADAPTED FOR USE IN "CORPS" PROGRAM LIBRARY
C      UNDER G-635 TIMESHARING SYSTEM,NOVEMBER
C      1976 BY ROY CAMPBELL,WES-CL,VICKSBURG,MS
C  ****MODIFIED NOV 1976 BY ROY CAMPBELL,WES-CL,
C      VICKSBURG,MS
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C      CORPS OF ENGINEERS
C      P. O. BOX 631
C      VICKSBURG,MS 39180
C
C
C  FOR ADDITIONAL INFORMATION OR ASSISTANCE IN USING
C      THIS PROGRAM CALL# ROY CAMPBELL (FTS 542-3266)
C                              USAEWES,VICKSBURG,MS
C                              CONCRETE LAB,STRUCTURES BR
C
C
C
      CHARACTER TITLE*72,STD*1
      COMMON DIST(4),BMLL(4),BMDLT(4),BMDLF(4),FTBWT(4),
&     FBBWT(4),FTSDL(4),FBSDL(4),FTCDL(4),FBCDL(4),
&     FSCDL(4),FSCLL(4),FTLL(4),FBLL(4),FTTOT(4),
&     FBTOT(4),Y(4),VLL(2),FSTOT(4),A(5),YA(5),BIO(5),
&     CONLL(8),M(4),FTPI(4),FBPI(4),F1T(4),F1B(4),
&     F2T(4),F2B(4),F3T(4),F3B(4),XP(17),XL(17),VDL(2),
&     DV(2),TG(2),SPACE(2),VU(2),YES(4),BMCDL(4),
&     L(4),TITLE,IDC,STRNS,YM,YB,IDBOX,IDLD,ICOMP,
&     IDSEC, IOTPT,FLOAD,SPAN,SDL,CDL,ALLFR,FIMP,FLL,WB,
&     DB,YTS,TBS,TSW,TMW,DH,DELTA,DSECT,ASECT,SECTI,YT,
&     YB,WTS,BB,DILOC,DIAPH,HDPT,AS,FSULT,RS,R,FCULT,FCI,
&     BOXI,SB,ST,Q,ACMP,CMPI,YTC,YBC,YTSC,STC,SBC,SYSC,
&     QTSC,IDPST,FCPC,FTENT,FTENB,FNPS,FV,AV,NSEC,WCS,TCS,
&     XNCS,ABOX,PSLS2,NFTRL,LINES,UM,UMD,STRMN,YSE,AVJ,
&     VRLL,DFLG,EMIN,ESR
      CHARACTER FILN*8,FILNAM*10
      LC=1
      GO TO 2
  200 CALL DETACH(02,,)
```

(Continued)

```
 201 PRINT,"IS JOB COMPLETED? Y OR N"
     READ(5,9997) STO
     IF(STO.EQ."Y") GO TO 9998
     IF(STO.EQ."N") GO TO 2
     PRINT,"*****CORRECT RESPONCE IS Y FOR YES OR N FOR NO*****"
     GO TO 201
   2 CALL MAKEFIL
     CALL SR1
     CALL  SR2
     CALL  SR2A
     CALL  SR3
     IF(NETRL)8,8,7
   8 CALL SR4A
     CALL SR5A(UMR,UMP)
     IF(NETRL) 20,200,200
  20 NETRL = 1
     IDC  =  1
     I    =  NETRL
     CALL SR4
     CALL SR5(UMR,UMP)
     CALL SR6
     CALL SR7
     GO TO 200
   7 DO 10 I = 1,NETRL
     READ (02,9999)LN,IDC,STRNS,YM,YE
  21 CALL SR4
     CALL SR5(UMR,UMP)
     CALL SR6
     CALL SR7
  10 CONTINUE
     GO TO 200
9997 FORMAT(A1)
9999 FORMAT(V)
9998 STOP
     END
     SUBROUTINE SR1
     CHARACTER TITLE*72
     COMMON DIST(4),BMLL(4),BMDLT(4),BMDLF(4),FTBWT(4),
&    FBBWT(4),FTSDL(4),FBSDL(4),FTCDL(4),FBCDL(4),
&    FSCDL(4),FSCLL(4),FTLL(4),FBLL(4),FTTOT(4),
&    FBTOT(4),Y(4),VLL(2),FSTOT(4),A(5),YA(5),BIO(5),
&    CONLL(8),M(4),FTPI(4),FBPI(4),F1T(4),F1B(4),
&    F2T(4),F2B(4),F3T(4),F3B(4),XP(17),XL(17),VDL(2),
&    DV(2),TG(2),SPACE(2),VU(2),YES(4),BMCDL(4),
&    L(4),TITLE,IDC,STRNS,YM,YE,IDBOX,IDLD,ICOMP,
&    IDSEC, IOTPT,FLOAD,SPAN,SDL,CDL,ALLFB,FIMP,FLL,WB,
&    DB,TTS,TBS,TSW,TMW,DH,DELTA,DSECT,ASECT,SECTI,YT,
&     YB,WTS,BB,DILOC,DIAPH,HDPT,AS,FSULT,RS,R,FCULT,FCI,
&     BOXI,SB,ST,Q,ACMP,CMPI,YTC,YBC,YTSC,STC,SBC,STSC,
&     QTSC,IDPST,FCPC,FTENT,FTENB,FNPS,FV,AV,NSEC,NCS,TCS,
&     XNCS,ABOX,PSLS2,NETRL,LINES,UM,UMD,STRMN,YSE,AVJ,
&     VRLL,DFLG,EMIN,ESR
```

(Continued)

```
      READ(02,50)TITLE
      IDBOX=0
      ICOMP=0
      READ(02,9999)LN,IDLD,IDSEC,IOTPT,IDPST,FLOAD,
&     SPAN,SDL,CDL,ALLFR,FIMP,FLL
      IF(IDSEC.EQ.9)IDBOX=1
      IF(IDSEC.EQ.10)IDBOX=2
      IF(IDSEC.LE.5)ICOMP=100
    3 IF(IDBOX-1)20,10,10
   10 READ(02,9999)LN,WB,DB,TTS,TBS,TSW,TMW,DH,DELTA
      GO TO 30
   20 READ(02,9999)LN,DSECT,ASECT,SECTI,YT,YB,WTS,YTS,BB
   30 READ(02,9999)LN,DILOC,DIAPH,HDPT,AS,FSULT,RSTR,EMIN,ESR
      READ(02,9999)LN,FCULT,FCI,FCPC,FTENT,FTENB,FNPS,FV,AV
      READ(02,9999)LN,NSEC,NETRL,(DIST(I),BMLL(I),I=1,NSEC)
      IF(ICOMP -100)22,21,22
   21 READ(02,9999)LN,WCS,TCS,XNCS
   22 RETURN
   50 FORMAT(A72)
 9999 FORMAT(V)
      END
      SUBROUTINE SR2
      CHARACTER TITLE*72
      COMMON DIST(4),BMLL(4),BMDLT(4),BMDLF(4),FTBWT(4),
&     FBBWT(4),FTSDL(4),FBSDL(4),FTCDL(4),FBCDL(4),
&     FSCDL(4),FSCLL(4),FTLL(4),FBLL(4),FTTOT(4),
&     FBTOT(4),Y(4),VLL(2),FSTOT(4),A(5),YA(5),BIO(5),
&     CONLL(8),M(4),FTPI(4),FBPI(4),F1T(4),F1B(4),
&     F2T(4),F2B(4),F3T(4),F3B(4),XP(17),XL(17),VDL(2),
&     DV(2),TG(2),SPACE(2),VU(2),YES(4),BMCDL(4),
&     L(4),TITLE,IDC,STRNS,YM,YE,IDBOX,IDLD,ICOMP,
&     IDSEC,IOTPT,FLOAD,SPAN,SDL,CDL,ALLFR,FIMP,FLL,WB,
&     DB,TTS,TBS,TSW,TMW,DH,DELTA,DSECT,ASECT,SECTI,YT,
&     YB,WTS,BB,DILOC,DIAPH,HDPT,AS,FSULT,RS,R,FCULT,FCI,
&     BOXI,SB,ST,Q,ACMP,CMPI,YTC,YBC,YTSC,STC,SBC,STSC,
&     OTSC,IDPST,FCPC,FTENT,FTENB,FNPS,FV,AV,NSEC,WCS,TCS,
&     XNCS,ABOX,PSLS2,NETRL,LINES,UM,UMD,STRMN,YSE,AVJ,
&     VRLL,DFLG,EMIN,ESR
      IF(IDBOX-1)20,5,5
    5 ABOX = 0.0
      AYBOX = 0.0
      BOXI = 0.0
      A(1) = WB*12.*TTS
      YA(1)=DB*12.-TTS/2.
      BIO(1) = A(1)*(TTS)**2/12.
      YA(2)=TBS/2.
      Y(2) = TBS/2.
      A(2) = WB*12.*TBS
      BIO(2) = A(2)* TBS**2/12.
      D = DB*12.-TTS - TBS
      A(3) = (2.*TSW + TMW)*D
      YA(3)=TBS+D/2.
```

(Continued)

```
      BIO(3) = A(3)*D*D/12.
      YA(4)=YA(3)
      A(4)  = 2.*DH*DH
      IF(IDBOX-2  )2,1,2
    1 A(4) = 2.*A(4)
    2 BIO(4) = A(4)*(DH)**2/18.   + A(4)*(D/2.-DH/3.)**2
      A(5)=WB*6.*DELTA
      YA(5)=DB*12.+DELTA/3.
      BIO(5)=A(5)*DELTA**2/18.
      DO 3 I=1,5
      ABOX = ABOX + A(I)
      AYBOX=AYBOX+A(I)*YA(I)
    3 BOXI  =   BOXI + BIO(I)
      YB =  AYBOX/ABOX
      YT = DB*12. - YB+DELTA
      DO 4 I = 1,5
    4 BOXI = BOXI +A(I)*(YB-YA(I))**2
      SB = BOXI/YB
      ST = BOXI/YT
      Q = A(1)*(YA(1)-YB)+A(4)/2.*(DB*12.-TTS-DH/3.-YB)+(2.*TSW+TMW)
     &*(DB*12.-TTS-YB)**2/2.+A(5)*(YA(5)-YB)
      WTS =WB*12.
      ASECT = ABOX
      SECTI = BOXI
      DSECT = DB*12.
      BB    = 2.*TSW+ TMW
      WRITE         (6,48)TITLE
      WRITE              (6,49)WB,DB,TTS,TBS
      WRITE              (6,50)TSW,TMW,DH,DELTA
      WRITE              (6,53)
      WRITE              (6,51)ABOX,YB,YT
      WRITE              (6,52)BOXI,SB,ST,Q
   48 FORMAT(1X,A72//)
   49 FORMAT("BOX WIDTH          = ",F7.3,"FT",/
     &       "BOX DEPTH          = ",F7.3,"FT",/
     &       "TOP SLAB           = ",F7.3,"IN",/
     &       "BOTTOM SLAB        = ",F7.3,"IN")
   50 FORMAT("SIDE WALL          = ",F7.3,"IN",/
     &       "CEN. WALL          = ",F7.3,"IN",/
     &       "FILLET             = ",F7.3,"IN",/
     &       "DELTA              = ",F7.3,"IN")
   51 FORMAT("SECTION PROPERTIES ",/
     &       "AREA               = ",F11.2,"SQ.IN",/
     &       "YT                 = ",F11.2,"IN",/
     &       "YB                 = ",F11.2,"IN")
   52 FORMAT("I                  = ",F11.2,"IN**4",/
     &       "SB                 = ",F11.2,"IN**3",/
     &       "ST                 = ",F11.2,"IN**3",/
     &       "Q                  = ",F11.2,"IN**3",/)
   53 FORMAT(1H /)
      RETURN
   20 SB = SECTI/YB
```

(Continued)

```
      ST = SECTI/YT
      IF(ICOMP-100)35,40,40
   35 WRITE(6,48)TITLE
      WRITE(6,58)ASECT,SECTI,YT,YB,WTS,BB,SB,ST
      RETURN
   40 ASLAB = TCS*WCS*XNCS
      YSLAB = YT + TCS/2.
      BIOS  = ASLAB*TCS**2/12.
      ACMP  = ASECT + ASLAB
      AYCMP = ASLAB*YSLAB
      YBARC = AYCMP/ACMP
      CMPI  = SECTI +ASLAB*YSLAB**2 + BIOS -ACMP*YBARC**2
      YTC   = YT -YBARC
      YBC   = YB +YBARC
      YTSC = YTC + TCS
      STC   = CMPI/YTC
      SBC   = CMPI/YBC
      STSC = CMPI/YTSC
      QTSC = ASLAB*(YTSC-TCS/2.)
      WRITE(6,48)TITLE
      WRITE(6,58)ASECT,SECTI,YT,YB,WTS,BB,SB,ST
      WRITE(6,59)WCS,TCS,XNCS
      WRITE(6,55)ACMP,CMPI
      WRITE(6,56)YTC,YBC,YTSC
      WRITE(6,57)STC,SBC,STSC,QTSC
   55 FORMAT("ACMP                 = ",F12.3,"IN**2",/
     &       "CMPI                 = ",F12.3,"IN**4")
   56 FORMAT("YTC                  = ",F12.3,"IN",/
     &       "YBC                  = ",F12.3,"IN",/
     &       "YTSC                 = ",F12.3,"IN")
   57 FORMAT("STC                  = ",F12.3,"IN**3",/
     &       "SBC                  = ",F12.3,"IN**3",/
     &       "STSC                 = ",F12.3,"IN**3",/
     &       "QTSC                 = ",F12.3,"IN**3",///)
   58 FORMAT("ASECT                = ",F12.3,"IN**2",/
     &       "SECTI                = ",F12.3,"IN**4",/
     &       "YT                   = ",F12.3,"IN",/
     &       "TB                   = ",F12.3,"IN",/
     &       "WTS                  = ",F12.3,"IN",/
     &       "BB                   = ",F12.3,"IN",/
     &       "SB                   = ",F12.3,"IN**3",/
     &       "ST                   = ",F12.3,"IN**3")
   59 FORMAT("WCS                  = ",F12.3,"IN",/
     &       "TCS                  = ",F12.3,"IN",/
     &       "XNCS                 = ",F12.3,"IN",///)
      RETURN
      END
      SUBROUTINE SR2A
      CHARACTER TITLE*72
      COMMON DIST(4),BMLL(4),BMDLT(4),BMDLF(4),FTBWT(4),
     &FBBWT(4),FTSDL(4),FBSDL(4),FTCDL(4),FBCDL(4),
     &FSCDL(4),FSCLL(4),FTLL(4),FBLL(4),FTTOT(4),
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(Continued)

```
      FBTOT(4),Y(4),VLL(2),FSTOT(4),A(5),YA(5),BIO(5),
      CONLL(8),M(4),FTPI(4),FBPI(4),F1T(4),F1B(4),
      F2T(4),F2B(4),F3T(4),F3B(4),XP(17),XL(17),VDL(2),
      DV(2),TG(2),SPACE(2),VU(2),YFS(4),BMCDL(4),
      L(4),TITLE,IDC,STRNS,YM,YE,IDBOX,IDLD,ICOMP,
      IDSEC, IOTPT,FLOAD,SPAN,SDL,CDL,ALLFR,FIMP,FLL,WB,
      DB,TTS,TBS,TSW,TMW,DN,DELTA,DSECT,ASECT,SECTI,YT,
      YB,WTS,BB,DILOC,DIAPH,HDPT,AS,FSULT,RS,R,FCULT,FCI,
      BOXI,SB,ST,Q,ACMP,CMPI,YTC,YBC,YTSC,STC,SBC,STSC,
      QTSC,IDPST,FCPC,FTENT,FTENB,FNPS,FV,AV,NSEC,WCS,TCS,
      XNCS,AHOX,PSLS2,NETRL,LINES,UM,UMD,STRMN,YSE,AVJ,
      VRLL,DFLG,FMIN,ESR
      IF(IDLD  -10  )30,1,30
    1 WLLF=FLOAD-54.
      IF(WLLF)2,3,3
    2 CONLL(1)=2.8
      CONLL(2)=57.72
      CONLL(3)=40.
      CONLL(4)=32.
      CONLL(5)=2.8
      CONLL(6)=0.0
      CONLL(7)=33.2
      CONLL(8)=28.
      GO TO 4
    3 CONLL(1)=4.6667
      CONLL(2)=146.
      CONLL(3)=72.
      CONLL(4)=64.
      CONLL(5)=9.333
      CONLL(6)=7.
      CONLL(7)=127.3
      CONLL(8)=56.
    4 IF(SPAN-CONLL(2))5,6,6
    5 ZM=(1.-CONLL(1)/SPAN)/2.
      GO TO 7
    6 ZM=.5
    7 FL=FLOAD/CONLL(3)
      FIMP=50./(SPAN+125.)
      IF(FIMP-.3)9,9,8
    8 FIMP=.3
    9 IF(FLOAD - 54.)60,610,610
  610 DO 10 I = 1,NSEC
      Z = DIST(I)
      IF(Z - .5)12,11,12
   11 Z = ZM
   12 CBM1 = SPAN * Z *(1.- Z)
      IF(SPAN - CONLL(2))13,14,14
   13 IF(.3333 - Z)41,46,46
   41 IF(Z*SPAN-CONLL(8)/4.)42,17,17
   42 IF(SPAN-24.)44,43,43
   44 BML = CONLL(4)/2.*SPAN/4.
      GO TO 10
```

(Continued)

```
   43 BML=(SPAN-7.)/SPAN*32.*(SPAN/2.-3.5)
      GO TO 10
   46 IF(Z*SPAN +CONLL(8)/2.-SPAN)15,15,47
   47 IF(Z*SPAN +CONLL(8)/4.-SPAN)49,48,48
   48 BML =(1.- Z)*CONLL(4)/2.*Z*SPAN
      GO TO 10
   49 BML =(SPAN -(Z*SPAN+ 7.))/SPAN*CONLL(4)*Z*SPAN
      GO TO 10
   15 FZ =672.* Z
      GO TO 16
   17 FZ = (1.+ 3.* Z)*112.
   16 BML = CONLL(3) * CBM1 - FZ
      GO TO 10
   14 BML = (.32 * SPAN + 18.)* CBM1
   10 BMLL(I) =  BML * FL * ALLFR *( 1.+ FIMP + FLL)
      GO TO 200
   60 DO 90 I = 1, NSEC
      Z = DIST(I)
      IF(Z-.5)62,61,62
   61 Z= ZM
   62 CBM1 = SPAN*Z*(1.-Z)
      IF(SPAN- CONLL(2))63,64,64
   63 IF(.3333-Z)71,76,76
   71 IF(Z*SPAN + 14.- SPAN)85,72,72
   72 BML = CONLL(4)*SPAN/4.
      GO TO 90
   76 IF(Z*SPAN + CONLL(8)/2.-SPAN)85,77,77
   77 BML = (1.-Z)*CONLL(4)*Z*SPAN
      GO TO 90
   85 FZ = 112.* Z
      BML = CONLL(3)*CBM1 - FZ
      GO TO 90
   64 BML =(.32*SPAN + 18.)*CBM1
   90 BMLL(I) = BML*FL*ALLFR*(1.+FIMP +FLL)
  200 Z = .25
      DO 20 I=1,2
      VL=(.32*SPAN*(1.-Z)+26.)*(1.-Z)
      IF(SPAN-CONLL(8))18,19,19
   18 IF(1.-Z-(CONLL(8)/2./SPAN))21,19,19
   21 FO=CONLL(6)/SPAN
      VKO=CONLL(4)
      GO TO 22
   19 FO=CONLL(5)/SPAN
      VKO=CONLL(3)
   22 VTRK=VKO*(1.-Z-FO)
      IF(VL-VTRK)23,24,24
   23 VLL(I)=VTRK
      GO TO 25
   24 VLL(I)=VL
   25 FIMP=50./(SPAN*(1.-Z)+125.)
      IF(FIMP-.3)27,27,26
   26 FIMP=.3
```

(Continued)

```
 27 VLL(I)=VLL(I)*FL*ALLFR*(1.+FIMP+FLL)
 20 Z=.3333
    FIMP = 50./(SPAN+125.)
    IF(FIMP -.3)300,300,301
301 FIMP = .3
300 VRULL  =(.32*SPAN + 26.)*FL*ALLFR*(1.+FIMP+FLL)
    IF(WLLF)91, 94, 94
 91 IF(SPAN- CONLL(8)/2.)92,92,93
 92 VRTLL  = CONLL(4)*FL* ALLFR*(1.+FIMP +FLL)
    GO TO 99
 93 VRTLL  = ( CONLL(4) + (1.-(CONLL(8)/2./SPAN))*8.)
    VRTLL  = VRTLL*FL*ALLFR*(1.+FIMP+FLL)
    GO TO 99
 94 IF(SPAN -CONLL(8)/2.)95,95,98
 95 IF(SPAN- CONLL(8)/4.)96,96,97
 96 VRTLL  = CONLL(4)/2.*FL*ALLFR*(1.+FIMP+FLL)
    GO TO 99
 97 VRTLL  = ( CONLL(4)/2.+ (1.-(CONLL(8)/4./SPAN))*32.)
    VRTLL  = VRTLL*FL*ALLFR*(1.+FIMP+FLL)
    GO TO 99
 98 VRTLL=( CONLL(4)/2. +(1.-(CONLL(8)/4./SPAN))*32. +(1.-(CONLL(8)/2.
&   /SPAN))*8.)*FL*ALLFR*(1.+FIMP+FLL)
 99 IF(VRULL-VRTLL)100,100,101
100 VRLL = VRTLL
    IF(IOTPT)30,102,102
101 VRLL = VRULL
    IF(IOTPT)30,102,102
102 WRITE(6,105)BMLL(1),VLL(1),VLL(2),VRLL
105 FORMAT("MAX LL+I MOMENT          =",F8.1,"FT KIPS",/
   &         "LL+I SHEAR AT 1/4 PT  =",F8.1,"KIPS",/
   &         "LL+I SHEAR AT 1/3 PT  =",F8.1,"KIPS",/
   &         "LL+I REACTION         =",F8.1,"KIPS",///)
 30 RETURN
    END
    SUBROUTINE SR3
    CHARACTER TITLE*72
    COMMON DIST(4),BMLL(4),BMDLT(4),BMDLF(4),FTBWT(4),
&   FBBWT(4),FTSDL(4),FBSDL(4),FTCDL(4),FBCDL(4),
&   FSCDL(4),FSCLL(4),FTLL(4),FBLL(4),FTTOT(4),
&   FBTOT(4),Y(4),VLL(2),FSTOT(4),A(5),YA(5),BIO(5),
&   CONLL(8),M(4),FTPI(4),FBPI(4),F1T(4),F1B(4),
&   F2T(4),F2B(4),F3T(4),F3B(4),XP(17),XL(17),VDL(2),
&   DV(2),TG(2),SPACE(2),VU(2),YES(4),BMCDL(4),
&   L(4),TITLE,IDC,STRNS,YM,E,INBOX,IDLD,ICOMP,
&   IDSEC, IOTPT,FLOAD,SPAN,SDL,CDL,ALLFR,FIMP,FLL,WB,
&   DBWTS,THS,TSW,TMW,DW,DELTA,DSECT,ASECT,SECTI,T,
&   YBWTS,BH,DILOC,DIAPH,HDPT,AS,FSULT,RS,RFCULT,FCI,
&   BOXI,SB,ST,Q,ACMP,CMPI,YTC,YBC,YTSC,STC,SBC,STSC,
&   QTSC,IDPST,FCPC,FTENT,FTENB,FNPS,FV,AV,NSEC,NCS,TCS,
&   XNCS,ABOX,PSLS2,NETRL,LINES,UM,UMO,STRMN,YSE,AVJ,
&   VRLL,DFLG,EMIN,ESR
    N = 1./(DILOC *2.)
```

(Continued)

```
      RDIA=DIAPH*(1./DILOC -1.)/2.
      DO 10 I=1,NSEC
      X = DIST(I)*SPAN
      BMDLT(I)=X*RDIA
      DO 10  J=1,N
      XN = J
      XD = XN*DILOC *SPAN
      IF(X-XD)1,2,2
    1 BM=0.0
      GO TO 10
    2 BM=DIAPH*(X-XD)
   10 BMDLT(I)=BMDLT(I)-BM
      IF(ICOMP -100)11,70,11
   11 DO 20 I = 1,NSEC
      X = DIST(I)*SPAN
      X = SPAN/2.*X-X*X/2.
      BMDLT(I) =BMDLT(I)+ X*ASECT*.15/144
   20 BMDLF(I) = SDL*X
   21 IF(IDLD  -10  )41,40,41
   40 GO TO 42
   41 DO 43 I = 1,NSEC
   43 BMLL(I) = BMLL(I)*FLOAD*ALLFR*(1.+FIMP+FLL)
   42 DO 44  I =1,NSEC
   45 FTBWT(I) = BMDLT(I)/ST*12.
   46 FBBWT(I) =-BMDLT(I)/SB*12.
   47 FTSDL(I) = BMDLF(I)/ST*12.
   48 FBSDL(I) =-BMDLF(I)/SB*12.
   49 FTLL(I) = BMLL(I)/ST*12.
   53 FBLL(I) =-BMLL(I) /SB*12.
   54 FTTOT(I) = FTBWT(I)+FTSDL(I)+FTLL(I)
   44 FBTOT(I) = FBBWT(I)+FBSDL(I)+FBLL(I)
      IF(IOTPT)156,55,55
  156 RETURN
   55 WRITE(6,150)
  150 FORMAT("STRESSES IN EXTREME FIBERS DUE TO EXTERNAL LOADS -
&       KIPS PER SQ.IN.")
      WRITE(6,273)(I,I=1,NSEC)
      WRITE(6,274)(DIST(I),I=1,NSEC)
      WRITE(6,276)(FTBWT(I),I=1,NSEC)
      WRITE(6,277)(FBBWT(I),I=1,NSEC)
      WRITE(6,278)(FTSDL(I),I=1,NSEC)
      WRITE(6,277)(FBSDL(I),I=1,NSEC)
      WRITE(6,282)(FTLL(I),I=1,NSEC)
      WRITE(6,277)(FBLL(I),I=1,NSEC)
      WRITE(6,284)(FTTOT(I),I=1,NSEC)
      WRITE(6,277)(FBTOT(I),I=1,NSEC)
  273 FORMAT("NSEC                  =",13X,I1,3(9X,I1))
  274 FORMAT("DIST                  =",10X,F5.3,"L",3(4X,F5.3,"L"))
  276 FORMAT("BEAM WT TOP           =",8X,F7.3,3(3X,F7.3))
  277 FORMAT("           BOTTOM     -",8X,F7.3,3(3X,F7.3))
  278 FORMAT("SDL        TOP        =",8X,F7.3,3(3X,F7.3))
  282 FORMAT("LL         TOP        =",8X,F7.3,3(3X,F7.3))
```

(Continued)

```
  284 FORMAT("TOTAL   TOP       -",8X,F7.3,3(3X,F7.3))
      LINES = 19 + NSEC
      RETURN
   70 DO 80 I = 1,NSEC
      X=DIST(I)*SPAN
      X=SPAN/2.*X - X*X/2.
      BMDLT(I) = BMDLT(I)+ X*ASECT*.15/144.
      BMDLF(I) = SDL*X
   80 BMCDL(I) = CDL*X
      IF(IDLD -10)82,81,82
   81 GO TO 84
   82 DO 83 I = 1,NSEC
   83 BMLL(I) = BMLL(I)*FLOAD*ALLFR*(1.+FIMP*FLL)
   84 DO 85 I = 1,NSEC
      FTBWT(I)= BMDLT(I)/ST*12.
      FBBWT(I)=-BMDLT(I)/SB*12.
      FTSDL(I)= BMDLF(I)/ST*12.
      FBSDL(I)=-BMDLF(I)/SB*12.
      FTCDL(I)= BMCDL(I)/STC*12.
      FBCDL(I)= -BMCDL(I)/SBC*12.
      FSCDL(I)= BMCDL(I)/STSC*12.
      FTLL(I) = BMLL(I)/STC * 12.
      FBLL(I) = -BMLL(I)/SBC * 12.
      FSCLL(I)= BMLL(I)/STSC * 12.
      FTTOT(I) = FTBWT(I) +FTSDL(I) + FTCDL(I) + FTLL(I)
      FBTOT(I) = FBBWT(I) +FBSDL(I) + FBCDL(I) + FBLL(I)
   85 FSTOT(I) = FSCDL(I) +FSCLL(I)
      IF(IOTPT)177,178,178
  178 WRITE (6,150)
      WRITE(6,373)(I,I=1,NSEC)
      WRITE(6,374)(DIST(I),I=1,NSEC)
      WRITE(6,376)(FTBWT(I),I=1,NSEC)
      WRITE(6,377)(FBBWT(I),I=1,NSEC)
      WRITE(6,378)(FTSDL(I),I=1,NSEC)
      WRITE(6,377)(FBSDL(I),I=1,NSEC)
      WRITE(6,380)(FTCDL(I),I=1,NSEC)
      WRITE(6,377)(FBCDL(I),I=1,NSEC)
      WRITE(6,382)(FTLL(I),I=1,NSEC)
      WRITE(6,377)(FBLL(I),I=1,NSEC)
      WRITE(6,384)(FTTOT(I),I=1,NSEC)
      WRITE(6,377)(FBTOT(I),I=1,NSEC)
  373 FORMAT("NSEC              -",13X,I1,3(9X,I1))
  374 FORMAT("DIST              -",10X,F5.3,"L",3(4X,F5.3,"L"))
  376 FORMAT("BEAM WT TOP       -",8X,F7.3,3(3X,F7.3))
  377 FORMAT("        BOTTOM    -",8X,F7.3,3(3X,F7.3))
  378 FORMAT("SDL     TOP       -",8X,F7.3,3(3X,F7.3))
  380 FORMAT("CDL     TOP       -",8X,F7.3,3(3X,F7.3))
  382 FORMAT("LL      TOP       -",8X,F7.3,3(3X,F7.3))
  384 FORMAT("TOTAL   TOP       -",8X,F7.3,3(3X,F7.3))
      WRITE(6,176)FSTOT(1)
  176 FORMAT(//,'COMPOSITE STRESS IN SLAB = ',F7.3,' KIPS PER SQ.IN.
     ',/)
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(Continued)

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3033T 01   05-05-77   15.199

  177 RETURN
      END
      SUBROUTINE SR4
      CHARACTER TITLE*72
      COMMON DIST(4),BMLL(4),BMDLT(4),BMDLF(4),FTBWT(4),
     &FBBWT(4),FTSDL(4),FBSDL(4),FTCDL(4),FBCDL(4),
     &FSCDL(4),FSCLL(4),FTLL(4),FBLL(4),FTTOT(4),
     &FBTOT(4),Y(4),VLL(2),FSTOT(4),A(5),YA(5),BIO(5),
     &CONLL(8),M(4),FTPI(4),FBPI(4),F1T(4),F1B(4),
     &F2T(4),F2B(4),F3T(4),F3B(4),XP(17),XL(17),VDL(2),
     &DV(2),TG(2),SPACE(2),VU(2),YFS(4),BMCDL(4),
     &L(4),TITLE,IDC,STRNS,YM,YE,IDBOX,IDLD,ICOMP,
     &IDSEC, IOTPT,FLOAD,SPAN,SDL,CDL,ALLFR,FIMP,FLL,WB,
     &DBWTS,TBS,TSW,TMW,DH,DELTA,DSECT,ASECT,SECTI,YT,
     &YBWTS,BB,DILOC,DIAPH,HDPT,AS,FSULT,RS,R,FCULT,FCI,
     &BOXI,SB,ST,Q,ACMP,CMPI,YTC,YBC,YTSC,STC,SBC,STBC,
     &DTSC,IDPST,FCPC,FTENT,FTENB,FNPS,FV,AV,NSEC,NCS,TCS,
     &XNCS,ABOX,PSLS2,NETRL,LINES,UM,UMD,STRMN,YSE,AVJ,
     &VRLL,DFLG,EMIN,ESR
      LINC = 18 + NSEC
      LINES = 6
      PI = STRNS *AS*FSULT*RS*ESR
      IF(IDPST-2)1,2,3
    1 DO 10 I =1,NSEC
   10 Y(I) = YM
      XS = 0.6
      GO TO 4
    2 HPT = (SPAN/2.-HDPT)*SPAN
      XS =  .6
      DO 11 I=1,NSEC
      X = DIST(I)-HPT
      IF(X)5,6,6
    5 Y(I) = YM + (YM-YE)*X/HPT
      GO TO 11
    6 Y(I) = YM
   11 CONTINUE
      K = 0
    4 I=0
   13 I=I+1
      F = PI/ASECT
      X = PI*(YB-Y(I))
      FTPI(I) = F - X/ST
      FBPI(I) = F + X/SB
      F1T(I) = FTPI(I) +  FTBWT(I)
      F1B(I) = FBPI(I) + FBBWT(I)
      F2T(I) = FTPI(I)*R/ESR  + FTBWT(I)+FTSDL(I)
      F2B(I) = FBPI(I)*R/ESR  + FBBWT(I)+FBSDL(I)
      IF(ICOMP -100)80,85,80
   80 FTCDL(I)=0.0
      FBCDL(I)=0.0
   85 F3T(I)= F2T(I) +FTCDL(I) +FTLL(I)
      F3B(I)= F2B(I) +FBCDL(I) +FBLL(I)
```

(Continued)

```
      KL=1
      IF(F1B(I)- XS*FCI)20,20,601
   20 KL=2
      IF(F1T(I)+FTENT)602,22,22
   22 KL=3
      IF(F1T(I)+.003*SQRT(FCI*1000.))603,77,77
   76 K=1
   77 KL=4
      IF(F3B(I)+FTENB)604,78,78
   78 KL=5
      IF(F3T(I)-.4*FCULT)79,79,605
   79 KL=6
      IF(F3B(I)-.4*FCULT)113,113,606
  113 IF(I.NE.NSEC) GO TO 13
      GO TO 32
  601 WRITE(6,701)I,F1B(I),XS
      GO TO 650
  602 WRITE(6,702)I,F1T(I)
      GO TO 650
  603 WRITE(6,703)I,F1T(I)
      WRITE(6,255)
       GO TO 650
  604 WRITE(6,704)I,F3B(I)
      GO TO 650
  605 WRITE(6,705)I,F3T(I)
      GO TO 650
  606 WRITE(6,706)I,F3B(I)
      GO TO 650
  650 IF(IDPST-2)651,651,652
  651 GO TO (20,22,76,78,79,13),KL
  652 GO TO (120,122,176,131,179,12),KL
    3 PI=PI/ESR
      F = PI/ASECT
      XS = .55
      K = 0
  125 I=0
   12 I=I+1
      X = (.5-DIST(I))*2
      Y(I) =  YM + (YE-YM)*X*X
      X=PI*(YB-Y(I))
      FTPI(I)=F-X/ST
      FBPI(I)=F+X/SB
      F1T(I)=FTPI(I)+FTBWT(I)
      F1B(I)=FBPI(I)+FBBWT(I)
      F2T(I)=FTPI(I)*R+FTBWT(I)+FTSDL(I)
      F2B(I) = FBPI(I)*R+FBBWT(I)+FBSDL(I)
      IF(ICOMP-100)90,95,90
   90 FTCDL(I)=0.0
      FBCDL(I)=0.0
   95 F3T(I)=F2T(I) +FTCDL(I)+FTLL(I)
      F3B(I)=F2B(I) +FBCDL(I)+FBLL(I)
      KL=1
```

(Continued)

```
      IF(F1B(I)-XS*FCI)120,120,601
120   KL=2
      IF(F1T(I)+FTENT)602,122,122
122   KL=3
      IF(F1T(I)+0.003*SQRT(FCI*1000))603,177,177
176   K = 1
177   KL=4
      IF(F3B(I)+FTENB)604,131,131
131   KL=5
      IF(F3T(I)-.4*FCULT)179,179,605
179   KL=6
      IF(F3B(I)-0.4*FCULT)112,112,606
112   IF(I.NE.NSEC) GO TO 12
 32   WRITE   (6,249)
      WRITE         (6,250)IDC,STRNS ,YM,YE
 24   WRITE(6,251)(I,I=1,NSEC)
      WRITE(6,252)(DIST(I),I=1,NSEC)
      WRITE(6,253)(FTPI(I),I=1,NSEC)
      WRITE(6,257)(FBPI(I),I=1,NSEC)
      WRITE(6,254)(F1T(I),I=1,NSEC)
      WRITE(6,258)(F1B(I),I=1,NSEC)
      WRITE(6,261)(F2T(I),I=1,NSEC)
      WRITE(6,259)(F2B(I),I=1,NSEC)
      WRITE(6,256)(F3T(I),I=1,NSEC)
      WRITE(6,260)(F3B(I),I=1,NSEC)
 34   LINES = LINES + LINC
249   FORMAT(1H /)
250   FORMAT(//,"CASE#",I2,/
     &"NO  OF STRANDS =  ",F4.0,10X"YM=",F7.3,10X,"YB=",F7.3,/////)
251   FORMAT("NSEC  -",17X,I1,3(9X,I1))
252   FORMAT("DIST  -",14X,F5.3,"L",3(4X,F5.3,"L"))
253   FORMAT("INITIAL PRESTRESS",/
     &   "             TOP-"8X,F7.3,3(3X,F7.3))
257   FORMAT("             BOTTOM",6X,F7.3,3(3X,F7.3))
254   FORMAT("BEAM WT +",/
     &        "INITIAL PRESTRESS",/
     &   "             TOP-"8X,F7.3,3(3X,F7.3))
258   FORMAT("             BOTTOM",6X,F7.3,3(3X,F7.3))
261   FORMAT("BEAM WT + SDL +",/
     &        "FINAL PRESTRESS",/
     &   "             TOP-"8X,F7.3,3(3X,F7.3))
259   FORMAT("             BOTTOM",6X,F7.3,3(3X,F7.3))
256   FORMAT("ALL LOADS +",/
     &        "FINAL PRESTRESS",/
     &   "             TOP-"8X,F7.3,3(3X,F7.3))
260   FORMAT("             BOTTOM",6X,F7.3,3(3X,F7.3),///)
701   FORMAT(/,"*****OVERSTRESS*****",/
     &        "SECTION NUMBER",I1,/
     &        "BEAM WT + INITIAL PRESTRESS(",F7.3,"),BOTTOM",/
     &        "EXCEEDS ",F4.2,"FCI",/)
702   FORMAT(/,"*****OVERSTRESS*****",/
     &        "SECTION NUMBER ",I1,/
```

(Continued)

```
     &         "BEAM WT + SDL + INITIAL PRESTRESS(",F7.3,")TOP",/
     &         "EXCEEDS FTENT",/)
 703 FORMAT(/,"*****WARNING*****",/
     &         "SECTION NUMBER",I1,/
     &         "BEAM WT + SDL + FINAL PRESTRESS(",F7.3,")TOP",/
     &         "EXCEEDS 0.03 SQRT FCI",/)
 704 FORMAT(/,"*****OVERSTRESS*****",/
     &         "SECTION NUMBER",I1,/
     &         "ALL LOADS + FINAL PRESTRESS(",F7.3,")BOTTOM",/
     &         "EXCEEDS FTENT",/)
 705 FORMAT(/,"*****OVERSTRESS*****",/
     &         "SECTION NUMBER",I1,/
     &         "ALL LOADS + FINAL PRESTRESS(",F7.3,")TOP",/
     &         "EXCEEDS 0.4 FCULT",/)
 706 FORMAT(/,"*****OVERSTRESS*****",/
     &         "SECTION NUMBER",I1,/
     &         "ALL LOADS + FINAL PRESTRESS(",F7.3,")BOTTOM",/
     &         "EXCEEDS 0.4 FCULT",/)
 255 FORMAT (/,46HCHECK CONVENTIONAL TENSILE REINF. AT TOP SLAB.,/)
     RETURN
     END
     SUBROUTINE SR5(UMR,UMP)
     CHARACTER TITLE*72
     COMMON DIST(4),BMLL(4),BMDLT(4),BMDLF(4),FTBWT(4),
    &FBBWT(4),FTSDL(4),FBSDL(4),FTCDL(4),FBCDL(4),
    &FSCDL(4),FSCLL(4),FTLL(4),FBLL(4),FTTOT(4),
    &FBTOT(4),Y(4),VLL(2),FSTOT(4),A(5),YA(5),BIO(5),
    &CONLL(8),M(4),FTPI(4),FBPI(4),F1T(4),F1B(4),
    &F2T(4),F2B(4),F3T(4),F3B(4),XP(17),XL(17),VDL(2),
    &DV(2),TG(2),SPACE(2),VU(2),YES(4),BMCDL(4),
    &L(4),TITLE,IDC,STRNS,YM,YE,IDBOX,IDLD,ICOMP,
    &IDSEC, IOTPT,FLOAD,SPAN,SDL,CDL,ALLFR,FIMP,FLL,WB,
    &DB,TTS,TBS,TSW,TMW,DH,DELTA,DSECT,ASECT,SECTI,YT,
    &YB,WTS,BB,DILOC,DIAPH,HDPT,AS,FSULT,RS,R,FCULT,FCI,
    &BOXI,SB,ST,Q,ACMP,CMPI,YTC,YBC,YTSC,STC,SBC,STSC,
    &QTSC,IDPST,FCPC,FTENT,FTENB,FNPS,FV,AV,NSEC,NCS,TCS,
    &XNCS,ABOX,PSLS2,NETRL,LINES,UM,UMD,STRMN,YSE,AVJ,
    &VRLL,DFLG,EMIN,ESR
     TTS=TTS+DELTA/2.
     IF(IDLD  -10  )2,1,2
   1 UMD = 1.5
     UML = 2.5
     GO TO 5
   2 IF(IDLD  -20  )21,3,21
  21 WRITE  (6,50)
     STOP
   3 UML = 2.3
     IF(SPAN-100.)6,6,4
   4 UMD = 1.6
     GO TO 5
   6 UMD = 2. - .004*SPAN
   5 UMR = UMD*(BMDLT(1)+BMDLF(1))+ UML*BMLL(1)
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(Continued)

```
      IF(ICOMP-100)301,300,301
  300 UMR=UMR+UMD*BMCDL(1)
  301 AST=AS*STRNS
      IF(ICOMP-100)30,60,60
   30 TTS = TTS + DELTA/2.
      D   = DSECT       -Y(1) + DELTA/2.
      P   = AST/WTS/D
      FSU = FSULT*(1.-.5*P*FSULT/FCULT)
      DFLG= 1.4 *D * P * FSU / FCULT
      IF(IDSEC-7)32,31,32
   31 TTS= DFLG
   32 IF(DFLG -TTS)11,11,10
   10 IF(IDSEC- 8)33,33,34
   34 BB = 2.*TSW + TMW
   33 ASF= .85*FCULT*(WTS-BB)*TTS/FSU
      ASR = AST - ASF
      PCR = ASR*FSU/BB/D/FCULT
      GO TO 12
   11 PCR = P*FSU/FCULT
   12 IF(PCR-.3) 14,14,13
   13 IF(DFLG-TTS) 16,16,15
   15 UMP  = 0.25*BB*D*D*FCULT  +0.85*FCULT*(WTS-BB)*TTS*(D-0.5*TTS)
      GO TO 19
   16 UMP  = 0.25*WTS*D*D*FCULT
      GO TO 19
   14 IF(DFLG - TTS)17,17,18
   17 UMP = AST*FSU*D*(1.-.6*P*FSU/FCULT)
      GO TO 19
   18 UMP  = ASR*FSU*D*(1. -.6*ASR*FSU/BB/D/FCULT) +.85*FCULT*(WTS-BB)*
     &TTS*(D -.5*TTS)
   19 UMP = UMP/12.
      AVJ = UMP/STRNS /AS/FSU/D*12.
      WRITE          (6,150)UMR,UMP
  150 FORMAT(//,"ULTIMATE MOMENT REQUIRED = ",F8.0,"
     &FT.KIPS ",/,"ULTIMATE MOMENT PROVIDED = " ,F8.0, "
     &FT.KIPS ")
      GO TO 500
   50 FORMAT(1H ,13HWRONG LL CODE)
   60 D = DSECT       -Y(1) +TCS
      P = AST/WCS/D
      FSU = FSULT*(1.-.5*P*FSULT/FCPC)
      DFLG =1.4*D*P*FSU/FCPC
      IF(DFLG -TCS)61,61,62
   62 IF(IDSEC-5) 64,63,64
   63 IF (DFLG -TCS -TTS)64,64,66
   66 ASF = .85*FCPC*(WCS-BB)*(TCS+TTS)/FSU
      ASR = AST -ASF
      PCR = ASR*FSU/BB/D/FCPC
      IF(PCR -.3)67,67,68
   67 UMP = ASR*FSU*D*(1.-.6*ASR*FSU/BB/D/FCPC) +.85*FCPC*(WCS-BB)*
     &(TCS+TTS)*(D -.5*(TCS+TTS))
      GO TO 19
```

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   68 UMP =0.25*BB*D*D*FCPC+.85*FCPC*(WCS-BB)*(TCS+TTS)*(D-.5*(TCS+TTS))
      GO TO 19
   64 IF(DFLG-TTS-TCS)61,61,81
   81 WRITE(6,160)
  160 FORMAT('DEPTH OF COMP BLOCK MORE THAN TCS+TTS,UMP CALC APPROX')
   80 ASF = 0.85 * FCPC *(WCS-WTS)*TCS/FSU
      ASR = AST  - ASF
      PCR = ASR*FSU/WTS/D/FCPC
      IF(PCR-.30)85,85,87
   87 UMP = 0.25* WTS*D*D*FCPC +.85*FCPC*(WCS-WTS)*TCS*(D-0.5*TCS)
      GO TO 19
   85 UMP = ASR*FSU*D*(1.-0.6*ASR*FSU/WTS/D/FCPC)+.85*FCPC*(WCS-WTS)*
&     TCS*(D-0.5*TCS)
      GO TO 19
   61 PCR = P*FSU/FCPC
      IF(PCR-0.3)70,70,75
   70 UMP = AST*FSU*D*(1.-.6*P*FSU/FCPC)
      GO TO 19
   75 UMP =0.25*WCS*D*D*FCPC
      GO TO 19
  500 RETURN
      END
      SUBROUTINE SR6
      CHARACTER TITLE*72
      COMMON DIST(4),BMLL(4),BMDLT(4),BMDLF(4),FTBWT(4),
&     FBBWT(4),FTSDL(4),FBSDL(4),FTCDL(4),FBCDL(4),
&     FSCDL(4),FSCLL(4),FTLL(4),FBLL(4),FTTOT(4),
&     FBTOT(4),Y(4),VLL(2),FSTOT(4),A(5),YA(5),BIO(5),
&     CONLL(8),M(4),FTPI(4),FBPI(4),F1T(4),F1B(4),
&     F2T(4),F2B(4),F3T(4),F3B(4),XP(17),XL(17),VDL(2),
&     DV(2),TG(2),SPACE(2),VU(2),YES(4),BMCDL(4),
&     L(4),TITLE,IDC,STRNS,YM,YE,IDBOX,IDLD,ICOMP,
&     IDSEC, IOTPT,FLOAD,SPAN,SDL,CDL,ALLFR,FIMP,FLL,WB,
&     DB,TTS,TBS,TSW,TMW,DH,DELTA,DSECT,ASECT,SECTI,YT,
&     YB,WTS,BB,DILOC,DIAPH,HDPT,AS,FSULT,RS,RYFCULT,FCI,
&     BOXI,SB,ST,Q,ACMP,CMPI,YTC,YBC,YTSC,STC,SBC,STSC,
&     DTSC,IDPST,FCPC,FTENT,FTENB,FNPS,FV,AV,NSEC,WCS,TCS,
&     XNCS,ABOX,PSLS2,NETRI,LINES,UM,UMD,STRMN,YSE,AVJ,
&     VRLL,DFLG,EMIN,ESR
      XP(1) = 1.
      XP(2) = 1.
      XP(3) = 1.
      XP(4) = 1.
      XP(5) = .65
      XP(6) = .65
      XP(7) = .65
      XP(8) = .65
      XP(9) = .5
      XP(10) = 1.
      XP(11) = 1.
      XP(12) = 1.
      XP(13) = 1.
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(Continued)

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      XP(14) = .65
      XP(15) = .65
      XP(16) = .65
      XP(17) = .65
      XL(1) = 0.0
      XL(2) = 5.
      XL(3) = 10.
      XL(4) = 15.
      XL(5) = 24.
      XL(6) = 29.
      XL(7) = 35.
      XL(8) = 40.
      XL(9) = 48.
      XL(10) = 56.
      XL(11) = 61.
      XL(12) = 66.
      XL(13) = 71.
      XL(14) = 80.
      XL(15) = 85.
      XL(16) = 91.
      XL(17) = 96.
      IF(ICOMP-100)150,151,150
  150 TCS = 0.0
  151 DSECT = DSECT      +TCS + DELTA/2.
      SPMN1 = DSECT *0.75
      SPMN2 = AV/.0025/88
      IF(SPMN1 -SPMN2 )101,101,102
  101 SPMIN = SPMN1
      GO TO 103
  102 SPMIN = SPMN2
  103 W = SDL +CDL + ASECT*.15/144.
      X = .25
    2 DO 20 I=1,2
      VDL(I) = SPAN*W*(.5-X) + DIAPH*(1.001/DILCC -1.)/2.
      IF(IDLD  -10  )82,83,82
   83 UML=2.5
      GO TO 81
   82 VLL(I)=0.0
      UML=2.3
      XPPP= SPAN*(1.-X)
      DO 5 N=1,17
      XPP =XPPP-XL(N)
      IF(XPP)4,5,5
    5 VLL(I) = XPP*XP(N)/SPAN + VLL(I)
      XPP = XPP - 5.
      IF(XPP)4,4,3
    3 VLL(I) = XPP*XPP/20./SPAN+ VLL(I)
    4 IF(X*SPAN-8.) 12,12,11
   11 VLL(I) = VLL(I)- 0.5*(X-8./SPAN)
   12 VLL(I) = VLL(I)*FLOAD*(1.+FIMP+FLL)*ALLFR
   81 XD=SPAN*(.5-X)
      IF(IDPST-2)6,7,8
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(Continued)

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    6 DV(I) =DSECT-YM +DELTA/2.
      GO TO 9
    8 DV(I) =DSECT -(YM+(XD/SPAN*2.)**2*(YE-YM))+DELTA/2.
      GO TO 9
    7 IF(HDPT-XD)10,6,6
   10 TG(I) = (YE-YM)/(SPAN/2.-HDPT)/12.
      DV(I) =DSECT -(YM+(XD-HDPT)*TG(I)*12.)+ DELTA/2.
    9 PF = AS*STRNS *FSULT*RS*R
      VU(I) =UMD*VDL(I)+UML*VLL(I)
      DJ = DV(I)*AVJ
      VC =.18*B3*DJ
      SPACE(I) = AV*FV*DJ*P /(VU(I)-VC)
      IF(SPACE(I))200,201,201
  201 IF(SPACE(I)-SPMIN)20,20,200
  200 SPACE(I) = SPMIN
   20 X = .3333
      WRITE(6,50)SPACE(1)
      WRITE(6,51)SPACE(2)
   50 FORMAT('AT 1/4 PT,REQUIRED STIRRUP SPACING =',F7.2,' IN.')
   51 FORMAT('AT 1/3 PT,REQUIRED STIRRUP SPACING =',F7.2,' IN.')
      IF(IDLD-10)70,210,70
  210 DLVR = W*SPAN/2.
      RVULL= DLVR*UMD +UML*VRLL
      REACT= DLVR +VRLL
      WRITE(6,52)REACT
   52 FORMAT('DL+LL+I REACTION PER BEAM = ',F10.2,' KIPS ')
      IF(ICOMP-100)70,71,70
   71 RDL = CDL*SPAN/2.
      RVULL = RDL*UMD + VRLL*UML
      HSHR  = RVULL *QTSC/CMPI/WTS*1000.
      WRITE(6,54)HSHR
   54 FORMAT('ULT SHEAR STRESS BETWEEN SLAB AND BEAM AT REACTION '
&      ' = ',F7.3,' PSI ')
   70 RETURN
      END
      SUBROUTINE SR7
      CHARACTER TITLE*72
      COMMON DIST(4),BMLL(4),BMDLT(4),BMDLF(4),FTBWT(4),
&     FBBWT(4),FTSDL(4),FBSDL(4),FTCDL(4),FBCDL(4),
&     FSCDL(4),FSCLL(4),FTLL(4),FBLL(4),FTTOT(4),
&     FBTOT(4),Y(4),VLL(2),FSTOT(4),A(5),YA(5),BIO(5),
&     CONLL(8),M(4),FTPI(4),FBPI(4),F1T(4),F1B(4),
&     F2T(4),F2B(4),F3T(4),F3B(4),XP(17),XL(17),VDL(2),
&     DV(2),TG(2),SPACE(2),VU(2),YFS(4),BMCDL(4),
&     L(4),TITLE,IDC,STRNS,YM,YE,IDBOX,IDLD,ICOMP,
&     IDSEC, IOTPT,FLOAD,SPAN,SDL,CDL,ALLFR,FIMP,FLL,WB,
&     DB,TTS,TBS,TSW,TMW,DH,DELTA,DSECT,ASECT,SECTI,YT,
&     YB,WTS,BB,DILOC,DIAPH,HDPT,AS,FSULT,RS,R,FCULT,FCI,
&     BOXI,SB,ST,Q,ACMP,CMPI,YTC,YBC,YTSC,STC,SBC,STSC,
&     QTSC,IDPST,FCPC,FTENT,FTENB,FNPS,FV,AV,NSEC,WCS,TCS,
&     XNCS,ABOX,PSLS2,NETRL,LINES,UM,UMD,STRMN,YSE,AVJ,
&     VRLL,DFLG,FMIN,ESR
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      IF(IDLD  -10  )10,11,10
 10   CDFL=180
      GO TO 15
 11   IF(SPAN-56.)12,13,13
 13   CDFL=(SPAN-55.)*.1+162.
      GO TO 15
 12   IF(FLOAD-54.)14,16,16
 14   CDFL=149.
      GO TO 15
 16   CDFL=162.
 15   ET = 145.**1.5*33.*SQRT(FCI*1000.)/1000.
      EF = 145.**1.5*33.*SQRT(FCULT*1000.)/1000.
      PI = AS*STRNS *FSULT*RS*ESR
      DEFM = -PI*(YB-YM)
      DEFPI = DEFM*(SPAN*12.)**2/ET/SECTI/8.
      IF(IDPST-2)1,2,3
  2   DEFM = PI*(YE-YM)
      X = SPAN/2. - HDPT
      DEFPI =  DEFPI + (DEFM*X/2.*SPAN/2.-DEFM*X/2.*(SPAN/2.-X/3.))*144.
     &/ET/SECTI
      GO TO 1
  3   DEFM = PI*(YE-YM)
      DEFPI = DEFPI +SPAN/2.*DEFM*SPAN*1.5/ET/SECTI
  1   IF(DILOC)20,20,5
 20   WTSEC = ASECT*.15/144.
      GO TO 6
  5   WTSEC = ASECT*.15/144.+DIAPH/DILOC/SPAN
  6   DFBW1 = 5.*WTSEC*SPAN**4*1728./384./ET/SECTI
      DFSDL = DFBW1*SDL/WTSEC*ET/EF
      IF(ICOMP-100)41,40,41
 40   DFCDL = DFSDL*CDL/SDL*SECTI/CMPI
      DFLL  = DFSDL*SECTI/CMPI*BMLL(1)/BMDLF(1)*CDFL/180.
 60   DEF2  = DEFPI*R/ESR  + DFBW1 + DFSDL +DFCDL
      DEF1 = DEFPI+DFBW1
      GO TO 51
 41   DFLL  = DFSDL*BMLL(1)/BMDLF(1)*CDFL/180.
      DFCDL =0.0
      GO TO 60
 51   WRITE(6,50)DEF1,DEF2,DFLL
      RETURN
 50   FORMAT(/,'DEFLECTIONS',/,'BEAM WEIGHT + PRESTRESS      = '
     &,F6.3,' IN.',/,'TOTAL DEAD LOAD + PRESTRESS = ',F6.3,' IN.',
     &/,'LIVE LOAD + IMPACT                = ',F6.3,' IN.',//)
      END
      SUBROUTINE  SR4A
      CHARACTER TITLE*72
      COMMON DIST(4),BMLL(4),BMDLT(4),BMDLF(4),FTBWT(4),
     &FBBWT(4),FTSDL(4),FBSDL(4),FTCDL(4),FBCDL(4),
     &FSCDL(4),FSCLL(4),FTLL(4),FBLL(4),FTTOT(4),
     &FBTOT(4),Y(4),YLL(2),FSTOT(4),A(5),YA(5),BIO(5),
     &CONLL(8),M(4),FTPI(4),FBPI(4),F1T(4),F1B(4),
     &F2T(4),F2B(4),F3T(4),F3B(4),XP(17),XL(17),VDL(2),
```

(Continued)

```
&          DV(2),TG(2),SPACE(2),VU(2),YES(4),BMCDL(4),
&          L(4),TITLE,IDC,STRNS,YM,YE,IDBOX,IDLD,ICOMP,
&          IDSEC, IOTPT,FLOAD,SPAN,SDL,CDL,ALLFR,FIMP,FLL,WB,
&          DB,TTS,TBS,TSW,TMW,DH,DELTA,DSECT,ASECT,SECTI,YT,
&          YB,WTS,BB,DILOC,DIAPH,HDPT,AS,FSULT,RS,R,FCULT,FCI,
&          BOXI,SB,ST,Q,ACMP,CMPI,YTC,YBC,YTSC,STC,SBC,STSC,
&          QTSC,IDPST,FCPC,FTENT,FTENB,FNPS,FV,AV,NSEC,NCS,TCS,
&          XNCS,ABOX,PSLS2,NETRL,LINES,UM,UMD,STRMN,YSE,AVJ,
&          VRLL,DFLG,EMIN,ESR
           ABOX = ASECT
           BOXI =SECTI
      101  IF(IDPST-2)1,2,3
        1  PI=-ABOX*(ST*FTENT*R*.90/ESR + SB*(FBTOT(1)+FTENB))/(SB+ST)
           DO 10 I=1,NSEC
       10  YES(I)=ST/ABOX + (ST/PI*R/ESR*FTENT*.90)
           IF(YES(1)+EMIN-YB) 90,90,95
       90  GO TO 98
       95  YES(1)=YB-EMIN
           PI=-ABOX*(FBTOT(1)+FTENB)*SB/(SB+ABOX*YES(1))
       98  YM=YB-YES(1)
           YE=YM
           XS=0.6
           GO TO 4
        2  HPT=(SPAN/2.-HDPT)
           N=1./(DILOC *2.)
           RDIA=DIAPH*(1./DILOC -1.)/2.
           BMMIN=HPT*RDIA
           DO 7 J=1,N
           XN=J
           XD=XN*DILOC *SPAN
           IF(HPT-XD)5,6,6
        5  BM=0.0
           GO TO 7
        6  BM=DIAPH*(HPT-XD)
        7  BMMIN=BMMIN-BM
           BMMIN=BMMIN+ABOX*.15*HPT*(SPAN-HPT)/288.
           FTMIN = R/ESR*(BMMIN/ST*12. - FTENT)
           PI= -ABOX*((FBTOT(1)+FTENB)*SB + FTMIN*ST)/(SB+ST)
           ECC=(FTMIN-FBTOT(1)-FTENB)*ST*SB/(SB+ST)/PI
           IF(ECC+EMIN-YB)70,70,75
       70  GO TO 80
       75  ECC = YB -EMIN
           PI=-ABOX*(FBTOT(1)+FTENB)*SB/(SB+ABOX*ECC)
       80  YM=YB-ECC
           YE1 = YB - ST/ABOX
           YE2 = YB - (SB*ABOX*.4*FCULT-SB*PI)/(ABOX*PI)
           IF(YE1-YE2)200,201,201
      200  YE= YE2 + 1.
           GO TO 203
      201  YE =YE1 + 1.
      203  XS =.6
           DO 11 I=1,NSEC
```

(Continued)

```
      X=DIST(I)* SPAN - HPT
      IF(X)8,9,9
    8 YES(I)=ECC-(YM-YE)*X/HPT
      GO TO 11
    9 YES(I)=ECC
   11 CONTINUE
      GO TO 4
    3 PI=-ABOX*((FBTOT(1)+FTENB)*SB+(FTENT+FTBWT(1))*R*ST)
      PI = PI/(ST + SB)
      XS=.55
      ECC=((FTBWT(1)+FTENT)*R+FBTOT(1)-FTENB)*SB*ST/(SB+ST)/PI
      IF(ECC+EMIN-YB)18,18,19
   18 GO TO 22
   19 ECC=YB-EMIN
      PI=-ABOX*(FBTOT(1)+FTENB)*SB/(SB+ABOX*ECC)
   22 YM=YB-ECC
      YE1 = YB - ST/ABOX
      YE2 = YB - (SB*ABOX*.4*FCULT-SB*PI)/(ABOX*PI)
      IF(YE1-YE2)300,301,301
  300 YE = YE2 + 1.
      GO TO 303
  301 YE=  YE1  + 1.
  303 DO 12 I = 1,NSEC
      X=(.5-DIST(I))/.5
   12 YES(I)=YB-YM-(YE-YM)*X*X
    4 STRMN =PI/AS/FSULT/RS/R
      DO 13 I=1,NSEC
      IF (IDPST-2) 16,16,15
   15 F=PI/R/ABOX
      X=PI/R*YES(I)
      GO TO 17
   16 F=PI*ESR /R/ABOX
      X=PI*ESR /R*YES(I)
   17 FTPI(I)=F-X/ST
      FBPI(I)=F+X/SB
      F1T(I)=FTPI(I)+FTBWT(I)
      F1B(I)=FBPI(I)+FBBWT(I)
      F2T(I)=PI/ABOX-PI*YES(I)/ST+FTBWT(I)+FTSDL(I)
      F2B(I)=PI/ABOX+PI*YES(I)/SB+FBBWT(I)+FBSDL(I)
      IF(ICOMP -100) 61,60,61
   61 FTCDL(I)=0.0
      FBCDL(I)=0.0
   60 F3T(I) = F2T(I) +FTCDL(I) +FTLL(I)
      F3B(I) = F2B(I) +FBCDL(I) +FBLL(I)
      KL=1
      IF(F1B(I)-XS*FCI)20,20,601
   20 KL=2
      IF(F3T(I)-.4*FCULT)99,99,605
   99 KL=3
      IF(F3B(I)+FTENB)604,13,13
   13 CONTINUE
      YSE=YES(1)
```

(Continued)

```
      IF(IOTPT)170,160,160
  170 RETURN
  601 WRITE(6,701)I,F1B(I),XS
      GO TO 650
  604 WRITE(6,704)I,F3B(I)
      GO TO 650
  605 WRITE(6,705)I,F3T(I)
      GO TO 650
  650 GO TO (20,99,13),KL
  160 WRITE(6,50)STRMN,YM,YE
      WRITE(6,500)
  500 FORMAT('STRESSES DUE TO EXTERNAL LOADS AND PRESTRESS - KIPS'
     &'PER SQ. IN.')
   24 WRITE(6,251)(I,I=1,NSEC)
      WRITE(6,252)(DIST(I),I=1,NSEC)
      WRITE(6,253)(FTPI(I),I=1,NSEC)
      WRITE(6,257)(FBPI(I),I=1,NSEC)
      WRITE(6,254)(F1T(I),I=1,NSEC)
      WRITE(6,258)(F1B(I),I=1,NSEC)
      WRITE(6,255)(F2T(I),I=1,NSEC)
      WRITE(6,259)(F2B(I),I=1,NSEC)
      WRITE(6,256)(F3T(I),I=1,NSEC)
      WRITE(6,260)(F3B(I),I=1,NSEC)
   50 FORMAT('MINIMUM STRANDS = ',F7.3,'     YM = ',F7.3,' IN. '
     &'     YE = ',F7.3,' IN. ',///)
  250 FORMAT(//,"CASE#",I2,/
     &"NO. OF STRANDS = ",F4.0,10X"YM=",F7.3,10X,"YE=",F7.3,/////)
  251 FORMAT("NSEC  -",17X,I1,3(9X,I1))
  252 FORMAT("DIST  -",14X,F5.3,"L",3(4X,F5.3,"L"))
  253 FORMAT("INITIAL PRESTRESS",/
     &       "               TOP-"8X,F7.3,3(3X,F7.3))
  257 FORMAT("               BOTTOM"6X,F7.3,3(3X,F7.3))
  254 FORMAT("BEAM WT +",/
     &       "INITIAL PRESTRESS",/
     &       "               TOP-"8X,F7.3,3(3X,F7.3))
  258 FORMAT("               BOTTOM"6X,F7.3,3(3X,F7.3))
  255 FORMAT("BEAM WT + SDL +",/
     &       "FINAL PRESTRESS",/
     &       "               TOP-"8X,F7.3,3(3X,F7.3))
  259 FORMAT("               BOTTOM"6X,F7.3,3(3X,F7.3))
  256 FORMAT("ALL LOADS +",/
     &       "FINAL PRESTRESS",/
     &       "               TOP-"8X,F7.3,3(3X,F7.3))
  260 FORMAT("               BOTTOM"6X,F7.3,3(3X,F7.3),///)
  701 FORMAT(/,"*****OVERSTRESS*****",/
     &       "SECTION NUMBER"I1,/
     &       "BEAM WT + INITIAL PRESTRESS(",F7.3,"),BOTTOM",/
     &       "EXCEEDS ",F4.2,"FCI",/)
  704 FORMAT(/,"*****OVERSTRESS*****",/
     &       "SECTION NUMBER"I1,/
     &       "ALL LOADS + FINAL PRESTRESS(",F7.3,")BOTTOM",/
     &       "EXCEEDS FTENT",/)
```

(Continued)

```
  705 FORMAT(/,"*****OVERSTRESS*****",/
     &        "SECTION NUMBER",I1,/
     &        "ALL LOADS + FINAL PRESTRESS(",F7.3,")TOP",/
     &        "EXCEEDS 0.4 FCULT",/)
      RETURN
      END
      SUBROUTINE   SR5A(UMR,UMP)
      CHARACTER TITLE*72
      COMMON DIST(4),BMLL(4),BMDLT(4),BMDLF(4),FTBWT(4),
     &FBBWT(4),FTSDL(4),FBSDL(4),FTCDL(4),FBCDL(4),
     &FSCDL(4),FSCLL(4),FTLL(4),FBLL(4),FTTOT(4),
     &FBTOT(4),Y(4),VLL(2),FSTOT(4),A(5),YA(5),BIO(5),
     &CONLL(8),M(4),FTPI(4),FBPI(4),F1T(4),F1B(4),
     &F2T(4),F2B(4),F3T(4),F3B(4),XP(17),XL(17),VDL(2),
     &DV(2),TG(2),SPACE(2),VU(2),YES(4),BMCDL(4),
     &L(4),TITLE,IDC,STRNS,YM,YE,IDBOX,IDLD,ICOMP,
     &IDSEC, IOTPT,FLOAD,SPAN,SDL,CDL,ALLFR,FIMP,FLL,WB,
     &DB,TTS,TBS,TSW,TMW,DH,DELTA,DSECT,ASECT,SECTI,YT,
     &YB,WTS,BB,DILOC,DIAPH,HDPT,AS,FSULT,RS,R,FCULT,FCI,
     &BOXI,SB,ST,Q,ACMP,CMPI,YTC,YBC,YTSC,STC,SBC,STSC,
     &QTSC,IDPST,FCPC,FTENT,FTENB,FNPS,FV,AV,NSEC,WCS,TCS,
     &XNCS,ABOX,PSLS2,NETRL,LINES,UM,UMD,STRMN,YSE,AVJ,
     &VRLL,DFLG,EMIN,ESR
      IF(IDLD  -10  )2,1,2
    1 UMD=1.5
      UML=2.5
      GO TO 5
    2 IF(IDLD  -20  )20,3,20
   20 WRITE              (6,50)
      STOP
    3 UML=2.3
      IF(SPAN-100.)6,4,4
    4 UMD=1.6
      GO TO 5
    6 UMD=2.-0.004*SPAN
    5 UMR=UMD*(BMDLT(1)+BMDLF(1))+UML*BMLL(1)
      IF(ICOMP-100)300,301,300
  301 UMR=UMR+UMD*BMCDL(1)
  300 IF(IOTPT)302,303,303
  303 WRITE(6,150)UMR
  302 ISTRN = STRMN
      IF(STRMN -ISTRN)100,101,100
  101 STRNS = STRMN
      GO TO 28
  100 STRNS = ISTRN + 1
   28 IF(ICOMP -100)40,60,60
   40 D= DSECT       +DELTA/2.-YB +YSE
      AST = AS* STRNS
      P = AST/WTS/D
      FSU = FSULT*(1. -.5*P*FSULT/FCULT)
      DFLG =1.4*D*P*FSU/FCULT
      TTS  = TTS + DELTA/2.
```

(Continued)

```
      IF(IDSEC -7)42,41,42
   41 TTS = DFLG
   42 IF(DFLG - TTS)11,11,43
   43 IF(IDSEC- 8)45,45,44
   44 BB =2.*TSW +TMW
   45 ASF = .85 * FCULT *(WTS-BB)*TTS/FSU
      ASR = AST - ASF
      PCR = ASR * FSU /BB / D / FCULT
      GO TO 12
   11 PCR  = P* FSU /FCULT
   12 IF(PCR-.3)14,14,13
   13 IF(DFLG-TTS)16,16,15
   15 UMP = 0.25*BB*D*D*FCULT + 0.85*FCULT*(WTS  *  BB)*TTS*(D-0.5*TTS)
      GO TO 32
   16 UMP = .25 *WTS*D*D*FCULT
   32 UMP = UMP/12.
      IF(UMP -UMR) 33,27,27
   33 WRITE(6,152)
  152 FORMAT(//,'P*FSU/FCULT MORE THAN .30,    UMP INADEQUATE ',//)
      GO TO 30
   14 IF(DFLG -TTS)17,17,18
   17 UMP = AST *FSU * D *(1.-.6*P*FSU/FCULT)
      GO TO 19
   18 UMP = ASR *FSU*D *(1.-.6*ASR*FSU/BB/D/FCULT) +.85*FCULT*
     &(WTS-BB)*TTS*(D-.5*TTS)
   19 UMP = UMP/12.
      IF (UMP -UMR)26,27,27
   26 STRNS = STRNS+ 1.
      GO TO 40
   27 IF(IOTPT)200,227,227
  227 WRITE(6,151)FCULT,STRNS,UMP
      GO TO 30
  201 IF(IOTPT)200,202,202
  202 WRITE(6,155)FCPC,STRNS,UMP
  155 FORMAT('FOR FCPC = ',F5.3,' PSI  AND ',F3.0,'  STRANDS ',
     &/,'ULTIMATE MOMENT PROVIDED = ',F8.0,' FT.KIPS ')
   30 CONTINUE
   50 FORMAT(/,14H WRONG LL CODE,/)
  150 FORMAT(//,'ULTIMATE MOMENT REQUIRED = ',F8.0,' FT.KIPS ')
  151 FORMAT('FOR FCULT = ',F5.3,' PSI  AND ',F3.0,' STRANDS ',
     &/,'ULTIMATE MOMENT PROVIDED = ',F8.0,' FT.KIPS ')
      WRITE        (6,49)
   49 FORMAT (1H1)
  200 RETURN
   60 D = DSECT    -YM *TCS
      AST = AS * STRNS
      P   = AST/WCS/D
      FSU = FSULT*(1.-.5*P*FSULT/FCPC)
      DFLG= 1.4*D*P*FSU/FCPC
      IF(DFLG-TCS)61,61,62
   62 IF(IDSEC-5)64,63,64
   63 IF(DFLG-TCS-TTS)61,61,66
```

(Continued)

```
   66 ASF =.85*FCPC*(WCS-BB)*(TCS+TTS)/FSU
      ASR = AST - ASF
      PCR = ASR*FSU/BB/D/FCPC
      IF(PCR -.3)67,67,69
   67 UMP =ASR*FSU*D*(1.-.6*ASR*FSU/BB/D/FCPC)+.85*FCPC*(WCS-BB)*
&     (TCS+TTS)*(D - 0.5*(TCS+TTS))
      UMP = UMP/12.
      IF(UMP -UMR)68,201,201
   68 STRNS= STRNS+1
      GO TO 60
   69 UMP = 0.25*BB*D*D*FCPC +.85*FCPC*(WCS-BB)*(TTS+TCS)
&     *(D-.5*(TCS+TTS))
      UMP = UMP/12.
      IF(UMP-UMR)33,201,201
   64 IF(DFLG -TCS-TTS)61,61,81
   81 IF(IOTPT)80,400,400
  400 WRITE(6,160)
  160 FORMAT(/,'DEPTH OF COMP BLOCK MORE THAN TCS+ TTS, UMP CALC ',
&     'APPROXIMATE ',/)
   80 ASF = 0.85*FCPC*(WCS-WTS)*TCS/FSU
      ASR = AST - ASF
      PCR = ASR*FSU/WTS/D/FCPC
      IF(PCR -.30)85,85,87
   87 UMP = 0.25*WTS*D*D*FCPC +.85*FCPC*(WCS-WTS)*TCS*(D-0.5*TCS)
      UMP = UMP/12.
      IF(UMP-UMR)33,201,201
   85 UMP = ASR *FSU*D*(1.-0.6*ASR*FSU/WTS/D/FCPC) +0.85*FCPC*(WCS-WTS)*
&     TCS*(D-0.5*TCS)
      UMP = UMP/12.
      IF(UMP-UMR)68,201,201
   61 PCR = P*FSU/FCPC
      IF(PCR-0.3)70,70,75
   70 UMP = AST* FSU * D * (1. - .6 *P *FSU/FCPC)
      UMP = UMP/12.
      IF(UMP -UMR)68,201,201
   75 UMP = 0.25 *WCS *12.* D * D * FCPC
      UMP = UMP/12.
      IF(UMP-UMR)33,201,201
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE MAKEFIL
      CHARACTER FILN*8,FILNAM*10,FILNAME*26
      CHARACTER STO*1
      COMMON L,LC
      DATA IOK / 0400000000000 /
      DATA INAFT / 0403700000000 /
    5 PRINT," "
      PRINT,"IS DATA TO BE INPUT FROM"
      PRINT,"EXISTING FILE(Y OR N)  ?"
      READ(5,9997) STO
      IF(STO.EQ."Y") GO TO 20
      IF(STO.EQ."N") GO TO 36
```

(Continued)

```
      PRINT," "
      PRINT,"*****CORRECT RESPONCE IS Y FOR YES OR N FOR NO - RETRY"
      GO TO 5
   20 PRINT," "
      PRINT,"NOTE# TO RETURN TO PREVIOUS QUESTION ENTER THE"
      PRINT,"       LETTER R AS A QUESTION RESPONCE."
   21 PRINT," "
      PRINT,"ENTER NAME OF INPUT FILE"
      PRINT,"(MAX. 8 CHAR.)           -"
      READ(5,9995)FILN
      IF(FILN.EQ."R       ") GO TO 5
      ENCODE(FILNAM,9996)FILN
   27 CALL ATTACH(02,FILNAM,3/0,ISTAT)
      IF(ISTAT.EQ.INAFT) GO TO 28
      IF(ISTAT.NE.IOK) GO TO 502
      RETURN
   28 CALL DETACH(02,,)
      GO TO 27
   36 PRINT," "
      PRINT,"NOTE# TO RETURN TO PREVIOUS QUESTION ENTER THE"
      PRINT,"       LETTER R AS A QUESTION RESPONCE."
   37 PRINT," "
      PRINT,"IS DATA ENTERED AT TERMINAL TO BE"
      PRINT,"SAVED IN PERMENANT FILE (Y OR N)!"
      LC=1
      READ(5,9997) STO
      IF(STO.EQ."Y") GO TO 38
      IF(STO.EQ."N") GO TO 41
      IF(STO.EQ."R") GO TO 5
      PRINT,"*****CORRECT RESPONCE IS Y FOR YES,N FOR NO*****"
      PRINT," "
      GO TO 36
   38 PRINT,"ENTER NAME OF DATA FILE TO"
      PRINT,"BE CREATED (MAX. 8 CHAR.)!"
      READ(5,9995)FILN
      IF(FILN.EQ."R       ") GO TO 36
      ENCODE(FILNAME,9994)FILN
      CALL ACCESS(FILNAME,$500)
      ENCODE(FILNAM,9996)FILN
      CALL ATTACH(02,FILNAM,3/0,ISTAT,)
      IF(ISTAT.NE.IOK) GO TO 501
      GO TO 400
   41 CALL CREATE(02,320,0,ISTAT)
      LC=2
  400 CALL FILDATA
      REWIND 2
      IF(LC.EQ.2) RETURN
      IF(LC.EQ.3) GO TO 37
      IF(L.EQ.1) GO TO 415
      GO TO 9999
  415 ENCODE(FILNAME,9998)FILN
      CALL ACCESS(FILNAME,$506)
```

(Continued)

```
      IF(STO.EQ."Y") GO TO 38
      GO TO 37
  506 PRINT 507,FILN
  507 FORMAT("*****UNABLE TO RELEASE FILE NAMED ",A8)
      IF(STO.EQ."Y") GO TO 38
      GO TO 36
  500 PRINT,"*****UNABLE TO CREATE FILE - RETRY*****"
      GO TO 38
  501 PRINT,"*****UNABLE TO ACCESS NEWLY CREATED FILE - RETRY*****"
      GO TO 38
  502 PRINT 503,FILN
  503 FORMAT("*****UNABLE TO ACCESS FILE NAMED ",A8)
      PRINT 504
  504 FORMAT("      CHECK YOUR CATALOGUE OR DECODE THE")
      PRINT 505,ISTAT
  505 FORMAT("      FOLLOWING OCTAL ERROR MESSAGE,",3X,O16)
      GO TO 21
 9994 FORMAT("CF,/",A8,",B/1,100/,R,W#")
 9995 FORMAT(A8)
 9996 FORMAT("/",A8,";")
 9997 FORMAT(A1)
 9998 FORMAT("RF,/",A8,"#")
 9999 RETURN
      END

C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE FILDATA
      CHARACTER X*15,V01*66,Y*1,Z*2,W*3
C
      DIMENSION V39(4),V40(4)
      COMMON L,LC
      PRINT 900
      PRINT,"*****OPTIONAL RESPONCES TO FOLLOWING QUESTIONS*****"
      PRINT," "
      PRINT,"      *ENTER LETTER H FOR HELP IN ANSWERING QUESTION*"
      PRINT 958
      PRINT,"      *ENTER LETTER R TO RETURN TO PREVIOUS QUESTION*"
      PRINT," "
      PRINT 900
  900 FORMAT(///)
  901 FORMAT(A1,65X)
  902 FORMAT(A1,14X)
  903 FORMAT(1X,A1)
  911 FORMAT("*****CORRECT RESPONCE IS#",//)
  931 FORMAT(A66)
  932 FORMAT(A1)
  934 FORMAT(A2)
  936 FORMAT(A3)
  938 FORMAT(I2)
  940 FORMAT(I1)
  942 FORMAT(I3)
```

(Continued)

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944 FORMAT(A15)
946 FORMAT(V)
951 FORMAT("*****NOTE#PRECAST SECTION IS THE NONCOMPOSITE SECTION")
952 FORMAT("*****NOTE#PRECAST SECTION IS THE BEAM PORTION OF A"
   &       /,"             COMPOSITE BEAM-SLAB SECTION")
958 FORMAT("       -NOTE#IF NO HELP GIVEN,CHECK OPERATING",/
   &       "        INSTRUCTION MANUAL.",//)
961 FORMAT("     -NOTE#FOR SECTIONS OTHER THAN THOSE ABOVE,USE",/
   &       "          NUMBER OF THE COMPOSITE OR NONCOMPOSITE"
   &       /,"          SECTION WHICH MOST CLOSELY RESEMBLES THE"
   &       /,"          SECTION UNDER DESIGN.",//)
    L=0
  5 PRINT," "
    PRINT,"TITLE"
    PRINT,"ENTER TITLE(MAX. 66 CHAR.) -"
    READ(5,931) V01
    DECODE(V01,901)Y
    IF(Y.EQ."R") GO TO 10
    IF(Y.EQ."H") GO TO 20
    GO TO 30
 10 IF(LC.EQ.2) GO TO 12
    L=1
    RETURN
 12 LC=3
    RETURN
 20 PRINT," "
    PRINT,"*****TITLE IS THE HEADER FOR PROGRAM OUTPUT."
    PRINT,"     IT CAN INCLUDE SUCH INFORMATION AS"
    PRINT,"     PROJECT NAME,DATE,DATA BY,CHECKED BY,ETC."
    GO TO 5
 30 PRINT," "
    PRINT,"IDLD"
    PRINT,"ENTER LIVE LOAD CODE(10 FOR HWY;20 FOR RR) - "
    READ(5,934) Z
    IF(Z.EQ."R ") GO TO 5
    IF(Z.EQ."H ") GO TO 40
    DECODE(Z,938)IV02
    IF(IV02.EQ.10) GO TO 50
    IF(IV02.EQ.20) GO TO 50
 40 PRINT," "
    PRINT 911
    PRINT,"     10 FOR HIGHWAY LOADING"
    PRINT,"     20 FOR RAILROAD LOADING"
    GO TO 30
 50 PRINT," "
    PRINT,"IDSEC"
    PRINT,"ENTER SECTION NUMBER (1-10) - "
    READ(5,934) Z
    IF(Z.EQ."H ") GO TO 60
    IF(Z.EQ."R ") GO TO 30
    DECODE(Z,946)IV03
    IF(IV03)60,60,55
```

(Continued)

```
55 IF(IV03-10)70,70,60
60 PRINT," "
   PRINT 911
   PRINT," "
   PRINT,"      (STANDARD SECTIONS WITH A COMPOSITE DECK)"
   PRINT," "
   PRINT,"      1 FOR SPREAD BOX"
   PRINT,"      2 FOR BOX"
   PRINT,"      3 FOR AASHO-PCI TYPES I-IV"
   PRINT,"      4 FOR AASHO-PCI TYPES V-VI"
   PRINT,"      5 FOR TEE"
   PRINT," "
   PRINT," "
   PRINT,"      (NONCOMPOSITE-STANDARD SECTIONS)"
   PRINT," "
   PRINT,"      6 FOR CHANNEL"
   PRINT,"      7 FOR SLAB"
   PRINT,"      8 FOR VOIDED SLAB"
   PRINT," "
   PRINT," "
   PRINT,"      (NONCOMPOSITE BOX BEAMS)"
   PRINT," "
   PRINT,"      9 SINGLE BOX"
   PRINT,"     10 DOUBLE BOX"
   PRINT," "
   PRINT 961
   GO TO 50
70 PRINT," "
   PRINT,"IOTPT"
   PRINT,"ENTER OUTPUT(TYPE) CODE(-1 FOR MIN;0 FOR TOT) - "
   READ(5,934) Z
   DECODE(Z,932)Y
   IF(Z.EQ."R ") GO TO 50
   IF(Z.EQ."-1") GO TO 86
   IF(Y.EQ."0") GO TO 88
   PRINT," "
   PRINT 911
   PRINT,"      -1 FOR MINIMUM OUTPUT"
   PRINT,"      0 (ZERO) FOR TOTAL OUTPUT"
   GO TO 70
86 DECODE(Z,938)IV04
   GO TO 90
88 DECODE(Z,940)IV04
   GO TO 90
90 PRINT," "
   PRINT,"IOPST"
   PRINT,"ENTER GEOMETRY OF PRESTRESSING"
   PRINT,"STRANDS (1,2 OR 3)          - "
   READ(5,932)Y
   IF(Y.EQ."R") GO TO 70
   IF(Y.EQ."H") GO TO 100
   DECODE(Y,940)IV05
```

(Continued)

```
      IF(IV05) 100,100,95
   95 IF(IV05-3)110,110,100
  100 PRINT," "
      PRINT 911
      PRINT,"     1 FOR STRAIGHT PARALLEL STRANDS"
      PRINT,"     2 FOR DEPRESSED STRANDS"
      PRINT,"     3 FOR PARABOLIC POSTTENSIONED STRANDS"
      GO TO 90
  110 PRINT," "
      PRINT,"FLOAD"
      PRINT,"ENTER LIVE LOAD CODE (KIPS) - "
      READ(5,944) X
      IF(X.EQ."R                ") GO TO 90
      IF(X.EQ."H                ") GO TO 120
      DECODE(X,946)V06
      GO TO 130
  120 PRINT," "
      PRINT,"*****STANDARD LOADS ARE AS FOLLOWS:"
      PRINT," "
      PRINT,"    (HIGHWAY LOADING)"
      PRINT,"     20 FOR H10-44"
      PRINT,"     30 FOR H15-44"
      PRINT,"     40 FOR H20-44"
      PRINT,"     54 FOR HS15-44"
      PRINT,"     72 FOR HS20-44"
      PRINT,"     90 FOR HS25-44"
      PRINT," "
      PRINT,"    (RAILROAD LOADINGS)"
      PRINT,"     60 FOR COPPER S E-60 LOADING"
      PRINT,"     72 FOR COPPER S E-72 LOADING"
      PRINT,"     80 FOR COPPER S E-80 LOADING"
      GO TO 110
  130 PRINT," "
      PRINT,"SPAN"
      PRINT,"ENTER SPAN LENGTH (FT) - "
      READ(5,944) X
      IF(X.EQ."R                ") GO TO 110
      IF(X.EQ."H                ") GO TO 140
      IF(X.EQ."                H") GO TO 140
      DECODE(X,946)V07
      IF(IV03.LE.5) GO TO 160
      GO TO 150
  140 PRINT," "
      PRINT,"*****SPAN LENGTH IS DISTANCE FROM CENTER"
      PRINT,"     TO CENTER OF BEARINGS IN FEET."
      GO TO 130
  150 PRINT," "
      PRINT,"SDL"
      PRINT,"ENTER EXTERNAL DEAD LOADS (KIPS/FT) - "
      READ(5,944) X
      IF(X.EQ."R                ") GO TO 130
      IF(X.EQ."H                ") GO TO 155
```

(Continued)

```
      DECODE(X,946) V08
      GO TO 190
  155 PRINT," "
      PRINT,"*****SDL IS THE DEAD LOAD APPLIED TO A NONCOMPOSITE"
      PRINT,"     SECTION,EXCLUSIVE OF BEAM WEIGHT."
      GO TO 150
  160 PRINT," "
      PRINT,"SDL"
      PRINT,"ENTER EXTERNAL DEAD LOAD(KIPS/FT) - "
      READ(5,944) X
      IF(X.EQ."R              ") GO TO 130
      IF(X.EQ."H              ") GO TO 165
      DECODE(X,946) V08
      GO TO 170
  165 PRINT," "
      PRINT,"*****SDL IS THE DEAD LOAD APPLIED TO THE PRECAST"
      PRINT,"     SECTION OF COMPOSITE SECTION,EXCLUSIVE OF"
      PRINT,"     WEIGHT OF PRECAST SECTION"
      GO TO 160
  170 PRINT," "
      PRINT,"CDL"
      PRINT,"ENTER EXTERNAL DEAD LOAD"
      PRINT,"FOR COMPOSITE SECTION (K/FT) - "
      READ(5,944) X
      IF(X.EQ."R              ") GO TO 160
      IF(X.EQ."H              ") GO TO 180
      DECODE(X,946)V08A
      GO TO 190
  180 PRINT," "
      PRINT,"*****CDL IS THE EXTERNAL DEAD LOAD APPLIED TO COMPOSITE"
      PRINT,"     SECTION,EXCLUSIVE OF PRECAST SECTION WEIGHT AND SDL"
      GO TO 170
  190 PRINT," "
      PRINT,"ALLFR"
      PRINT,"ENTER FRACTION OF TRUCK OR TRACK "
      PRINT,"LOAD TO BE APPLIED TO SECTION    - "
      READ(5,944) X
      IF(X.EQ."R              ") GO TO 195
      IF(X.EQ."H              ") GO TO 200
      DECODE(X,946) V09
      V10A=0.
      IF(IV02.EQ.20) GO TO 210
      GO TO 230
  195 IF(IV03.LE.5) GO TO 170
      GO TO 150
  200 PRINT," "
      PRINT,"*****ENTER 1.0 FOR ONE TRUCK LOAD PER BEAM (TWO LINES"
      PRINT,"     OF WHEELS),0.5 FOR ONE-HALF TRUCK LOAD PER BEAM,ETC"
      GO TO 190
  210 PRINT," "
      PRINT,"FIMP"
      PRINT,"ENTER IMPACT FRACTION - "
```

(Continued)

```
      READ(5,944) X
      IF(X.EQ."R                 ") GO TO 190
      IF(X.EQ."H                 ") GO TO 220
      DECODE(X,946)V10A
      GO TO 230
  220 PRINT," "
      PRINT,"*****FIMP IS THE IMPACT FRACTION TO BE USED FOR RR"
      PRINT,"     LOADING.  ENTER AS DECIMAL FRACTION,I.E.,0.3 FOR"
      PRINT,"     30 PERCENT."
      GO TO 210
  230 PRINT," "
      PRINT,"FLL"
      PRINT,"ENTER FRACTION OF ALLFR - "
      READ(5,944) X
      IF(X.EQ."R                 ") GO TO 235
      IF(X.EQ."H                 ") GO TO 240
      DECODE(X,946)V11
      GO TO 250
  235 IF(IV02.EQ.20) GO TO 210
      GO TO 190
  240 PRINT,"*****FLL IS FRACTION OF ALLFR TO ACCOUNT FOR"
      PRINT,"     ECCENTRICITY AND CENTRIFUGAL FORCE."
      GO TO 230
  250 IF(IV03.GT.8) GO TO 410
      PRINT," "
      PRINT,"DSECT"
      PRINT,"ENTER DEPTH OF PRECAST SECTION(INCHES) - "
      READ(5,944) X
      IF(X.EQ."R                 ") GO TO 230
      IF(X.EQ."H                 ") GO TO 260
      DECODE(X,946)V12
      GO TO 270
  260 PRINT," "
      PRINT,"**** TOTAL DEPTH OF PRECAST SECTION"
      IF(IV03.LE.5) PRINT 952
      IF(IV03.GT.5) PRINT 951
      GO TO 250
  270 PRINT," "
      PRINT,"ASECT"
      PRINT,"ENTER AREA (INCHES**2) - "
      READ(5,944) X
      IF(X.EQ."R                 ") GO TO 250
      IF(X.EQ."H                 ") GO TO 280
      DECODE(X,946)V13
      GO TO 290
  280 PRINT," "
      PRINT,"*****TOTAL AREA OF PRECAST SECTION"
      IF(IV03.LE.5) PRINT 952
      IF(IV03.GT.5) PRINT 951
      GO TO 270
  290 PRINT," "
      PRINT,"SECTI"
```

(Continued)

```
      PRINT,"ENTER MOMENT INERTIA (INCHES**4) - "
      READ(5,944) X
      IF(X.EQ."R          ") GO TO 270
      IF(X.EQ."H          ") GO TO 300
      DECODE(X,946)V14
      GO TO 310
  300 PRINT," "
      PRINT,"*****TOTAL MOMENT OF INERTIA OF PRECAST SECTION"
      IF(IV03.LE.5) PRINT 952
      IF(IV03.GT.5) PRINT 951
      GO TO 290
  310 PRINT," "
      PRINT,"YT"
      PRINT,"DISTANCE BETWEEN CENTROIDAL AXIS AND"
      PRINT,"TOP OF PRECAST SECTION (INCHES)    - "
      READ(5,944) X
      IF(X.EQ."R          ") GO TO 290
      IF(X.EQ."H          ") GO TO 320
      DECODE(X,946) V15
      GO TO 330
  320 PRINT," "
      IF(IV03.LE.5) PRINT 952
      IF(IV03.GT.5) PRINT 951
      GO TO 310
  330 PRINT," "
      PRINT,"YB"
      PRINT,"DISTANCE BETWEEN CENTROIDAL AXIS AND"
      PRINT,"BOTTOM OF PRECAST SECTION (INCHES) - "
      READ(5,944) X
      IF(X.EQ."R          ") GO TO 310
      IF(X.EQ."H          ") GO TO 340
      DECODE(X,946) V16
      GO TO 350
  340 PRINT," "
      IF(IV03.LE.5) PRINT 952
      IF(IV03.GT.5) PRINT 951
      GO TO 330
  350 PRINT," "
      PRINT,"WTS"
      PRINT,"ENTER WIDTH OF TOP SLAB OR FLANGE"
      PRINT,"OF PRECAST SECTION (INCHES)        - "
      READ(5,944) X
      IF(X.EQ."R          ") GO TO 330
      IF(X.EQ."H          ") GO TO 360
      DECODE(X,946) V17
      GO TO 370
  360 PRINT," "
      IF(IV03.LE.5) PRINT 952
      IF(IV03.GT.5) PRINT 951
      GO TO 350
  370 PRINT," "
      PRINT,"TTS"
```

(Continued)

```
      PRINT,"ENTER MINIMUM THICKNESS OF TOP SLAB"
      PRINT,"OR FLANGE OF PRECAST SECTION (INCHES) - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 350
      IF(X.EQ."H                    ") GO TO 380
      DECODE(Y,946) V18
      GO TO 390
  380 PRINT," "
      IF(IV03.LE.5) PRINT 952
      IF(IV03.GT.5) PRINT 951
      GO TO 370
  390 IF(IV03.EQ.7) V19=0.
      IF(IV03.EQ.7) GO TO 550
      PRINT," "
      PRINT,"BB"
      PRINT,"ENTER MINIMUM WIDTH OF WEB"
      PRINT,"OF PRECAST SECTION (INCHES) - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 370
      IF(X.EQ."H                    ") GO TO 400
      DECODE(X,946)V19
      GO TO 570
  400 PRINT," "
      IF(IV03.LE.5) PRINT 952
      IF(IV03.GT.5) PRINT 951
      GO TO 390
  410 PRINT," "
      PRINT,"WB"
      PRINT,"ENTER TOTAL WIDTH OF BOX BEAM (FEET) - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 230
      IF(X.EQ."H                    ") GO TO 410
      DECODE(X,946)V12A
  430 PRINT," "
      PRINT,"DB"
      PRINT,"ENTER TOTAL DEPTH OF BOX BEAM(FEET) -"
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 410
      IF(X.EQ."H                    ") GO TO 440
      DECODE(X,946)V13A
      GO TO 450
  440 PRINT," "
      PRINT,"*****NOTE*USE DEPTH AT LOWER EDGE WHEN"
      PRINT,"            TOP SURFACE IS SLOPED."
      GO TO 430
  450 PRINT," "
      PRINT,"TTS"
      PRINT,"ENTER MINIMUM THICKNESS OF TOP"
      PRINT,"SLAB OF BOX BEAM (INCHES )   - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 430
      IF(X.EQ."H                    ") GO TO 450
```

(Continued)

```
      DECODE(X,946)V14A
  470 PRINT," "
      PRINT,"TBS"
      PRINT,"ENTER THICKNESS OF BOTTOM"
      PRINT,"SLAB OF BOX BEAM (INCHES) - "
      READ(5,944) X
      IF(X.EQ."R                ") GO TO 450
      IF(X.EQ."H                ") GO TO 470
      DECODE(X,946) V15A
  490 PRINT," "
      PRINT,"TSW"
      PRINT,"ENTER THICKNESS OF SIDEWALLS"
      PRINT,"OF BOX BEAM (INCHES)         - "
      READ(5,944) X
      IF(X.EQ."R                ") GO TO 470
      IF(X.EQ."H                ") GO TO 490
      DECODE(X,946) V16A
      V17A=0.
  510 IF(IV03.EQ.9) GO TO 530
      PRINT," "
      PRINT,"TMW"
      PRINT,"ENTER THICKNESS OF CENTER WALL OF"
      PRINT,"DOUBLE-CELLED BOX BEAM (INCHES)  - "
      READ(5,944) X
      IF(X.EQ."R                ") GO TO 490
      IF(X.EQ."H                ") GO TO 510
      DECODE(X,946) V17A
  530 PRINT," "
      PRINT,"DH"
      PRINT,"ENTER DEPTH AND WIDTH OF FILLET (INCHES)  - "
      READ(5,944) X
      IF(X.EQ."R                ") GO TO 535
      IF(X.EQ."H                ") GO TO 540
      DECODE(X,946) V18A
      GO TO 550
  535 IF(IV03.EQ.9) GO TO 490
      GO TO 510
  540 PRINT," "
      PRINT,"*****NOTE*FILLET IS THE TRIANGULAR AREA THAT FORMS"
      PRINT,"            THE CORNER OF A CELL IN A BOX BEAM."
      GO TO 530
  550 PRINT," "
      PRINT,"DELTA"
      PRINT,"ENTER INCREASE IN THICKNESS OF TOP SLAB"
      PRINT,"OF BOX BEAM DUE TO SLOPING (INCHES)  - "
      READ(5,944) X
      IF(X.EQ."R                ") GO TO 530
      IF(X.EQ."H                ") GO TO 550
      DECODE(X,946) V19A
  570 PRINT," "
      PRINT,"DILOC"
      PRINT,"ENTER DIAPHRAM LOCATION AS"
```

(Continued)

```
      PRINT,"A FRACTION OF SPAN LENGTH - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 575
      IF(X.EQ."H                    ") GO TO 580
      DECODE(X,946) V20
      GO TO 590
575   IF(IV03.EQ.7) GO TO 370
      IF(IV03.GT.8) GO TO 550
      GO TO 390
580   PRINT," "
      PRINT,"*****NOTE,FOR DIAPHRAMS AT THIRD POINTS ENTER 0.33."
      PRINT,"             IF NO DIAPHRAMS ARE USED ENTER ZERO."
      GO TO 570
590   IF(V20.EQ.0.) GO TO 605
      PRINT," "
      PRINT,"DIAPH"
      PRINT,"ENTER WEIGHT PER DIAPHRAM (KIPS) - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 570
      IF(X.EQ."H                    ") GO TO 590
      DECODE(X,946) V21
      GO TO 610
605   V21=0.
      V20=0.5
610   IF(IV05.NE.2) GO TO 630
      PRINT," "
      PRINT,"HDPT"
      PRINT,"ENTER DISTANCE FROM MIDSPAN TO HOLD-DOWN"
      PRINT,"POINT FOR DEPRESSED STRANDS (FEET)       - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 615
      IF(X.EQ."H                    ") GO TO 610
      DECODE(X,946)V22
      GO TO 630
615   IF(V21.EQ.0.) GO TO 570
      GO TO 590
630   PRINT," "
      PRINT,"AS"
      PRINT,"ENTER AREA OF A SINGLE PRESTRESSING"
      PRINT,"STRAND OR CABLE (INCHES**2)          - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 635
      IF(X.EQ."H                    ") GO TO 630
      DECODE(X,946) V23
      GO TO 650
635   IF(IV05.EQ.2) GO TO 610
      IF(V21.EQ.0.) GO TO 570
      GO TO 590
650   PRINT," "
      PRINT,"FSULT"
      PRINT,"ENTER ULTIMATE STRENGTH OF"
      PRINT,"PRESTRESSING STEEL (KSI) - "
```

(Continued)

```
      READ(5,944) X
      IF(X.EQ."R                  ") GO TO 630
      IF(X.EQ."H                  ") GO TO 650
      DECODE(X,946) V24
  670 PRINT," "
      PRINT,"RS"
      PRINT,"ENTER RATIO OF STEEL STRESS AT TIME OF STRAND"
      PRINT,"RELEASE OR ANCHORAGE TO ULTIMATE PRESTRESSING"
      PRINT,"STEEL STRENGTH"
      READ(5,944) X
      IF(X.EQ."R                  ") GO TO 650
      IF(X.EQ."H                  ") GO TO 670
      DECODE(X,946) V25
  690 PRINT," "
      PRINT,"R"
      PRINT,"ENTER RATIO OF STEEL STRESS AFTER LOSS OF"
      PRINT,"PRESTRESS TO STEEL STRESS AT ANCHORAGE     - "
      READ(5,944) X
      IF(X.EQ."R                  ") GO TO 670
      IF(X.EQ."H                  ") GO TO 690
      DECODE(X,946) V26
  710 PRINT," "
      PRINT,"EMIN"
      PRINT,"ENTER MINIMUM FEASIBLE ECCENTRICITY OF CENTER OF"
      PRINT,"GRAVITY OF PRESTRESSING TENDONS FROM BOTTOM OF BEAM"
      PRINT,"(INCHES)"
      READ(5,944) X
      IF(X.EQ."R                  ") GO TO 690
      IF(X.EQ."H                  ") GO TO 720
      DECODE(X,946) V27
      GO TO 730
  720 PRINT 971
      PRINT 972
      GO TO 710
  730 PRINT," "
      PRINT,"ESR"
      PRINT,"ENTER FACTOR TO ALLOW FOR STRAND RELAXATION AND MEMBER"
      PRINT,"SHORTENING PRIOR TO COMPUTING STAGE I STRESSES          - "
      READ(5,944) X
      IF(X.EQ."R                  ") GO TO 710
      IF(X.EQ."H                  ") GO TO 740
      DECODE(X,946) V28
      GO TO 750
  740 PRINT 971
      PRINT 972
      GO TO 730
  750 PRINT," "
      PRINT,"FCULT"
      PRINT,"ENTER COMPRESSIVE STRENGTH OF CONCRETE IN"
      PRINT,"PRESTRESSED MEMBER AT 28 DAYS (KIPS PER SQ IN) - "
      READ(5,944) X
      IF(X.EQ."R                  ") GO TO 730
```

(Continued)

```
      IF(X.EQ."H                    ") GO TO 750
      DECODE(X,946) V29
  770 PRINT," "
      PRINT,"FCI"
      PRINT,"ENTER COMPRESSIVE STRENGTH OF CONCRETE IN"
      PRINT,"PRESTRESSED MEMBER AT TIME OF ANCHORAGE"
      PRINT,"OR STRAND RELEASE (KIPS PER SQ. IN.)      - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 750
      IF(X.EQ."H                    ") GO TO 770
      DECODE(X,946) V30
      V31A=0.
  790 IF(IV03.LE.5) GO TO 810
      GO TO 830
  810 PRINT," "
      PRINT,"FCPC"
      PRINT,"ENTER COMPRESSIVE STRENGTH OF CONCRETE "
      PRINT,"IN COMPOSITE DECK SLAB (KIPS PER SQ. IN.) - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 770
      IF(X.EQ."H                    ") GO TO 810
      DECODE(X,946) V31A
  830 PRINT," "
      PRINT,"FTENT"
      PRINT,"ENTER ALLOWABLE TENSILE STRESS IN TOP FIBERS"
      PRINT,"OF PRESTRESSED MEMBER (KIPS PER SQ. IN.)   - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 835
      IF(X.EQ."H                    ") GO TO 830
      DECODE(X,946) V32
      GO TO 850
  835 IF(IV03.LE.5) GO TO 810
      GO TO 770
  850 PRINT," "
      PRINT,"FTENB"
      PRINT,"ENTER ALLOWABLE TENSILE STRESS IN BOTTOM FIBERS"
      PRINT,"PRESTRESSED MEMBER (KIPS PER SQ. IN.)                - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 830
      IF(X.EQ."H                    ") GO TO 850
      DECODE(X,946) V33
  870 PRINT," "
      PRINT,"FNPS"
      PRINT,"ENTER ALLOWABLE STEEL STRESS OF NONPRESTRESSED"
      PRINT,"REINFORCEMENT (KIPS PER SQ. IN.)                - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 850
      IF(X.EQ."H                    ") GO TO 870
      DECODE(X,946) V34
  890 PRINT," "
      PRINT,"FV"
      PRINT,"ENTER ULTIMATE STEEL STRESS OF STIRRUP"
```

(Continued)

```
      PRINT,"REINFORCEMENT (KIPS PER SQ. IN.)        - "
      READ(5,944) X
      IF(X.EQ."R                  ") GO TO 870
      IF(X.EQ."H                  ") GO TO 890
      DECODE(X,946) V35
910   PRINT," "
      PRINT,"AV"
      PRINT,"ENTER AREA OF ALL LEGS OF STIRRUPS AT"
      PRINT,"ONE SECTION IN THE MEMBER (SQ. IN.) - "
      READ(5,944) X
      IF(X.EQ."R                  ") GO TO 890
      IF(X.EQ."H                  ") GO TO 910
      DECODE(X,946) V36
930   PRINT," "
      PRINT,"NSEC"
      PRINT,"ENTER NUMBER OF SECTIONS AT WHICH BEAM IS TO"
      PRINT,"BE ANALYZED FOR MOMENT (MAXIMUM OF 4)        - "
      READ(5,932) Y
      IF(Y.EQ."R") GO TO 910
      IF(Y.EQ."H") GO TO 930
      DECODE(Y,940) IV37
950   V39(1)=0.5
      DO 953 I=2,IV37
953   V39(I)=0.
      DO 954 I=1,IV37
954   V40(I)=0.
      PRINT 2000
      IF(IV02.EQ.20) GO TO 965
955   IF(IV37.EQ.1) GO TO 970
      DO 960 I=2,IV37
      J=I
      PRINT 2001,I
      PRINT 2002,I
      READ(5,944) X
      IF(X.EQ."R                  ") GO TO 930
      IF(X.EQ."H                  ") GO TO 955
960   DECODE(X,946) V39(J)
      GO TO 970
965   PRINT 2004
      J=1
      PRINT 2006,J,V39(1)
      READ(5,944) X
      IF(X.EQ."R                  ") GO TO 950
      IF(X.EQ."H                  ") GO TO 965
      DECODE(X,946) V40(1)
     IF(IV37.EQ.1) GO TO 970
      DO 968 I=2,IV37
      J=I
      PRINT 2001,I
      PRINT 2002,I
      READ(5,944) X
      IF(X.EQ."R                  ") GO TO 930
```

(Continued)

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      IF(X.EQ."H                    ") GO TO 965
      DECODE(X,946) V39(J)
      PRINT 2006,J,V39(J)
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 965
      IF(X,EQ."H                    ") GO TO 965
      DECODE(X,946) V40(J)
  968 CONTINUE
  970 PRINT," "
      PRINT,"NETRL"
      PRINT,"IS NUMBER AND LOCATION OF PRESTRESSING"
      PRINT,"STRANDS TO BE INPUT DATA (Y OR N)    ? "
      READ(5,932) Y
      IF(Y.EQ."R") GO TO 950
      IF(Y.EQ."H") GO TO 970
      IF(Y.EQ."Y") GO TO 973
      IF(Y.EQ."N") GO TO 974
      PRINT,"*****CORRECT RESPONCE IS Y FOR YES AND N FOR NO*****"
      GO TO 970
  973 IV38=1
      GO TO 990
  974 IV38=-1
      GO TO 1070
  990 PRINT," "
      PRINT,"IDC"
      PRINT,"ENTER A NUMBER TO IDENTIFY THE CASE (1 DIGIT MAX) - "
      READ(5,932) Y
      IF(Y.EQ."R") GO TO 970
      IF(Y.EQ."H") GO TO 990
      DECODE(Y,940) IV41A
 1010 PRINT," "
      PRINT,"STRNS"
      PRINT,"ENTER NUMBER OF PRESTRESSING STRANDS - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 990
      IF(X.EQ."H                    ") GO TO 1010
      DECODE(X,946) V42A
 1030 PRINT," "
      PRINT,"YM"
      PRINT,"ENTER DISTANCE FROM BOTTOM OF BEAM TO CENTROID OF"
      PRINT,"PRESTRESSING STRANDS AT MIDSPAN (INCHES)"
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 1010
      IF(X.EQ."H                    ") GO TO 1030
      DECODE(X,946) V43A
 1050 PRINT," "
      IF(IV05.EQ.1) V44A=V43A
      IF(IV05.EQ.1) GO TO 1070
      PRINT,"YE"
      PRINT,"ENTER DISTANCE FROM BOTTOM OF BEAM TO CENTROID"
      PRINT,"OF PRESTRESSING STRANDS AT END OF BEAM (INCHES) - "
      READ(5,944) X
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(Continued)

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      IF(X.EQ."R                    ") GO TO 1030
      IF(X.EQ."H                    ") GO TO 1050
      DECODE(X,946) V44A
 1070 IF(IV03.GT.5) GO TO 1130
 1075 PRINT," "
      PRINT,"WCS"
      PRINT,"ENTER WIDTH OF COMPRESSIVE SLAB (INCHES) - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 1080
      IF(X.EQ."H                    ") GO TO 1075
      DECODE(X,946) V45A
      GO TO 1090
 1080 IF(IV38) 970,970,1085
 1085 IF(IV05.EQ.1) GO TO 1030
      GO TO 1050
 1090 PRINT," "
      PRINT,"TCS"
      PRINT,"ENTER THICKNESS OF COMPOSITE DECK SLAB (INCHES) - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 1075
      IF(X.EQ."H                    ") GO TO 1090
      DECODE(X,946) V46A
 1110 PRINT," "
      PRINT,"XNCS"
      PRINT,"ENTER RATIO OF MODULUS OF ELASTICITY OF COMPOSITE"
      PRINT,"DECK TO MODULUS OF ELASTICITY OF PRECAST MEMBER - "
      READ(5,944) X
      IF(X.EQ."R                    ") GO TO 1090
      IF(X.EQ."H                    ") GO TO 1110
      DECODE(X,946) V47A
 1130 PRINT," "
  971 FORMAT(///,20X,"TABLE 1",///,
     &" SECTION         TYPE OF            APPROX.       APPROX.",/
     &" NUMBER          SECTION            VALUE OF      VALUE",/,
     &"                                    EMIN (IN)     OF ESR",///,
     &"    1      COMPOSITE SPREAD ROX       2.0            0.925",//,
     &"    2      COMPOSITE AASHO-PCI",//,
     &"    3      STANDARD SECTIONS",/,
     &"           TYPE I 30 FT SPAN          2.0            0.915",/,
     &"           TYPE I 45 FT SPAN          3.0            0.88",/,
     &"           TYPE II 40 FT SPAN         2.5            0.915",/,
     &"           TYPE II 60 FT SPAN         3.5            0.88",/,
     &"           TYPE III 55 FT SPAN        3.5            0.915",/,
     &"           TYPE III 80 FT SPAN        4.0            0.88",/,
     &"           TYPE IV 70 FT SPAN         3.5            0.915",/,
     &"           TYPE IV 100 FT SPAN        4.5            0.88",/,
     &"    4      TYPE V 90 FT SPAN          4.5            0.905",/,
     &"           TYPE V 120 FT SPAN         5.0            0.88",/,
     &"           TYPE VI 110 FT SPAN        5.0            0.905",/,
     &"           TYPE VI 140 FT SPAN        5.5            0.88",//)
  972 FORMAT(3X,"5",5X,"COMPOSITE TEE",/,
     &"                40 FT SPAN            4.5            0.905",/,
```

(Continued)

```
      &"                    50 FT SPAN           5.0              0.905",/,
      &"                    60 FT SPAN           6.0              0.905",//,
      &"   6                CHANNEL",/,
      &"                    20 FT SPAN           3.0              0.905",/,
      &"                    30 FT SPAN           4.0              0.905",/,
      &"                    40 FT SPAN           5.0              0.905",//,
      &"   7               SOLID SLAB            2.0              0.935",//,
      &"   8               VOIDED SLAB           2.0              0.93",//,
      &"   9               SINGLE BOX            2.0              0.925",//,
      &"  10               DOUBLE BOX            2.0              0.925",////)
 2000 FORMAT(/,"*****NOTE*SECTION 1 MUST BE AT MIDSPAN;THEREFORE",/,
      &         "         DIST(1) SET EQUAL TO 0.5 BY PROGRAM",//)
 2002 FORMAT("ENTER DISTANCE TO SECTION ",I1,/,
      &       "FROM SUPPORT AS A FRACTION OF SPAN = ")
 2004 FORMAT(/,"*****NOTE*MOMENTS FOR COOPER'S E-1 RR LOADING MAY",/,
      &         "          BE ENTERED WITH APPROPIATE FLOAD AND",/,
      &         "          ALLFR VALUES,OR 1. MAY BE ENTERED FOR",/,
      &         "          FLOAD AND ALLFR WITH THE BMLL VALUES",/,
      &         "          ENTERED AS ACTUAL MOMENTS TO BE APPLIED",/,
      &         "          TO SECTION.",///)
 2001 FORMAT(/,"DIST(",I1,")")
 2006 FORMAT(/,"BMLL(",I1,")",/,
      &       "ENTER LIVE LOAD MOMENTS FOR RAILROAD LOADING AT",/,
      &       "POINT CORRESPONDING TO SECTION DISTANCE OF ",F7.4,"L",/,
      &       "(FT KIPS)")
      LN=1
      PRINT 5500,LN
      PRINT 5502,V01
      LN=2
      PRINT 5501,LN
      PRINT 5504,IV02,IV03,IV04,IV05,V06,V07,V08,V08A,V09,V10A,V11
      LN=3
      PRINT 5501,LN
      IF(IV03.GT.8) GO TO 3000
      PRINT 5506,V12,V13,V14,V15,V16,V17,V18,V19
      GO TO 3020
 3000 PRINT 5508,V12A,V13A,V14A,V15A,V16A,V17A,V18A,V19A
 3020 LN=4
      PRINT 5501,LN
      PRINT 5510,V20,V21,V22,V23,V24,V25,V26,V27,V28
      LN=5
      PRINT 5501,LN
      PRINT 5512,V29,V30,V31A,V32,V33,V34,V35,V36
      LN=6
      PRINT 5501,LN
      PRINT 5514,IV37,IV38,(V39(J),V40(J),J=1,IV37)
      LN=7
      IF(IV03.GT.5) GO TO 3050
      PRINT 5501,LN
      PRINT 5516,V45A,V46A,V47A
      IF(IV38)3060,3060,3040
 3040 LN=8
```

(Continued)

```
      PRINT 5501,LN
      PRINT 5518,IV41A,V42A,V43A,V44A
      GO TO 3060
 3050 IF(IV38)3060,3060,3055
 3055 PRINT 5520,IV41A,V42A,V43A,V44A
 3060 LN=1
      WRITE(02,5522)LN,V01
      LN=2
      WRITE(02,5524)LN,IV02,IV03,IV04,IV05,V06,V07,V08,V08A,V09,V10A,V11
      LN=3
      IF(IV03.GT.8) GO TO 3080
      WRITE(02,5525)LN,V12,V13,V14,V15,V16,V17,V18,V19
      GO TO 3100
 3080 WRITE(02,5526)LN,V12A,V13A,V14A,V15A,V16A,V17A,V18A,V19A
 3100 LN=4
      WRITE(02,5528)LN,V20,V21,V22,V23,V24,V25,V26,V27,V28
      LN=5
      WRITE(02,5530)LN,V29,V30,V31A,V32,V33,V34,V35,V36
      LN=6
      WRITE(02,5532)LN,IV37,IV38,(V39(J),V40(J),J=1,IV37)
      LN=7
      IF(IV03.GT.5) GO TO 3200
      WRITE(02,5534)LN,V45A,V46A,V47A
      IF(IV38)3230,3230,3190
 3190 LN=8
      WRITE(02,5536)LN,IV41A,V42A,V43A,V44A
      GO TO 3230
 3200 IF(IV38)3230,3230,3210
 3210 WRITE(02,5536)LN,IV41A,V42A,V43A,V44A
 5500 FORMAT(" LINE NUMBER ",I1,/,
     &       "INPUT  SYMBOL   VALUE",//)
 5502 FORMAT("   1     TITLE   "A66,//)
 5501 FORMAT(" LINE NUMBER ",I1,/,
     &      "INPUT  SYMBOL      VALUE           COMMENT",//)
 5504 FORMAT("   2     IDLD       ",I2,
     &   /,"   3     IDSEC      ",I2,
     &   /,"   4     IOTPT      ",I2,
     &   /,"   5     IDPST      ",I1,
     &   /,"   6     FLOAD      ",F6.2,
     &   /,"   7     SPAN    ",F10.3,
     &   /,"   8     SDL     ",F10.3,
     &   /,"   9     CDL     ",F10.3,3X,"SET EQUAL TO ZERO FOR"
     &  /,"                          NONCOMPOSITE SECTION"
     &   /,"  10     ALLFR   ",5X,F5.3,
     &   /,"  11     FIMP    ",5X,F5.3,3X,"SET EQUAL TO ZERO FOR",
     &   /,"                              HIGHWAY LOAD",
     &   /,"  12     FLL     ",5X,F5.3,///)
 5506 FORMAT("  13     DSECT   ",F10.3,
     &   /,"  14     ASECT   ",F10.3,
     &   /,"  15     SECTI   ",F11.3
     &   /,"  16     YT      ",F10.3,
     &   /,"  17     YB      ",F10.3,
```

(Continued)

```
          &        /,"  18        WTS   ",F10.3,
          &        /,"  19        TTS   ",F10.3,
          &        /,"  20         BE   ",F10.3,3X,"SET EQUAL TO ZERO FOR",
          &/,"                                  IDSEC EQUAL TO 7 (SLAB)",///)
     5508 FORMAT("  13         WR   ",F10.3,
          &        /,"  14         DE   ",F10.3,
          &        /,"  15        TTS   ",F10.3,
          &        /,"  16        TBS   ",F10.3,
          &        /,"  17        TSW   ",F10.3,
          &        /,"  18        TMW   ",F10.3,
          &        /,"  19         DH   ",F10.3,
          &        /,"  20      DELTA   ",F10.3,///)
     5510 FORMAT("  21      DILOC    ",4X,F5.3,3X,"WHEN ZERO OR BLANK,SET TO"
          &        /,"                                    0.5"
          &        /,"  22      DIAPH   ",F10.3,3X,"WHEN DILOC EQUAL ZERO,SET"
          &    /,"                                 EQUAL TO ZERO"
          &        /,"  23       HDPT   ",F10.3,3X,"WHEN IDPST NOT EQUAL 2,SET"
          &    /,"                                 EQUAL TO ZERO"
          &        /,"  24         AS   ",F10.3,
          &        /,"  25      FSULT   ",F10.3,
          &        /,"  26         RS    ",4X,F5.3,
          &        /,"  27          R    ",4X,F5.3,
          &        /,"  28       EMIN    ",4X,F5.3,
          &        /,"  29        ESR    ",4X,F5.3,///)
     5512 FORMAT("  30      FCULT   ",F10.3,
          &        /,"  31        FCI   ",F10.3,
          &        /,"  32       FCPC   ",F10.3,3X,"SET EQUAL TO ZERO FOR"
          &     /,"                                  NONCOMPOSITE SECTION"
          &        /,"  33      FTENT   ",F10.3,
          &        /,"  34      FTENB   ",F10.3,
          &        /,"  35       FNPS   ",F10.3,
          &        /,"  36         FV   ",F10.3,
          &        /,"  37         AV   ",F10.3,///)
     5514 FORMAT("  38       NSEC          ",I2,
          &        /,"  39      NSTRL          ",I2,3X,"   SET EQUAL TO 1 IF",
          &    /,"                                 STRAND DATA INPUT,OTHERWISE",
          &    /,"                                 SET EQUAL TO -1",
          &        /,"  40 DIST,SMLL   ",F5.3,F8.3,/,3(16X,F5.3,F8.3,/),///)
     5516 FORMAT("  41        WCS   ",F10.3,
          &        /,"  42        TCS   ",F10.3,
          &        /,"  43       XNCS   ",F10.3,///)
     5518 FORMAT("  44        IDC   ",6X,I2,
          &        /,"  45      STRNS   ",F10.3,
          &        /,"  46         YM   ",F10.3,
          &        /,"  47         YE   ",F10.3,///)
     5520 FORMAT("  41        IDC   ",6X,I2,/,
          &         "  42      STRNS   ",F10.3,/,
          &         "  43         YM   ",F10.3,/,
          &         "  44         YE   ",F10.3,///)
     5522 FORMAT(I1,1X,A66)
     5524 FORMAT(I1,3(1X,I2),1X,I1,4(1X,F7.3),3(1X,F5.3))
     5525 FORMAT(I1,2(1X,F8.3),1X,F11.3,5(1X,F7.3))
```

(Continued)

```
5526 FORMAT(I1,8(1X,F7.3))
5528 FORMAT(I1,1X,F5.3,4(1X,F7.3),4(1X,F6.3))
5530 FORMAT(I1,8(1X,F7.3))
5532 FORMAT(2(I1,1X),I2,4(1X,F5.3,1X,F7.3))
5534 FORMAT(I1,3(1X,F7.3))
5536 FORMAT(I1,1X,I1,3(1X,F7.3))
3230 PRINT," "
     IF(LC.EQ.2) GO TO 3231
     PRINT,"NOTE#EXIT PROGRAM TO CORRECT ERRORS IN DATA FILE"
     PRINT," "
3231 PRINT,"DO YOU WISH TO EXIT PROGRAM(Y OR N) ? "
     READ(5,932)Y
     IF(Y.EQ."Y") STOP
     IF(Y.EQ."N") GO TO 3240
     PRINT," "
     PRINT,"*****CORRECT RESPONCE IS Y FOR YES AND N FOR NO*****"
     GO TO 3230
3240 RETURN
     END
```

APPENDIX F: CONCRETE PRECASTING FACILITY

General Requirements

1. A typical concrete precast facility comprises the following elements:

- a. Cement and aggregates storage areas.
- b. Reinforcing steel and prestressing strand storage areas and fabricating facility.
- c. Forms.
- d. Concrete casting and curing area.
- e. Concrete placing and consolidation equipment.
- f. Means of accelerated curing.
- g. Lifting and handling equipment.
- h. Stressing means (usually hydraulic jacking equipment, etc.).
- i. Storage area for finished products.
- j. Transportation equipment, e.g. trucks.
- k. Equipment for testing and inspection.
- l. Facilities for maintenance and repair.
- m. Utilities (water, power, fuel supply, compressed air, etc.).
- n. Storage and fabrication of inserts, voids, picking loops, etc.
- o. Burning and welding equipment.
- p. Shop engineering for shop and working drawings and computations.
- q. Plant management and administration office.

Obviously some of the items above may be performed offsite, or by outside agencies. However, the coordination of all of these items into a manufacturing system requires extremely careful planning and management. Some principles and general requirements for the concrete precasting facility are given below.[6]

Materials flow

2. The flow of the materials must be laid out so as to minimize

distance of movement and prevent congestion.

Proper roads and drainage

3. In all work areas and in the storage area, proper road and drainage must be provided. It is extremely important to eliminate ruts or holes that might cause a crane or forklift truck to tip, possibly injuring a worker or damaging product or equipment.

Utilities

4. The outlets for the utilities must be conveniently located in the work area. Boxes or guards should be installed to keep outlets and receptacles dry and clean and to protect them from accidental impact. Adequate lighting should be provided for night work.

Communications

5. Particularly from point of concrete placement in forms to batch and mixing plant, communications, such as a two-way voice radio, should be provided.

Casting beds

6. These beds must be designed to remain level and true despite repeated loading and frequent wetting of ground. Height of bed should be set at the best working level, particularly where considerable handwork is required.

Proper storage

7. Prestressing steel, mild reinforcing steel, and inserts must be stored where they will be kept clean and dry.

Hydraulic jacks
and strand vises

8. Stressing equipment must be properly maintained, cleaned, and lubricated in accordance with the manufacturer's recommendations.

Quality control

9. It is important to have quality control for the achievement of economy, schedules, and performance. Definite inspection, checking, and testing procedures must be provided to ensure that the product is correctly produced, not only for strength, but also for dimensional accuracy (within prescribed tolerance).

Suggested Concrete Precasting Facility

10. The suggested concrete precasting facility (Figure F1) for producing prestressed channel elements and pile bents for the recommended precast concrete military bridges (Appendix D) is composed of the following:

- a. Two parallel concrete casting and curing areas, 20 by 200 ft each.
- b. Two stockpile areas for coarse aggregates and one stockpile area for fine aggregate.
- c. One cement silo.
- d. One 66-cu yd, 100-ton standard Corps of Engineers aggregate batching plant.[3]
- e. One 200-barrel standard Corps of Engineers cement batching plant.[3]
- f. Four truck mixers.
- g. One temporary storage and prestressing area.
- h. One storage area for finished product.
- i. One reinforcement and equipment shop for fabrication and storage of reinforcing bars, prestressing steel, forms, inserts, picking loops, placing and consolidation equipment, etc.
- j. One administration building for administration office, shop engineering office, and quality control laboratory.

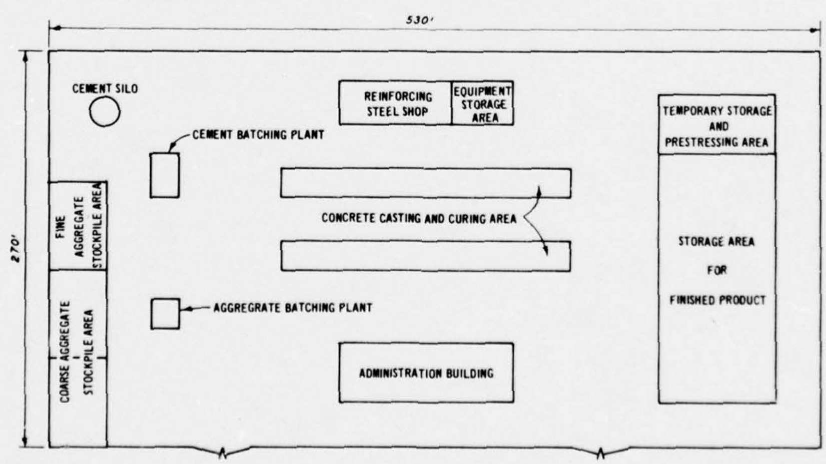
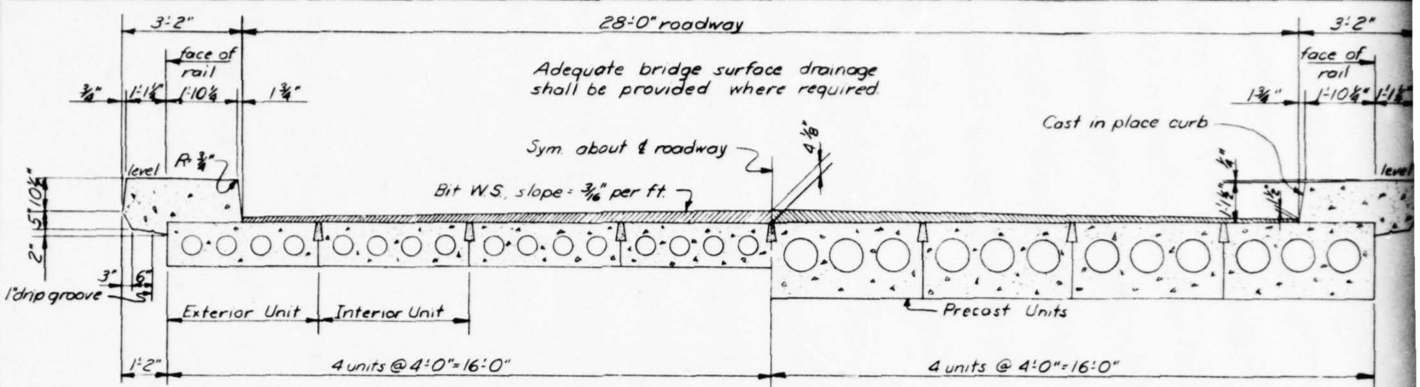


Figure F1. General plan of concrete precasting facility

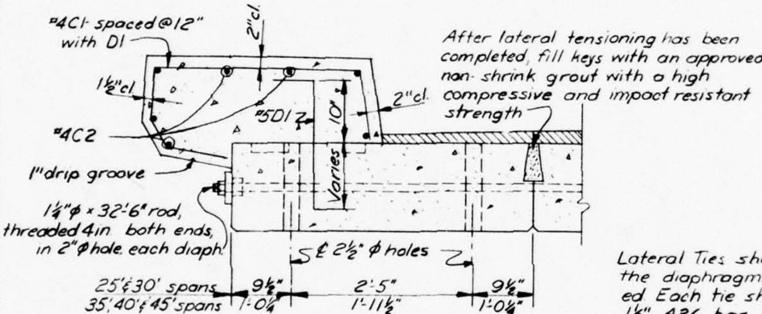
APPENDIX G: TYPICAL PLANS FOR PRECAST CONCRETE HIGHWAY BRIDGES[63]



HALF SECTION
25' AND 30' SPANS

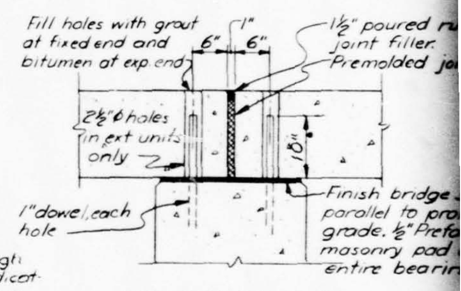
HALF SECTION
35', 40' AND 45' SPANS

TYPICAL CROSS SECTION AT MID SPAN

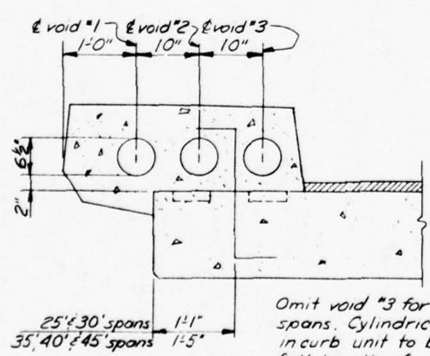


PART END ELEVATION

Lateral Ties shall be provided through the diaphragms in the positions indicated. Each tie shall be equivalent to a 1¼" A36 bar tensioned to 45000 lbs. Tension in 1¼" steel ties may be applied by a torque of approximately 870 foot pounds

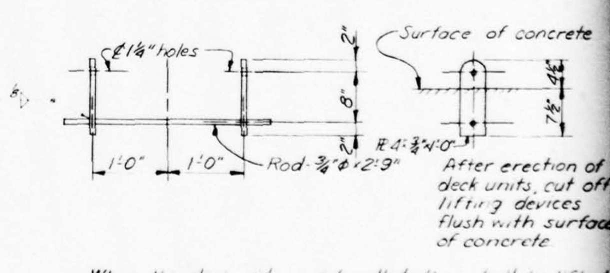


END DETAIL AT BEARING



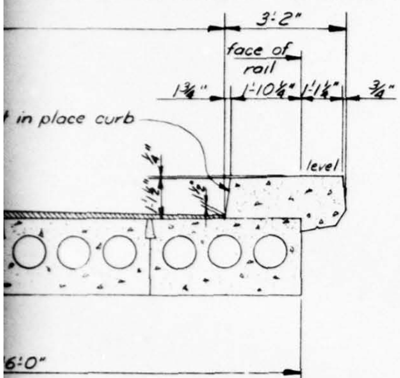
Omit void #3 for 35', 40' & 45' spans. Cylindrical voids in curb unit to be continuous full length of unit, except that all voids shall be stopped off 3" on either side of railing posts so as not to interfere with those elements.

ALTERNATE CURB DETAIL



When the deck units are handled they shall be lifted devices provided at the ends of the unit. Other types devices may be used, provided they meet with the app of the engineer.

DETAIL OF LIFTING DEVICE
2 REQUIRED PER UNIT



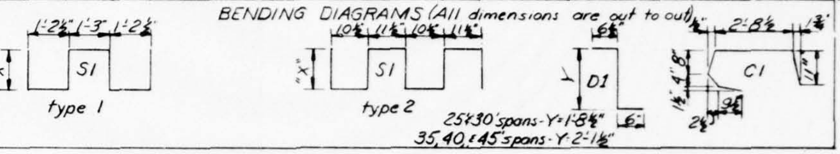
CN

SPANS

SCHEDULE OF MATERIAL · PER SPAN

SPAN (Ft)	CONCRETE, C.Y.			REINFORCING STEEL (*Bent Bars)																No. of ⅜"φ PRE-TENSION STRANDS	HANDLING WEIGHT PER 4 FOOT DECK UNIT	
	8 DECK UNITS	2 CURBS	TOTAL	#3S1 *				#3S2		#3S3		#5D1 *		#4C1 *		#4C2		TOTAL WEIGHT (lbs)			SPAN	WT.
				TYPE	No	LENGTH	"X"	No	LENGTH	No	LENGTH	No	LENGTH	No	LENGTH	No	LENGTH					
25	29.8	7.0	36.8	2	280	7'-0	8"	24	25'-9	–	–	52	2'-9	52	5'-6	14	25'-9	1550		264	25	7.7[T]
30	41.2	8.4	49.6	2	296	7'-0	8"	24	30'-9	–	–	62	2'-9	62	5'-6	14	30'-9	1750		336	30	10.7[T]
35	56.1	9.7	65.8	1	392	7'-4	11"	16	35'-9	–	–	72	3'-2	72	5'-6	14	35'-9	2140		368	35	14.4[T]
40	65.2	11.1	76.3	1	424	8'-0	13"	16	40'-9	–	–	82	3'-2	82	5'-6	14	40'-9	2480		384	40	16.7[T]
45	86.3	12.4	98.7	1	472	9'-0	16"	16	45'-9	48	6'-0	92	3'-2	92	5'-6	14	45'-9	3060		416	45	22.1[T]

BENDING DIAGRAMS (All dimensions are out to out)



GENERAL NOTES

Specifications: "A.A.S.H.O. Standard Specifications for Highway Bridges," 1961, with tentative revisions for 1961.

Live Load: H20-S16-44

Steel Reinforcement: Reinforcing steel shall be deformed bars of intermediate, hard or rail grade conforming to A.S.T.M. A15 or A.S.T.M. A16 specifications.
Unless otherwise noted, dimensions relative to placement of reinforcing steel are given to bar centers.

Structural Steel: Structural steel transverse tensioning rods shall conform to A.S.T.M. A36. Threads on the rods shall be cut to the Coarse Thread Series Class 2A. If desired, equivalent rods with rolled threads may be substituted. The rods shall be furnished with one heavy semifinished hexagon nut and one bearing plate at each end. The rods shall be shop painted with two coats of red lead iron oxide paint. The field paint for the exposed parts at the ends of the rod assemblies shall consist of one coat of tinted red lead iron oxide followed by a final coat of paint, the color of which will be specified by the engineer.

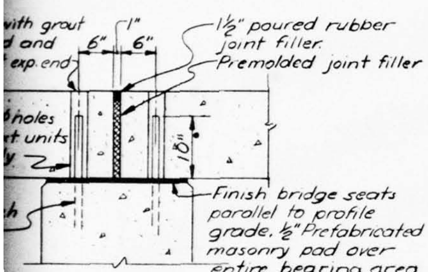
Pretensioning Steel: Individual tendons in all pretensioned sections shall consist of 7-wire cable strands which have a nominal diameter of ⅜" and shall conform to A.S.T.M. A416. An initial tensile force of 14,000 lbs. shall be applied to each strand in all beams.

Cast-in-place Concrete: Cast-in-place concrete shall be Class A(AE) with a minimum 28 day compressive strength of 3000 psi. The air entraining agent shall meet with the approval of the engineer. The alternate curb section with cylindrical voids, shown on this drawing, if desired, may be used in lieu of the solid type curb. The concrete quantities for the cast-in-place curbs are based on the solid curb detail.

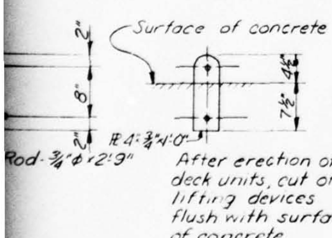
Precast Pretensioned Concrete: The minimum compressive strength of prestressed concrete at the age of 28 days shall be 5000 psi. The design mix shall meet the approval of the engineer. The minimum compressive strength of concrete at the transfer of prestress shall be 4000 psi. If desired an admixture approved by the engineer may be used to increase the plasticity of the concrete mix.

Drainage: No provision for drainage have been made in these plans. See Appendix "A" for recommended drainage details.

Handrail: See Appendix B for recommended handrail details.



END DETAIL AT BEARING



s are handled they shall be lifted by the
the ends of the unit. Other types of lifting
d, provided they meet with the approval

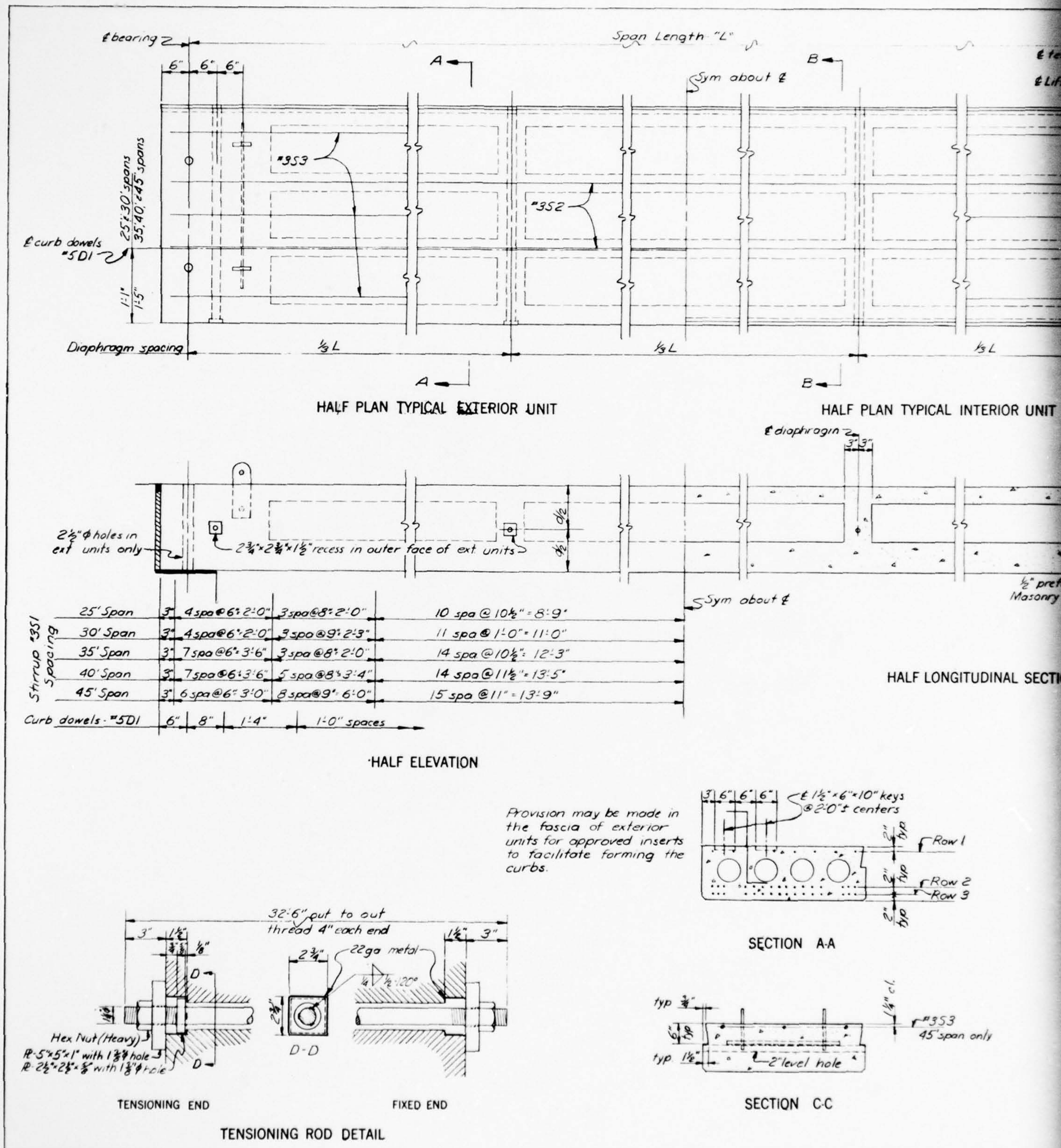
OF LIFTING DEVICE
UIRED PER UNIT

CONSTRUCTION TOLERANCES

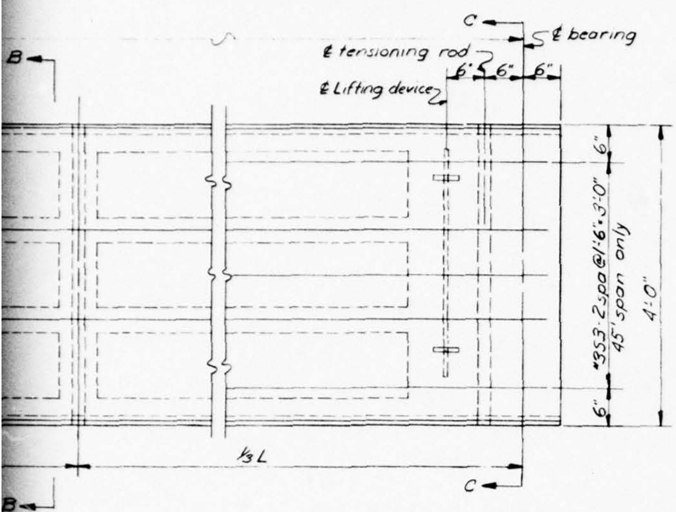
Length: ± ⅛" in 10', max ± ¾"
Depth: ± 1/16" in 12", max ± 3/16"
Width: ± 1/16" in 12", max ± 3/16"
Straightness: 1/16" in 10', max ⅜"
Out of square: 1/16" in 12", max ¼"

ABUTMENT REACTIONS (kips)					
ITEM	SPAN (feet)				
	25	30	35	40	45
D.L.	89	117	153	177	225
L.L.*	92	99	106	110	114
TOTAL*	181	216	259	287	339
*Excluding Impact					

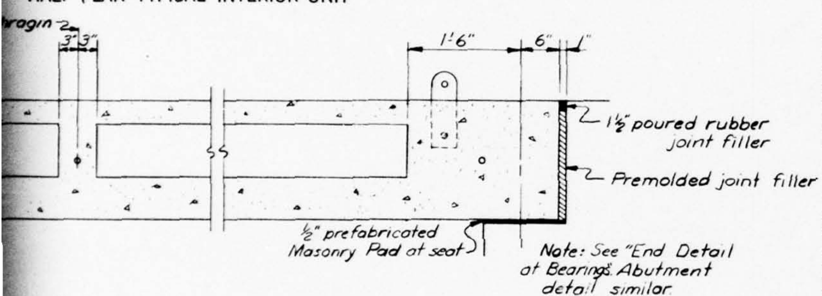
Figure G1. Sections and quantities of standard precast prestressed concrete voided slab bridges



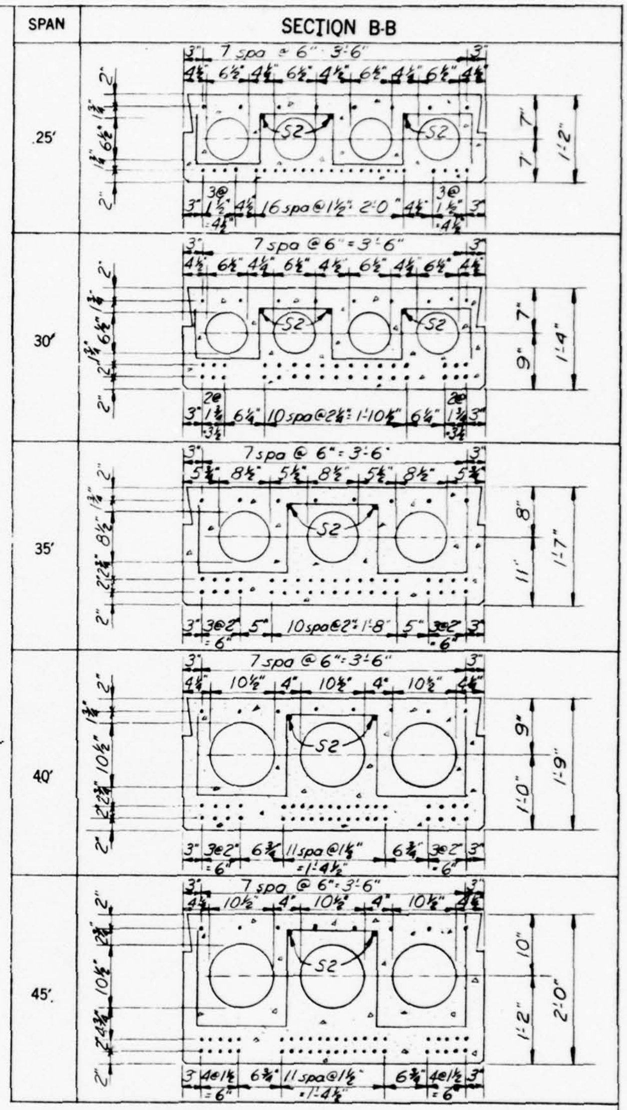
℄ bearing
Span Length "L"
6"
6"
6"
A
B
Sym about ℄
#353
#352
25', 30' spans
35', 40', & 45' spans
℄ curb dowels
#5D1
1'-1"
1'-5"
Diaphragm spacing
⅓ L
⅓ L
⅓ L
HALF PLAN TYPICAL EXTERIOR UNIT
HALF PLAN TYPICAL INTERIOR UNIT
℄ diaphragm
3" 3"
d/2
d/2
2½" φ holes in ext units only
2¾"×2¾"×1½" recess in outer face of ext units
Sym about ℄
½" prefo
Masonry
HALF LONGITUDINAL SECTIO
Stirrup #351 Spacing
25' Span | 3" | 4 spa @ 6" = 2'-0" | 3 spa @ 8" = 2'-0" | 10 spa @ 10½" = 8'-9"
30' Span | 3" | 4 spa @ 6" = 2'-0" | 3 spa @ 9" = 2'-3" | 11 spa @ 1'-0" = 11'-0"
35' Span | 3" | 7 spa @ 6" = 3'-6" | 3 spa @ 8" = 2'-0" | 14 spa @ 10½" = 12'-3"
40' Span | 3" | 7 spa @ 6" = 3'-6" | 5 spa @ 8" = 3'-4" | 14 spa @ 11½" = 13'-5"
45' Span | 3" | 6 spa @ 6" = 3'-0" | 8 spa @ 9" = 6'-0" | 15 spa @ 11" = 13'-9"
Curb dowels - #5D1 | 6" | 8" | 1'-4" | 1'-0" spaces
HALF ELEVATION
Provision may be made in the fascia of exterior units for approved inserts to facilitate forming the curbs.
3 6" 6" 6"
℄ 1½"×6"×10" keys @ 2'-0" ± centers
2" typ
Row 1
Row 2
Row 3
SECTION A-A
32'-6" out to out
thread 4" each end
3"
1½"
⅛"
D
2¾"
22 ga metal
¼ ½-120°
1½"
3"
Hex Nut (Heavy)
Pl 5"×5"×1" with 1⅜" φ hole
Pl 2½"×2½"×⅝" with 1⅜" φ hole
D-D
TENSIONING END
FIXED END
TENSIONING ROD DETAIL
typ ¾"
6" typ
typ 1½"
1¼" cl.
#353
45' span only
2" level hole
SECTION C-C

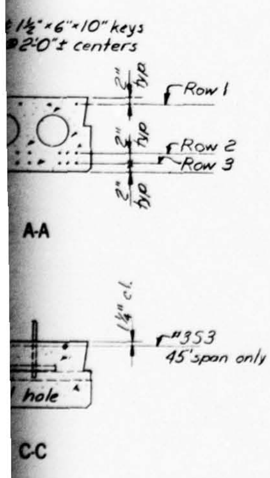


HALF PLAN TYPICAL INTERIOR UNIT



HALF LONGITUDINAL SECTION

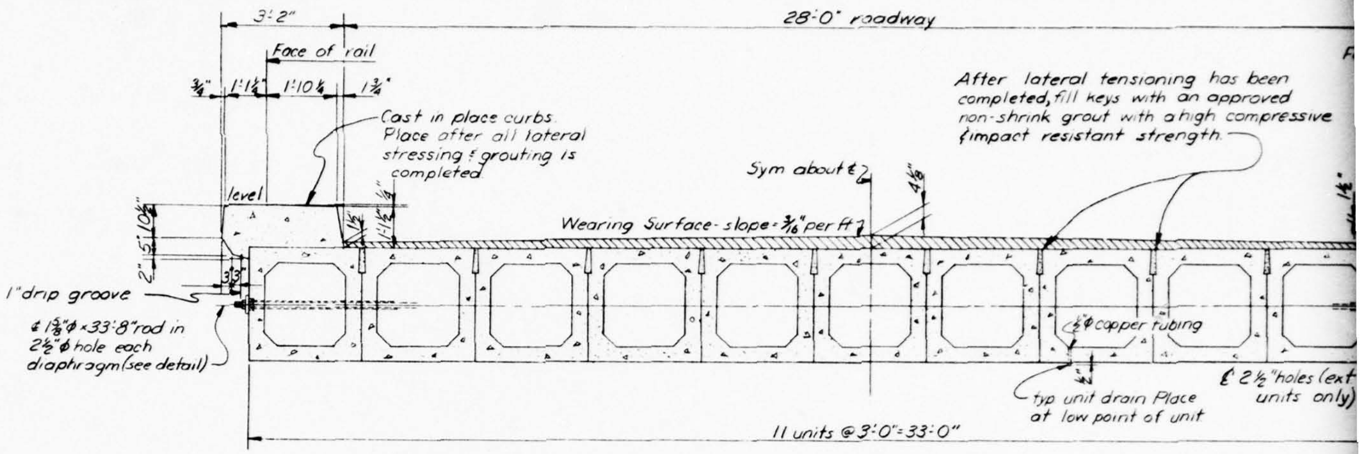




DESIGN DETAILS FOR PRE-TENSIONED UNITS *					
DIMENSION	SPAN				
	25'	30'	35'	40'	45'
No strands: Row 1	8	8	8	8	8
No strands: Row 2	0	17	19	20	22
No strands: Row 3	25	17	19	20	22
total	33	42	46	48	52
No of cyl voids	4	4	3	3	3
#353 in top @ ends	0	0	0	0	6

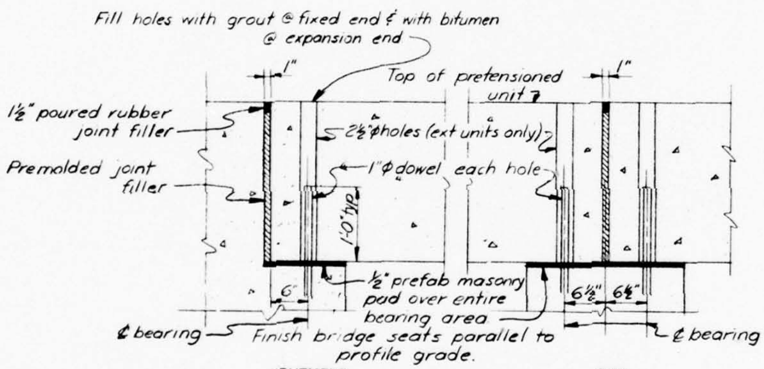
*Same for exterior & interior units except for curb dowels & shear keys

Figure G2. Details of standard precast prestressed concrete voided slab bridges



HALF SECTION AT MID SPAN

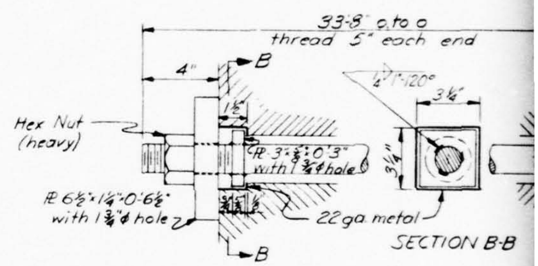
HALF SECTION AT BEARING



ABUTMENT

PIER

END DETAILS



TENSIONING END

TENSIONING ROD DETA

CON

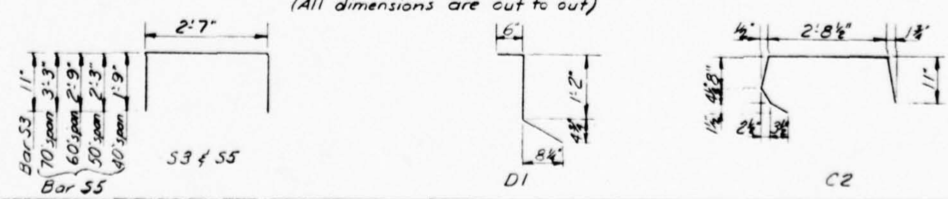
Len
Dep
Wid
Str
Out

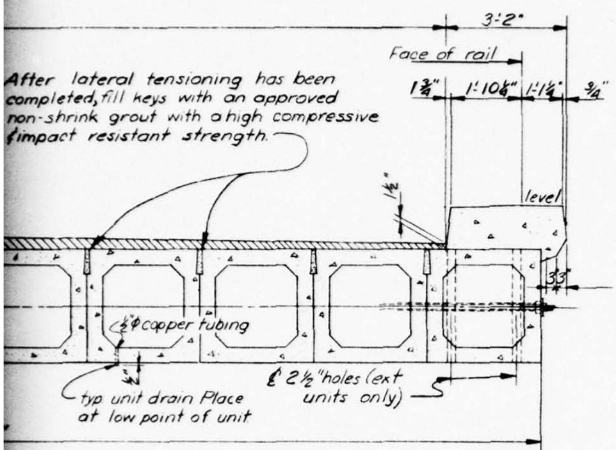
SPAN (feet)	CONCRETE (cy)			REINFORCING STEEL																	NO. OF 3/8"φ PRE-TENSION STRANDS	HANDLING WT. PER UNIT (tons)
	11 DECK UNITS	CURBS	TOTAL	#5S1-40&50 #6S1-60&70		#4S2		#4S3*		#4S4		#4S5*		#5D1*		#4C1		#4C2*		TOTAL WT. (lbs)		
				NO.	L'GTH	NO.	L'GTH	NO.	L'GTH	NO.	L'GTH	NO.	L'GTH	NO.	L'GTH	NO.	L'GTH	NO.	L'GTH			
40	64.5	8.8	73.3	66	5'-0	44	40'-9	682	4'-5	605	2'-8	374	6'-1	64	2'-6	14	40'-9	64	5'-0	6920	209	11.7
50	90.3	10.9	101.2	66	5'-0	88	25'-9	847	4'-5	770	2'-8	462	7'-1	80	2'-6	28	25'-9	80	5'-0	8880	275	16.3
60	123.0	13.0	136.0	88	5'-0	88	30'-9	1012	4'-5	935	2'-8	550	8'-1	94	2'-6	28	30'-9	94	5'-0	11230	308	22.2
70	156.0	15.1	171.1	88	5'-0	88	35'-9	1177	4'-5	1100	2'-8	627	9'-1	110	2'-6	28	35'-9	110	5'-0	13330	352	28.1

SCHEDULE OF MATERIAL - PER SPAN

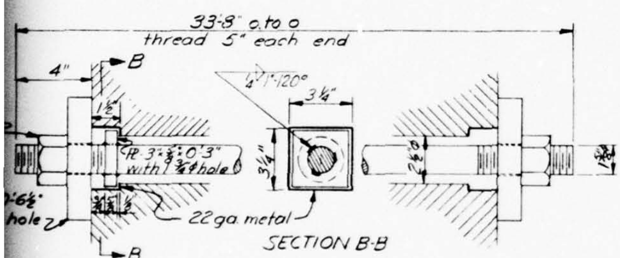
*Denotes bent bars

BENDING DIAGRAM
(All dimensions are out to out)





HALF SECTION AT BEARING



TENSIONING END

FIXED END

TENSIONING ROD DETAIL

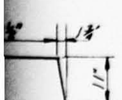
	4C2*			
Q	L'GTH	TOTAL WT. (lbs)	NO. OF ⅜"φ PRE-TENSION STRANDS	HANDLING WT PER UNIT (tons)
4	5'-0	6920	209	11.7
0	5'-0	8880	275	16.3
9	5'-0	11230	308	22.2
0	5'-0	13330	352	28.1

CONSTRUCTION TOLERANCES

Length: ± ⅛" in 10', max. ± ⅜"
Depth: ± 1/16" in 12", max. ± 3/16"
Width: ± 1/16" in 12", max. ± 3/16"
Straightness: 1/16" in 10', max. ⅜"
Out of square: 1/16" in 12", max. ¼"

ABUTMENT REACTIONS (KIPS)			
SPAN	DL	LL*	TOTAL
40'	171	110	281
50'	233	117	350
60'	309	122	431
70'	386	125	511

*No Impact



GENERAL NOTES

Specifications: "A.A.S.H.O. Standard Specifications for Highway Bridges", 1961 with tentative revisions for 1961.

Live Load: H20-S16-44

Steel Reinforcement: Reinforcing steel shall be deformed bars of intermediate, hard or rail grade conforming to ASTM specifications A15 or A16. Unless otherwise noted, dimensions relative to placement of reinforcing steel are given to bar centers.

Structural Steel: Structural steel transverse tensioning rods shall conform to ASTM A36. Threads on the rod shall be cut to the coarse thread series Class 2A. If desired equivalent rods with rolled threads may be substituted. The rods shall be furnished with one heavy semifinished hexagon nut and one bearing plate at each end. The rods shall be shop painted with two coats of red lead iron oxide paint. The field paint for the exposed parts at the ends of the rod assemblies shall consist of one coat of tinted red lead iron oxide followed by a final coat of paint, the color of which shall be specified by the engineer.

Pretensioning Steel: Individual tendons in all pretensioned sections shall consist of seven-wire cable strands which have a nominal diameter of ⅜" and shall conform to ASTM A416, with an applied initial tensile force of 14000 lbs per strand.

Cast-in-place Concrete: Cast-in-place concrete shall be Class A(AE) with a minimum 28 day compressive strength of 3000 psi. The air entraining agent shall meet with the approval of the engineer. Cylindrical voids, placed as shown, may be used in the curbs if desired. The concrete quantities for the cast-in-place curbs are based on the solid curb detail. All exposed corners are to be chamfered ¾" unless otherwise noted.

Precast Pretensioned Concrete: The minimum compressive strength of prestressed concrete at the age of 28 days shall be 5000 psi. The design mix shall meet the approval of the engineer. The minimum compressive strength of concrete at the transfer of prestress shall be 4000 psi. If desired an admixture approved by the engineer may be used to increase the plasticity of the mix.

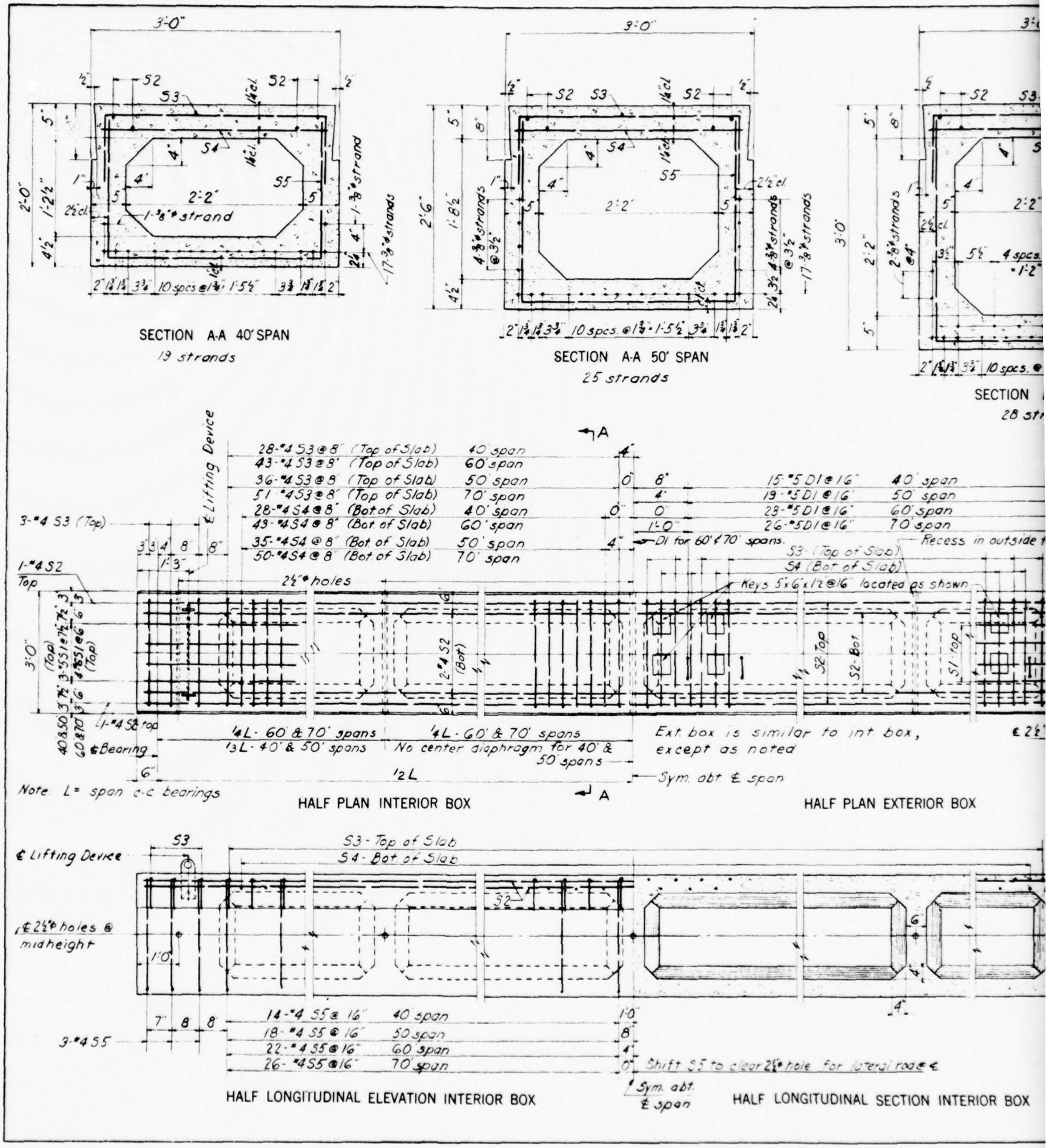
Lateral Tensioning: Lateral ties shall be provided through the diaphragms in the positions indicated. Each tie shall be equivalent to a 1⅝" A36 steel bar tensioned to 57,000 lbs. Tension in 1⅝" steel bars may be applied by a torque of approximately 1100 foot pounds.

Handling Pretensioned Deck Units: When the deck units are handled they shall be lifted by the devices provided in the tops at the ends of the units. Other types of lifting devices than those shown on the plans may be used provided they meet with the approval of the engineer.

Drainage: No provisions for drainage have been made in these plans. See Appendix "A" for recommended drainage details.

Handrail: See Appendix B for recommended handrail details.

Figure G3. Sections and quantities of standard precast prestressed concrete box bridges


SECTION A-A 40' SPAN
19 strands
SECTION A-A 50' SPAN
25 strands
SECTION
28 str
28-#4 S3 @ 8" (Top of Slab) 40' span
43-#4 S3 @ 8" (Top of Slab) 60' span
36-#4 S3 @ 8" (Top of Slab) 50' span
51-#4 S3 @ 8" (Top of Slab) 70' span
28-#4 S4 @ 8" (Bot of Slab) 40' span
43-#4 S4 @ 8" (Bot. of Slab) 60' span
35-#4 S4 @ 8" (Bot. of Slab) 50' span
50-#4 S4 @ 8" (Bot. of Slab) 70' span
15-#5 D1 @ 16" 40' span
19-#5 D1 @ 16" 50' span
23-#5 D1 @ 16" 60' span
26-#5 D1 @ 16" 70' span
D1 for 60' & 70' spans.
Recess in outside
Keys 5"x6"x1/2" @ 16" located as shown
2 1/2"φ holes
¼L - 60' & 70' spans
⅓L - 40' & 50' spans
¼L - 60' & 70' spans
No center diaphragm for 40' & 50' spans
½L
Ext. box is similar to int. box, except as noted
Sym. abt. ℄ span
Note: L = span c-c bearings
HALF PLAN INTERIOR BOX
HALF PLAN EXTERIOR BOX
℄ Lifting Device
℄ 2½"φ holes @ midheight
S3 - Top of Slab
S4 - Bot. of Slab
14-#4 S5 @ 16" 40' span
18-#4 S5 @ 16" 50 span
22-#4 S5 @ 16" 60 span
26-#4 S5 @ 16" 70' span
Shift S5 to clear 2½"φ hole for lateral rod ℄
Sym. abt. ℄ span
HALF LONGITUDINAL ELEVATION INTERIOR BOX
HALF LONGITUDINAL SECTION INTERIOR BOX

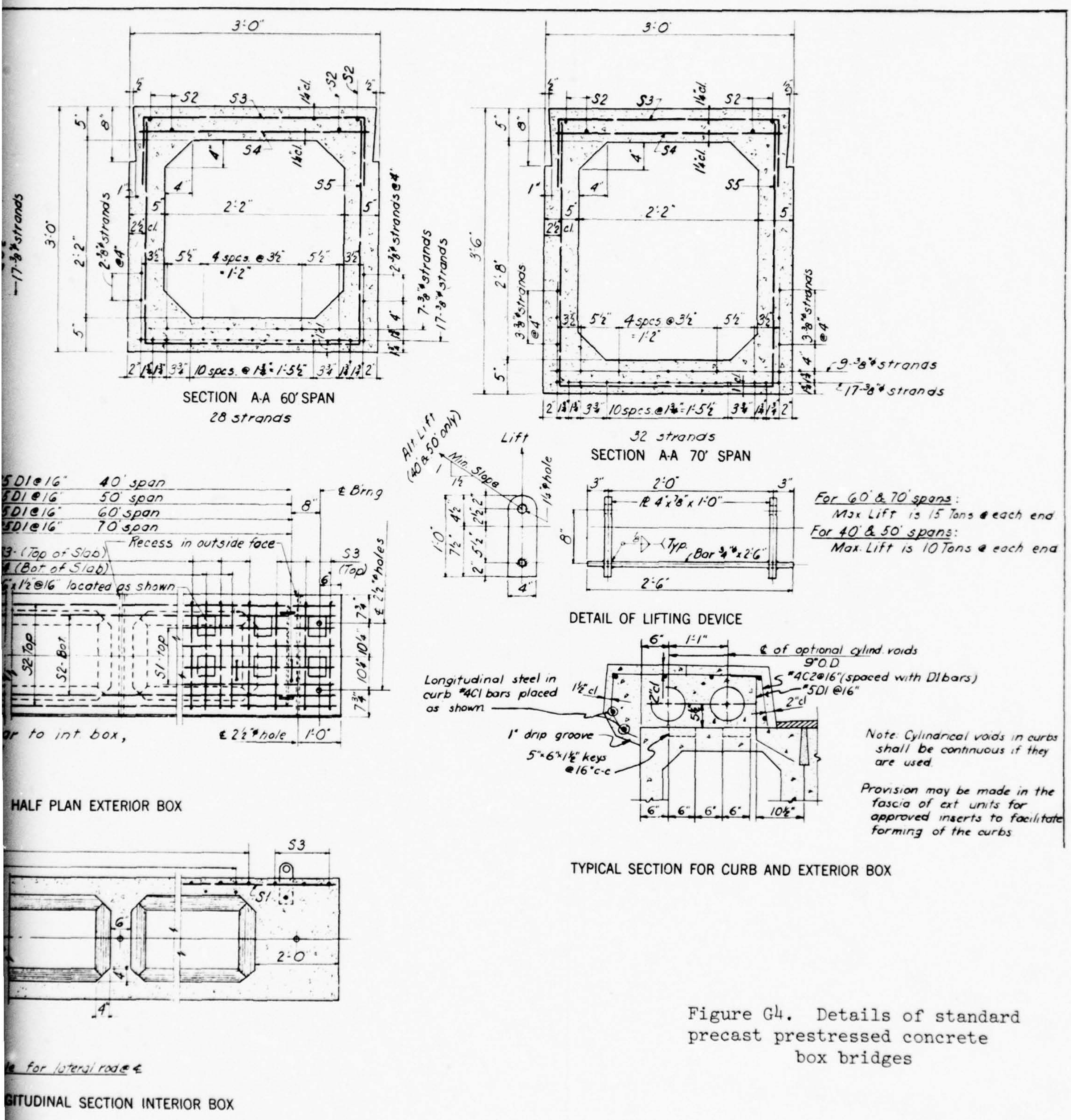


Figure G4. Details of standard precast prestressed concrete box bridges

SUMMARY OF QUANTITIES FOR ONE SP[illegible]

REINFORCING STEEL SCHEDULE

SLAB, CURBS, AND DIAPHRAGMS

	SPAN IN FEET	A.A.S.H.O. BEAM TYPE	#4 S1		#5 S2		#5 S3		#4 C		#4 S4		#4 P		#4 D1		#8 D2		#8 D3	
			Length	No.	Length	No.	Length	No.	Length	No.	Length	No.	Length	No.	Length	No.	Length	No.	Length	No.
24' ROADWAY	35	I	36'-4"	54	28'-10"	73	26'-6"	73	7'-2"	76	18'-1"	32	6'-7"	76	3'-9"	48	22'-3"	2	6'-1"	6
	40	II	21'-2"	108	"	83	"	83	"	84	20'-7"	"	"	84	"	"	"	"	"	"
	45	II	23'-8"	"	"	93	"	93	"	96	23'-1"	"	"	96	"	"	"	"	"	"
	50	III	26'-2"	"	"	103	"	103	"	102	17'-0"	48	"	102	"	"	22'-4"	"	5'-9"	"
	55	III	28'-8"	"	"	113	"	113	"	114	18'-8"	"	"	114	"	"	"	"	"	"
	60	III	31'-2"	"	"	123	"	123	"	126	20'-4"	"	"	126	"	"	"	"	"	"
	70	III	36'-2"	"	"	143	"	143	"	144	17'-8"	64	"	144	"	"	"	"	"	"
	80	IV	27'-10"	162	"	163	"	163	"	168	20'-2"	"	"	168	"	"	22'-5"	"	5'-5"	"
	90	IV	31'-2"	"	"	183	"	183	"	184	22'-8"	"	"	184	"	"	"	"	"	"
28' ROADWAY	35	II	36'-4"	69	33'-10"	73	31'-0"	73	8'-2"	76	18'-1"	32	6'-7"	76	3'-9"	56	26'-3"	2	5'-3"	8
	40	II	21'-2"	138	"	83	"	83	"	84	20'-7"	"	"	84	"	"	"	"	"	"
	45	II	23'-8"	"	"	93	"	93	"	96	23'-1"	"	"	96	"	"	"	"	"	"
	50	III	26'-2"	"	"	103	"	103	"	102	17'-0"	48	"	102	"	"	26'-4"	"	4'-11"	"
	55	III	28'-8"	"	"	113	"	113	"	114	18'-8"	"	"	114	"	"	"	"	"	"
	60	III	31'-2"	"	"	123	"	123	"	126	20'-4"	"	"	126	"	"	"	"	"	"
	70	III	36'-2"	"	"	143	"	143	"	144	17'-8"	64	"	144	"	"	"	"	"	"
	80	IV	27'-10"	207	"	163	"	163	"	168	20'-2"	"	"	168	"	"	26'-5"	"	4'-7"	"
	90	IV	31'-2"	"	"	183	"	183	"	184	22'-8"	"	"	184	"	"	"	"	"	"

GENERAL NOTES

Design Specifications: "AASHO Standard Specifications for Highway Bridges", 1961, with tentative revisions for 1961.

Design Dead Load: 19 psf of roadway included for future wearing surface.

Design Live Load: H15 for 24' roadway, H20-S16 for 28' roadway.

Beam Sections: The sections of prestressed members shown on the plans are the standard prestressed sections adopted by the Joint Committee of AASHO and the Prestressed Concrete Institute.

Precast Prestressed Concrete: The minimum compressive strength of prestressed concrete at the age of 28 days shall be 5,000 psi. The design mix shall be as approved by the engineer. The minimum compressive strength of concrete at the transfer of prestress shall be as called for on the plans for the various designs, but shall not be less than 4,000 psi.

Cast-in-Place Concrete: Cast-in-place concrete shall be Class A (AE) with a minimum 28-day compressive strength f'_c = 3,000 psi. The air entraining agent shall meet with the approval of the engineer.

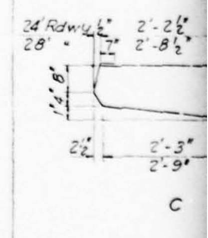
Reinforcement Steel: Reinforcement steel shall be deformed bars of intermediate, hard or rail grade conforming to ASTM Specification A15 or A16.

Pretensioning Steel: Individual tendons in all pretensioned designs shall consist of high tensile strength 7-wire strands conforming to the requirements of ASTM Designation A416. In the designs which have deflected strands, proper allowance must be made in tensioning these strands so as to yield the required initial tension after the strands are in the deflected position. The initial tensile force applied to each 7/16 inch strand shall be 18,900 lb. The initial tensile force applied to each 1/2 inch strand shall be 25,200 lb.

Post-Tensioning Steel: The proposed types of tendons which will be used in the post-tensioned designs, all necessary additional details including those for end anchorages, methods to be employed, and procedures to be followed, shall be as approved by the engineer. A portion of the tendons shall be draped longitudinally in parabolic positions. All tendons shall be placed so that their center of gravity will be at the position shown on plans. The total relaxed post-tension force required at midspan shall be provided as called for in the various designs. The required relaxed forces shall be obtained by applying initial tensile forces of sufficient magnitude to allow for all subsequent losses, including those for elastic deformation, shrinkage, creep, friction, and efficiency of end anchorages. After securing the end anchorages all tendons shall be pressure grouted in their conduits in accordance with "Specifications".

Handling Prestressed Concrete Beams: The beams shall be maintained in an upright position, and shall be lifted by the devices provided in the top flanges at the ends of the beams. Other types of lifting devices than those shown on the plans may be used, provided they meet with the approval of the engineer.

SPAN IN FEET		35
		Ext.
24' RDWY.	Dead Load	22.6
	Live Load	14.4
	Impact	4.3
	Total	41.3
	Total One Abut.	149.[illegible]
28' RDWY.	Dead Load	24.1
	Live Load	25.6
	Impact	7.7
	Total	57.4
	Total One Abut.	224.



C

All dimensions [illegible]
Bars S1, 2, 4, an[illegible]

SUMMARY OF QUANTITIES FOR ONE SPAN

REINFORCING STEEL SCHEDULE

, AND DIAPHRAGMS													BEAMS	CONCRETE	
#4 D1		#8 D2		#8 D3		#4 D4		#6 D5		#6 D6		Total Weight	Total Weight	SLAB, ETC. Volume	BEAMS Volume
ngth	No.	Length	No.	Length	No.	Length	No.	Length	No.	Length	No.	Lbs.	Lbs.	Cu. Yd.	Cu. Yd.
3'-9"	48	22'-3"	2	6'-1"	6	4'-8"	18	6'-7"	12	3'-0"	4	7,140	1,060, 800*	32.0	10.6, 10.2*
"	"	"	"	"	"	5'-8"	"	"	"	"	"	8,070	1,380, 1,040*	36.3	16.1, 15.6*
"	"	"	"	"	"	"	"	"	"	"	"	9,000	1,500, 1,170*	40.4	18.0, 17.5*
"	"	22'-4"	"	5'-9"	"	6'-9"	36	6'-6"	24	"	8	10,080	2,240, 1,490*	45.8	31.0, 29.3*
"	"	"	"	"	"	"	"	"	"	"	"	11,000	2,380, 1,690*	49.9	34.0, 32.3*
"	"	"	"	"	"	"	"	"	"	"	"	11,920	2,470	54.0	36.8
"	"	"	"	"	"	"	"	"	"	"	"	13,710	2,730	62.2	42.6
"	"	22'-5"	"	5'-5"	"	7'-10"	"	6'-5"	"	"	"	15,590	3,730	70.4	69.4
"	"	"	"	"	"	"	"	"	"	"	"	17,360	4,600	78.6	77.5
3'-9"	56	26'-3"	2	5'-3"	8	5'-8"	20	5'-9"	16	3'-0"	6	8,380	1,560, 1,200*	37.0	17.7, 17.1*
"	"	"	"	"	"	"	"	"	"	"	"	9,470	1,720, 1,380*	41.7	20.1, 19.5*
"	"	"	"	"	"	"	"	"	"	"	"	10,550	1,870, 1,540*	46.5	22.3, 21.7*
"	"	26'-4"	"	4'-11"	"	6'-9"	40	5'-8"	32	"	12	11,820	2,790, 2,030*	52.6	38.8, 36.7*
"	"	"	"	"	"	"	"	"	"	"	"	12,900	2,970, 2,240*	57.3	42.5, 40.4*
"	"	"	"	"	"	"	"	"	"	"	"	13,980	3,080	62.0	46.0
"	"	"	"	"	"	"	"	"	"	"	"	16,080	3,410	71.4	53.2
"	"	26'-5"	"	4'-7"	"	7'-10"	"	5'-7"	"	"	"	18,300	4,660	80.8	86.7
"	"	"	"	"	"	"	"	"	"	"	"	20,380	5,750	90.2	96.8

*Without end blocks

MAXIMUM BEAM REACTIONS TO KIPS

SPAN IN FEET		35		40		45		50		55		60		70		80		90	
		Ext.	Int.	Ext.	Int.	Ext.	Int.	Ext.	Int.	Ext.	Int.	Ext.	Int.	Ext.	Int.	Ext.	Int.	Ext.	Int.
24' RDWY.	Dead Load	22.6	24.0	27.6	29.1	30.8	32.5	39.6	41.9	43.3	45.8	47.9	50.5	55.4	58.2	73.5	76.7	82.2	85.6
	Live Load	14.4	19.8	15.2	20.6	16.0	21.4	16.7	22.2	17.5	23.0	18.2	23.8	19.7	25.4	21.2	27.0	22.7	28.6
	Impact	4.3	5.9	4.6	6.2	4.7	6.3	4.8	6.4	4.9	6.4	5.0	6.6	5.1	6.5	5.2	6.6	5.3	6.7
	Total	41.3	49.7	47.4	55.9	51.5	60.2	61.1	70.5	65.7	75.2	71.1	80.9	80.2	90.1	99.9	110.3	110.2	120.9
	Total One Abut.	149.0		171.6		187.2		226.0		243.6		264.6		299.8		377.8		417.8	
28' RDWY.	Dead Load	24.1	23.7	27.3	26.8	30.5	29.9	39.1	38.8	42.8	42.4	47.3	46.8	54.7	53.9	72.8	71.8	81.3	80.1
	Live Load	25.6	35.7	27.0	37.2	28.1	38.3	28.9	39.1	29.6	39.9	30.2	40.5	31.1	41.4	31.8	42.1	32.4	42.7
	Impact	7.7	10.7	8.1	11.2	8.3	11.3	8.3	11.2	8.2	11.1	8.2	10.9	8.0	10.6	7.8	10.3	7.6	10.0
	Total	57.4	70.1	62.4	75.2	66.9	79.5	76.3	89.1	80.6	93.4	85.7	98.2	93.8	105.9	112.4	124.2	121.3	122.8
	Total One Abut.	224.9		245.4		264.7		311.6		332.4		356.6		395.9		488.2		531.9	

rands, prop-
nsioning these
initial tension
cted position.
each 7/16 inch
nitial tensile
nd shall be

ns of tendons
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luding those
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approved by
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positions. All
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The beams
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d in the top
Other types
on the plans
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BENDING DIAGRAM

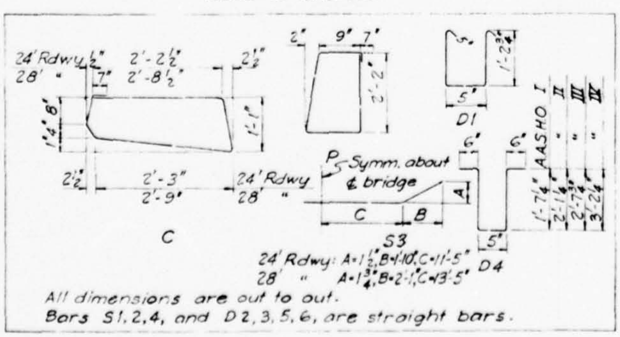
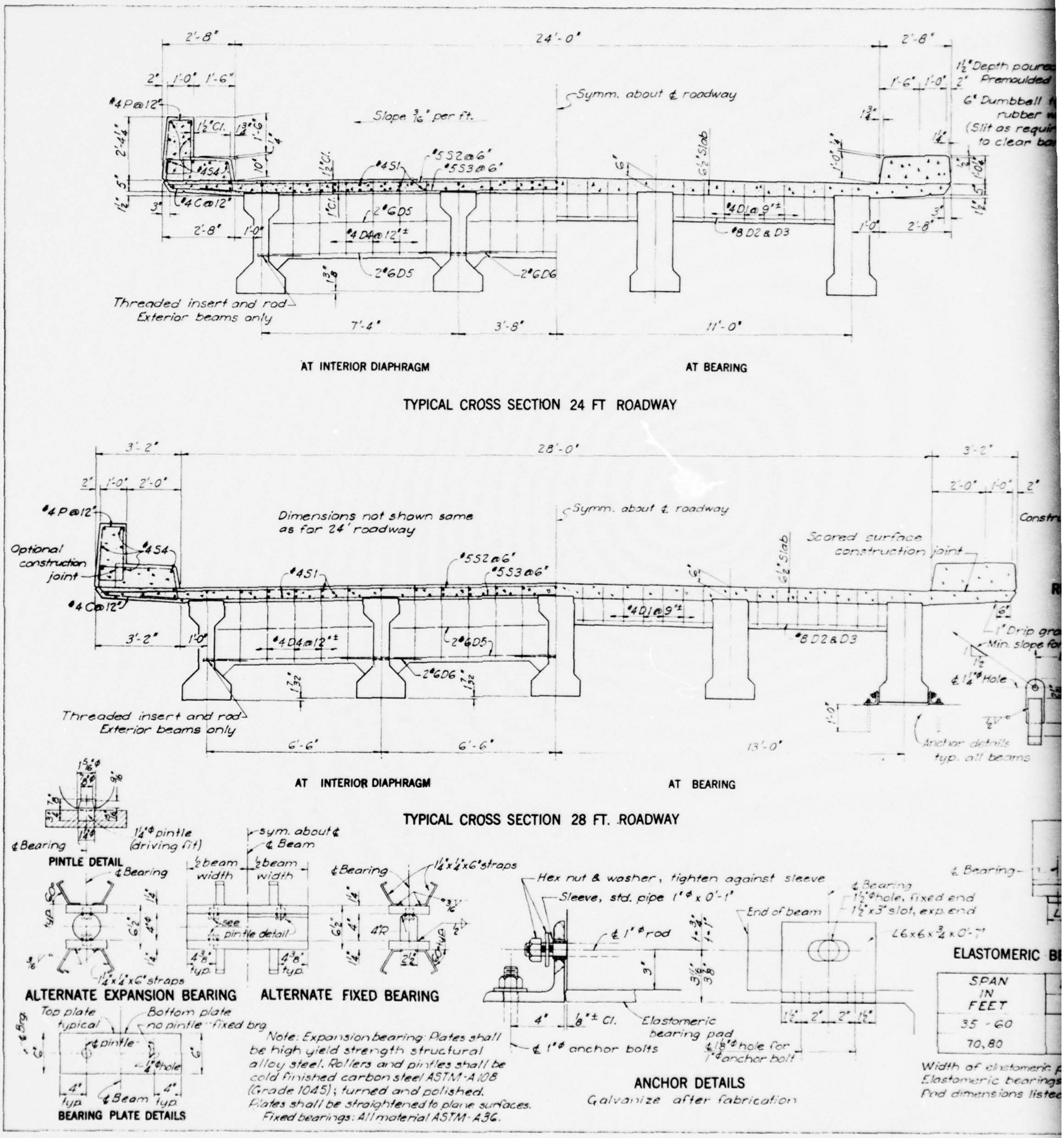
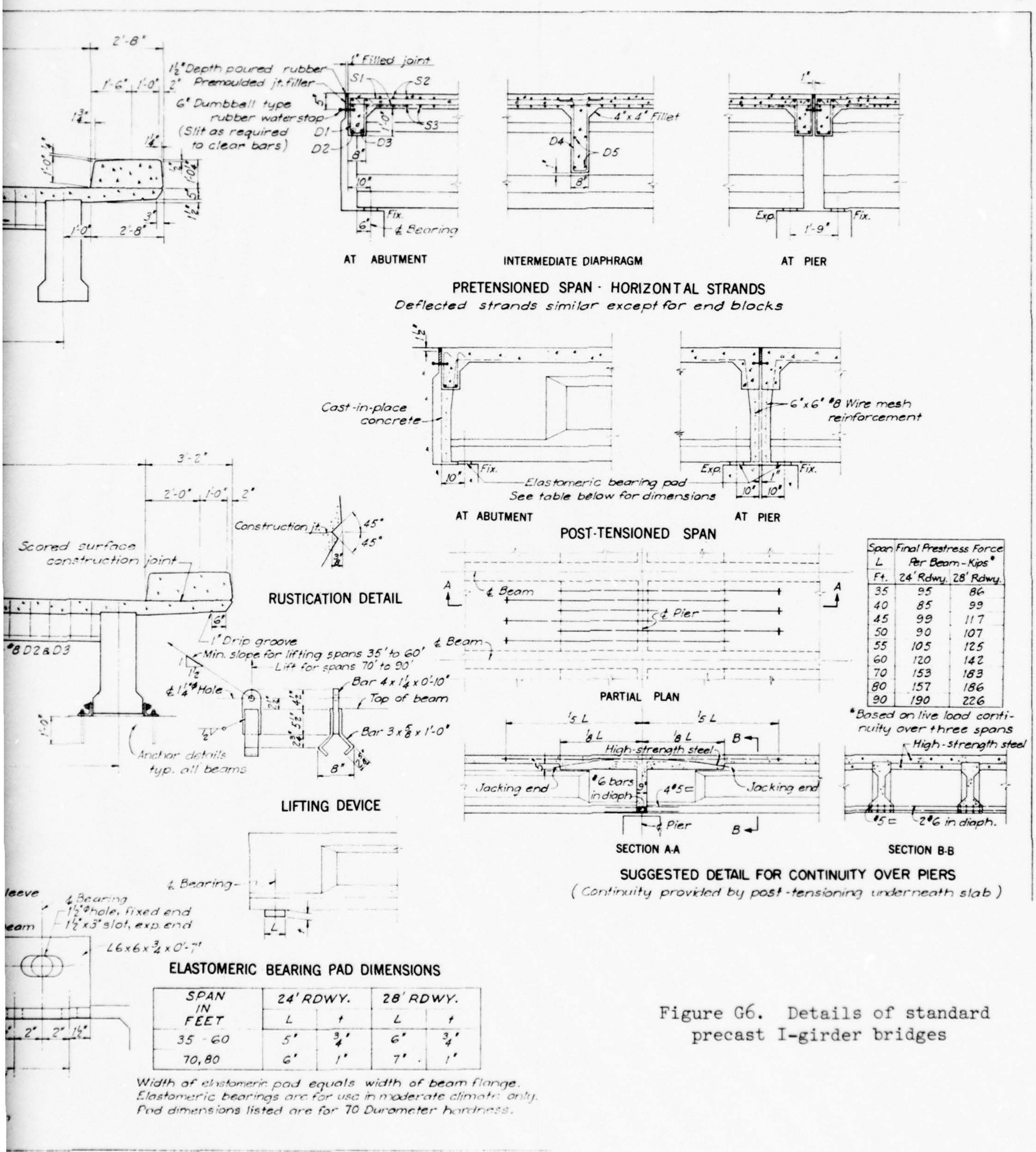


Figure G5. General notes and reinforcement quantities of standard precast I-girder bridges


2'-8"
24'-0"
2'-8"
2" 1'-0" 1'-6"
#4 P @ 12"
1½" Cl.
Slope 3/16" per ft.
Symm. about ℄ roadway
6½" Slab
#4 S1
#5 S2 @ 6"
#5 S3 @ 6"
#4 S4
#4 C @ 12"
2 #6 D5
#4 D4 @ 12"±
2 #6 D6
#4 D1 @ 9"±
#8 D2 & D3
1½" Depth poured
2" Premoulded
6" Dumbbell
rubber
(Slit as required
to clear bar
Threaded insert and rod
Exterior beams only
7'-4"
3'-8"
11'-0"
AT INTERIOR DIAPHRAGM
AT BEARING
TYPICAL CROSS SECTION 24 FT ROADWAY
3'-2"
28'-0"
3'-2"
2" 1'-0" 2'-0"
#4 P @ 12"
Dimensions not shown same
as for 24' roadway
Symm. about ℄ roadway
Optional
construction
joint
#4 S4
#4 S1
#5 S2 @ 6"
#5 S3 @ 6"
Scored surface
construction joint
6½" Slab
#4 C @ 12"
#4 D1 @ 9"±
#4 D4 @ 12"±
2 #6 D5
2 #6 D6
#8 D2 & D3
1" Drip groove
Min. slope
℄ 1¼" Hole
Threaded insert and rod
Exterior beams only
6'-6"
6'-6"
13'-0"
Anchor details
typ. all beams
AT INTERIOR DIAPHRAGM
AT BEARING
TYPICAL CROSS SECTION 28 FT. ROADWAY
℄ Bearing
PINTLE DETAIL
1¼" ϕ pintle
(driving fit)
℄ Bearing
sym. about ℄
℄ Beam
½ beam width
½ beam width
see pintle detail
℄ Bearing
1¼" x ¼" x 6" straps
1¼" x ¼" x 6" straps
ALTERNATE EXPANSION BEARING
ALTERNATE FIXED BEARING
Top plate typical
Bottom plate
no pintle - fixed brg
℄ pintle
1¼" ϕ hole
℄ Beam
4" typ
4" typ.
BEARING PLATE DETAILS
Note: Expansion bearing: Plates shall be high yield strength structural alloy steel. Rollers and pintles shall be cold finished carbon steel ASTM-A108 (Grade 1045); turned and polished. Plates shall be straightened to plane surfaces.
Fixed bearings: All material ASTM-A36.
Hex nut & washer, tighten against sleeve
Sleeve, std. pipe 1" ϕ x 0'-1"
℄ 1" ϕ rod
End of beam
℄ Bearing
1½" ϕ hole, fixed end
1½" x 3" slot, exp. end
∠6 x 6 x ¾ x 0'-7"
⅛" ± Cl.
Elastomeric
bearing pad
℄ 1" ϕ anchor bolts
1⅛" ϕ hole for
1" ϕ anchor bolt
ANCHOR DETAILS
Galvanize after fabrication
℄ Bearing
ELASTOMERIC BE
SPAN
IN
FEET
35 - 60
70, 80
Width of elastomeric
Elastomeric bearings
Pad dimensions listed



Span L Ft.	Final Prestress Force Per Beam-Kips* 24' Rdwy.	28' Rdwy.
35	95	86
40	85	99
45	99	117
50	90	107
55	105	125
60	120	142
70	153	183
80	157	186
90	190	226

*Based on live load continuity over three spans

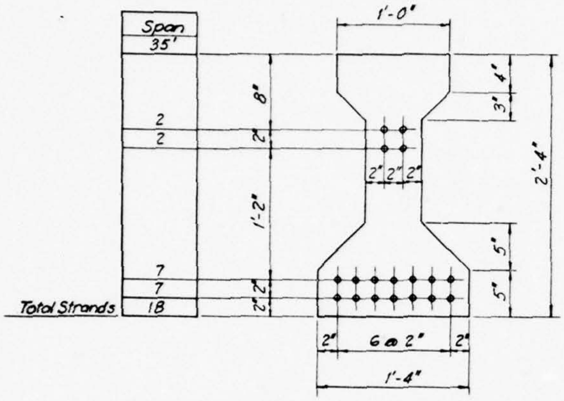
ELASTOMERIC BEARING PAD DIMENSIONS

SPAN IN FEET	24' RDWY. L	24' RDWY. t	28' RDWY. L	28' RDWY. t
35 - 60	5"	¾"	6"	¾"
70, 80	6"	1"	7"	1"

Width of elastomeric pad equals width of beam flange.
Elastomeric bearings are for use in moderate climate only.
Pad dimensions listed are for 70 Durometer hardness.

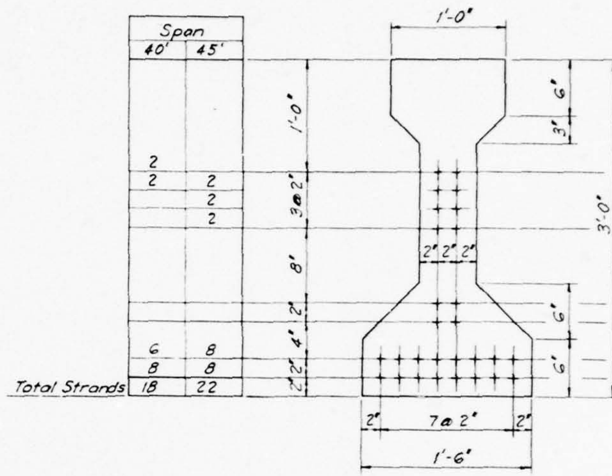
Figure G6. Details of standard precast I-girder bridges

24 FT. ROADWAY



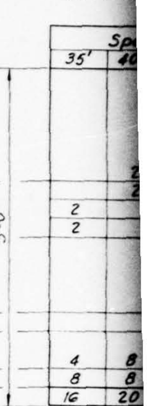
AASHO TYPE I BEAM

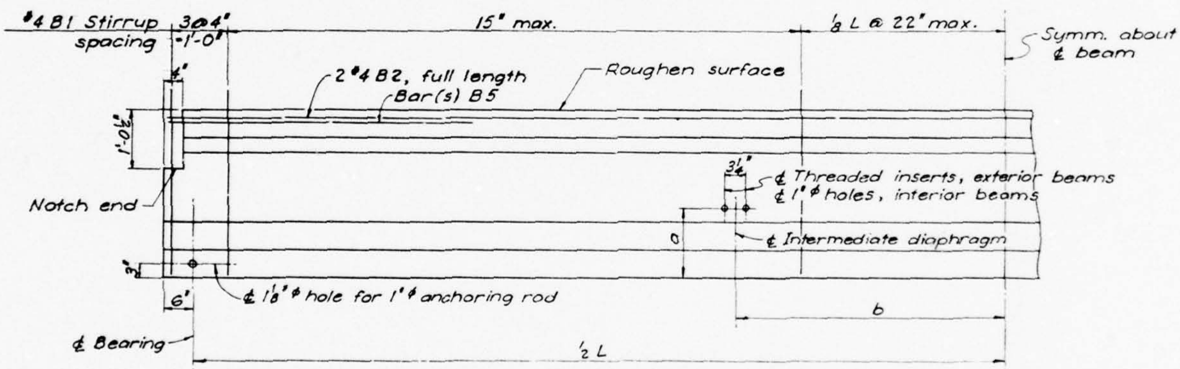
24 FT. ROADWAY



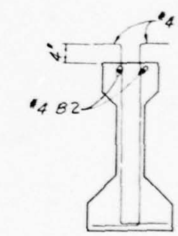
AASHO TYPE II BEAM

28 FT. RO





ELEVATION

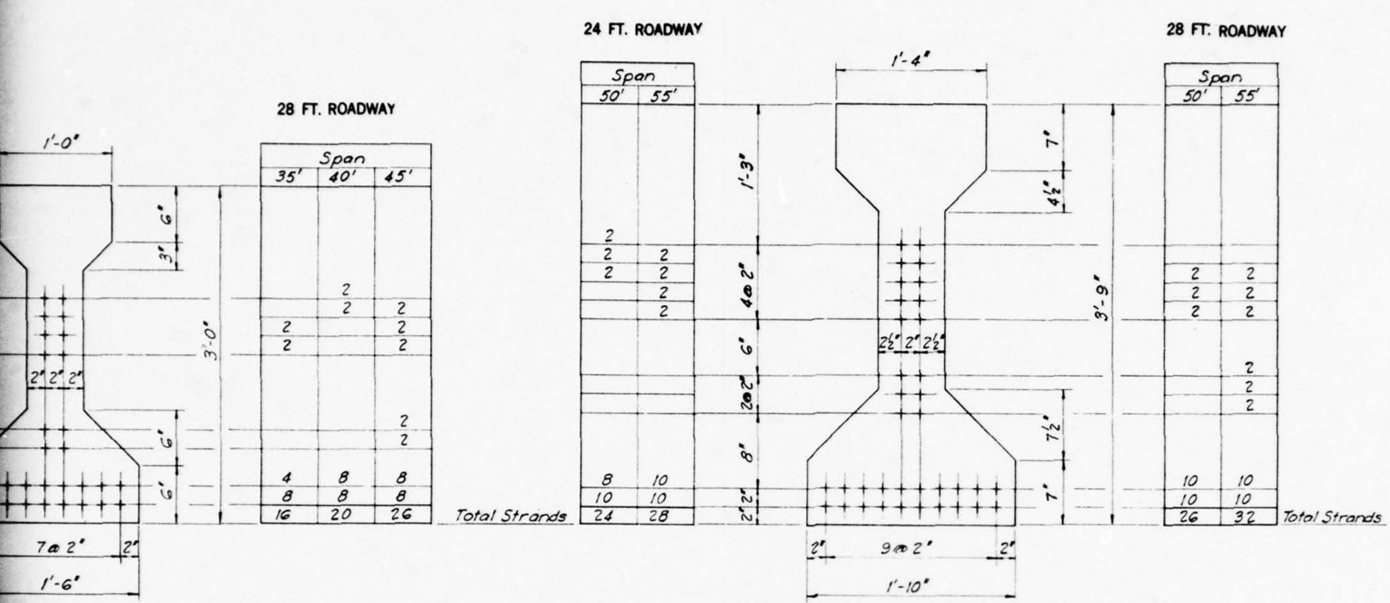


SECTION

SUMMARY OF QUANTITIES · FOR ONE BEAM

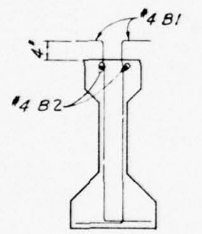
SPAN IN FEET		A.A.S.H.O. BEAM TYPE	DIMENSION		REINFORCEMENT STEEL							CONCRETE	
					#4 B1		#4 B2		#4 B5		Total Weight	Volume	Weight
			a	b	Length	No.	Length	No.	Length	No.	Lbs.	Cu. Yd.	L
24' RDWY.	35	I	1'-1½"	0"	3'-9"	60	35'-8"	2	-	-	198	2.6	10,
	40	II	1'-3½"	"	4'-6"	68	20'-11"	4	-	-	260	3.9	15,
	45	II	"	"	"	76	23'-5"	"	-	-	291	4.4	17,
	50	III	1'-6"	8'-6"	5'-6"	82	25'-11"	"	-	-	371	7.3	29,
	55	III	"	9'-0"	"	90	28'-5"	"	11'-0"	2	421	8.1	32,
28' RDWY.	35	II	1'-3½"	0"	4'-6"	60	35'-8"	2	9'-0"	2	240	3.4	13,
	40	II	"	"	"	68	20'-11"	4	11'-0"	"	275	3.9	15,
	45	II	"	"	"	76	23' 5"	"	12'-0"	"	307	4.4	17,
	50	III	1'-6"	8'-6"	5'-6"	82	25'-11"	"	13'-0"	4	405	7.3	29,
	55	III	"	9'-0"	"	90	28'-5"	"	15'-0"	"	447	8.1	32,

2



mm. about
beam

eams



SECTION

NOTES

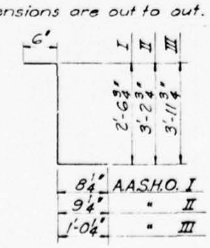
All pretensioning strands are 7/16 inch in diameter and shall have a minimum ultimate strength of 27,000 lb. per strand. The initial tension applied shall be 18,900 lb. per strand.

The required strength of concrete at transfer of prestress shall be 4,000 psi, except in the case of the 45 foot span, 28 foot roadway, where it shall be 4,300 psi.

	CONCRETE	
Total Weight	Volume	Weight of Beam
Lbs.	Cu. Yd.	Lbs.
198	2.6	10,400
260	3.9	15,800
291	4.4	17,700
371	7.3	29,700
421	8.1	32,700
240	3.4	13,900
275	3.9	15,800
307	4.4	17,700
405	7.3	29,700
447	8.1	32,700

BENDING DIAGRAM

All dimensions are out to out.

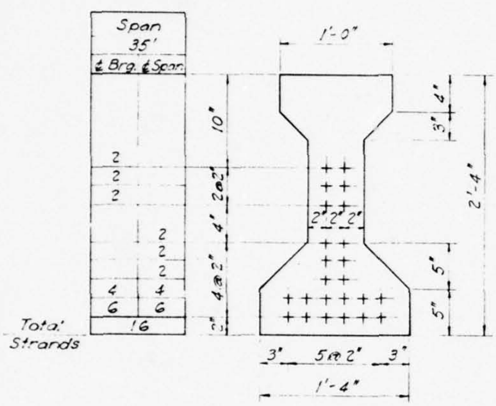


B1

Bars B2 and B5 are straight bars.

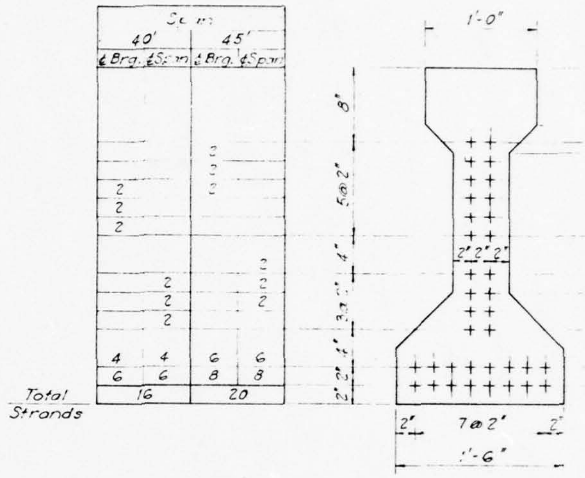
Figure G7. Beam sections and elevations (pretensioned-straight strands) of standard precast I-girder bridges (spans 35 to 55 ft)

24 FT. ROADWAY



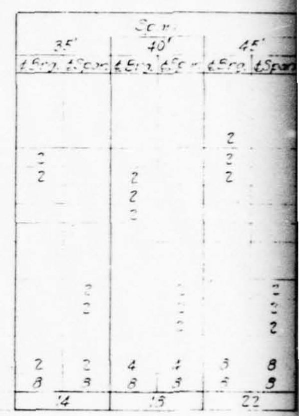
AASHO TYPE I BEAM

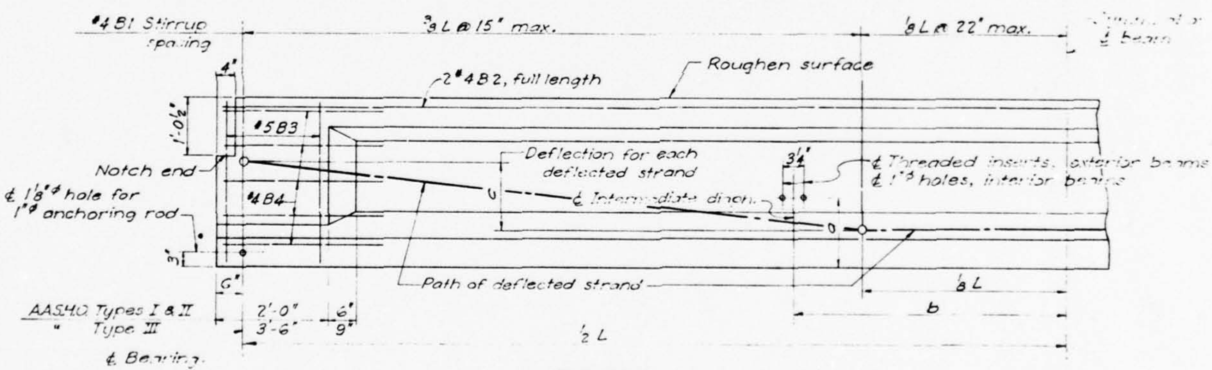
24 FT. ROADWAY



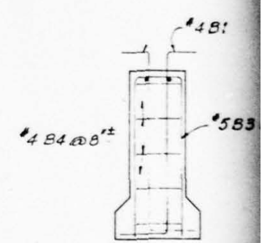
AASHO TYPE II BEAM

28 FT. ROADWAY





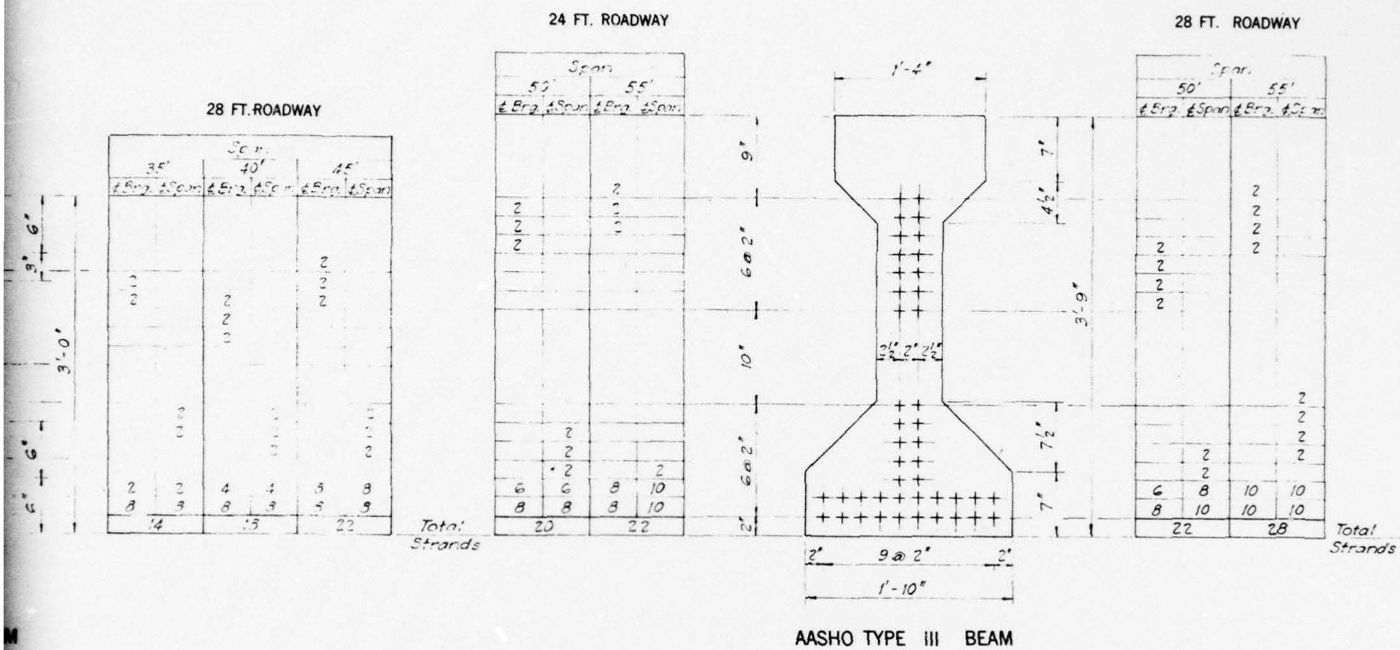
ELEVATION

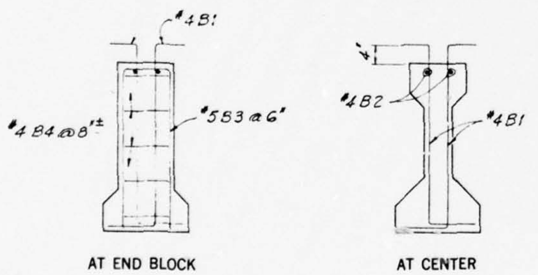


AT END BLOCK

SUMMARY OF QUANTITIES FOR ONE BEAM

	SPAN IN FEET	A.A.S.H.O. BEAM TYPE	DIMENSION			REINFORCEMENT STEEL									CONCRETE	
						#4 B1		#4 B2		#5 B3		#4 B4		Total Weight	Volume	Weight
			a	b	c	Length	No.	Length	No.	Length	No.	Length	No.	Lbs.	Cu. Yd.	[illegible]
24' RDWY.	35	I	1'-1½"	0"	8"	3'-9"	54	35'-8"	2	5'-0"	8	3'-7"	16	263	2.7	10,8
	40	II	1'-3½"	"	10"	4'-6"	62	20'-11"	4	6'-4"	-	"	20	343	4.0	16,3
	45	II	"	"	1'-0"	"	70	23'-5"	"	"	"	"	"	374	4.5	18,2
	50	III	1'-6"	8'-6"	2'-0"	5'-6"	76	25'-11"	"	8'-2"	14	5'-8"	24	558	7.8	31,5
	55	III	"	9'-0"	2'-6"	"	84	28'-5"	"	"	"	"	"	594	8.5	34,4
28' RDWY.	35	II	1'-3½"	0"	1'-2"	4'-6"	54	35'-8"	2	6'-4"	8	3'-7"	20	311	3.5	14,3
	40	II	"	"	1'-0"	"	62	20'-11"	4	"	"	"	"	343	4.0	16,3
	45	II	"	"	1'-4"	"	70	23'-5"	"	"	"	"	"	374	4.5	18,2
	50	III	1'-6"	8'-6"	1'-10"	5'-6"	76	25'-11"	"	8'-2"	14	5'-8"	24	558	7.8	31,5
	55	III	"	9'-0"	"	"	84	28'-5"	"	"	"	"	"	594	8.5	34,4





SECTIONS

NOTES

All pretensioning strands are 7/16 inch in diameter and shall have a minimum ultimate strength of 27,000 lb. per strand. The initial tension applied at ℄ span shall be 18,900 lb. for each strand in final position.

The required strength of concrete at transfer of prestress shall be 4,000 psi.

At transfer of prestress the sequence of release shall be: (a) the deflected strands, (b) the hold-down devices, and (c) the straight strands. An alternate procedure shall meet with the approval of the engineer.

E BEAM

	CONCRETE	
Total Weight	Volume	Weight of Beam
Lbs.	Cu. Yd.	Lbs.
263	2.7	10,800
343	4.0	16,300
374	4.5	18,200
558	7.8	31,500
594	8.5	34,400
311	3.5	14,300
343	4.0	16,300
374	4.5	18,200
558	7.8	31,500
594	8.5	34,400

BENDING DIAGRAM

All dimensions are out to out

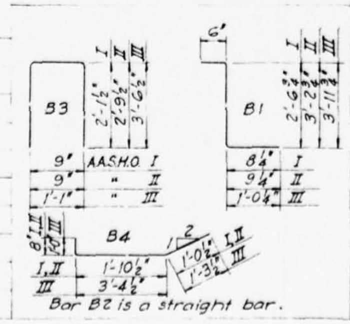
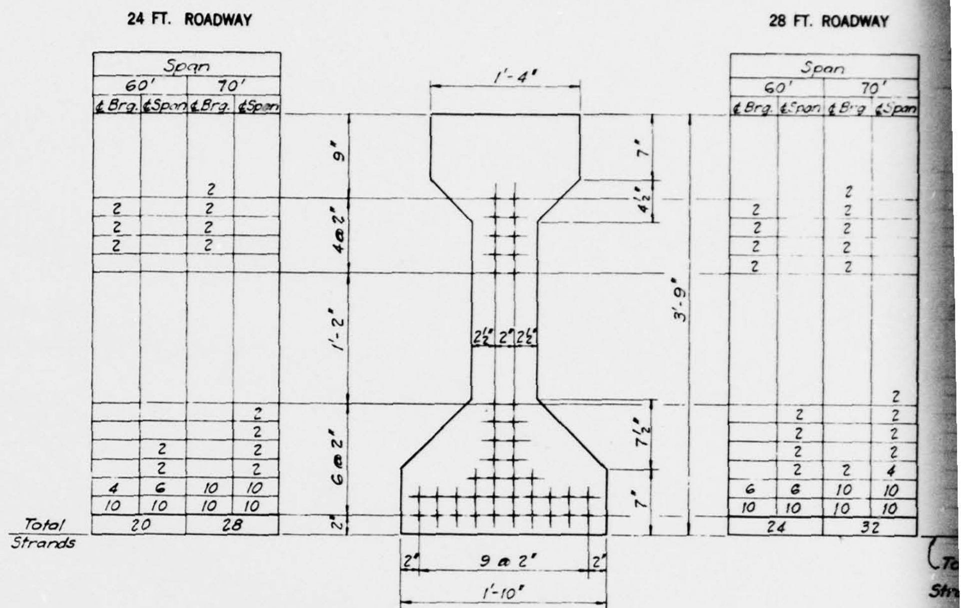
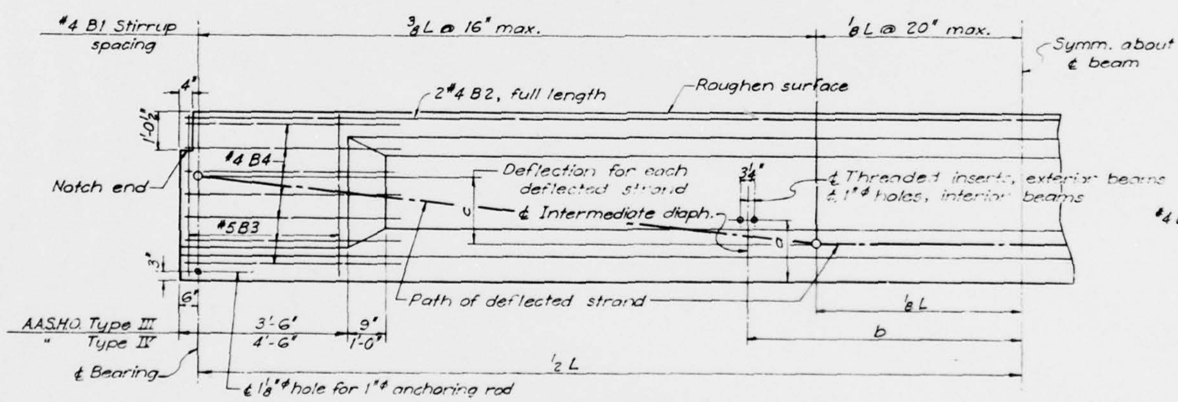


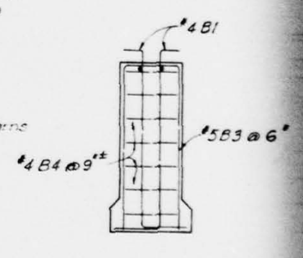
Figure G8. Beam sections and elevations (pretensioned-deflected strands) of standard precast I-girder bridges (spans 35 to 55 ft)



AASHO TYPE III BEAM



ELEVATION



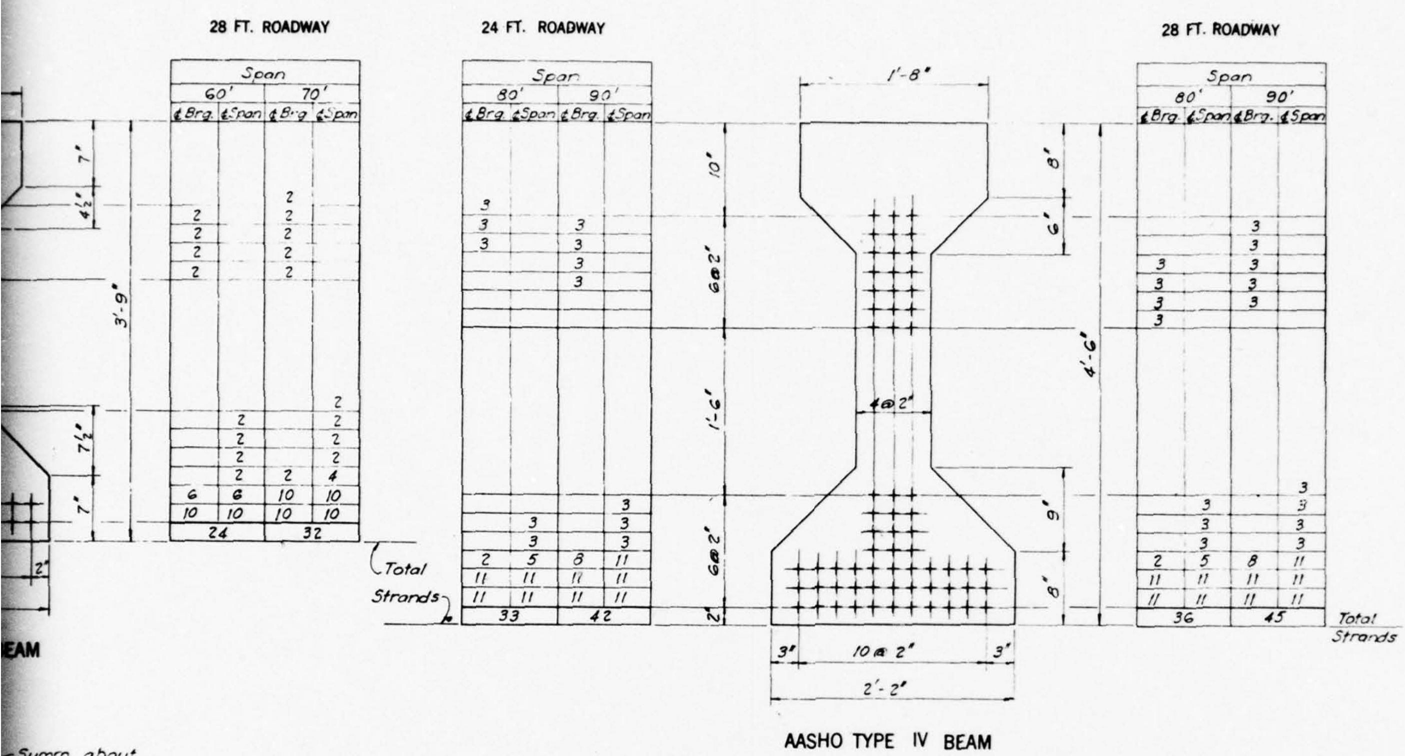
AT END BLOCK

SECT

SUMMARY OF QUANTITIES FOR ONE SPAN

SPAN IN FEET		AASHO BEAM TYPE	DIMENSION			REINFORCEMENT STEEL									CONCRETE	
						#4 B1		#4 B2		#5 B3		#4 B4		Total Weight	Volume	Weight o
			a	b	c	Length	No.	Length	No.	Length	No.	Length	No.	Lbs.	Cu. Yd.	Lbs
24' RDWY.	60	III	1'-6"	10'-0"	2'-2"	5'-6"	88	30'-11"	4	8'-2"	14	5'-8"	24	616	9.2	37,3
	70	III	"	11'-8"	2'-0"	"	102	35'-11"	"	"	"	"	"	681	10.6	43,1
	80	IV	1'-8½"	13'-4"	2'-10"	6'-5"	116	27'-8"	6	10'-1"	18	7'-2"	28	931	17.3	70,2
	90	IV	"	15'-0"	2'-6"	"	130	31'-0"	"	"	"	"	"	1,005	19.4	78,4
28' RDWY.	60	III	1'-6"	10'-0"	1'-10"	5'-6"	88	30'-11"	4	8'-2"	14	5'-8"	24	616	9.2	37,3
	70	III	"	11'-8"	"	"	102	35'-11"	"	"	"	"	"	681	10.6	43,1
	80	IV	1'-8½"	13'-4"	2'-2"	6'-5"	116	27'-8"	6	10'-1"	18	7'-2"	28	931	17.3	70,2
	90	IV	"	15'-0"	2'-4"	"	130	31'-0"	"	"	"	"	"	1,005	19.4	78,

2

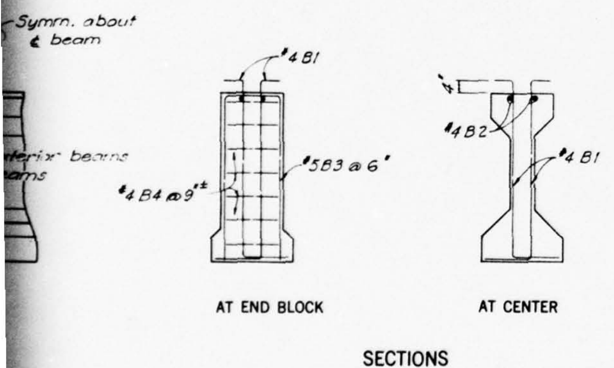


NOTES

All pretensioning strands are ½ inch in diameter and shall have a minimum ultimate strength of 36,000 lb. per strand. The initial tension applied at ¢ span shall be 25,200 lb. for each strand in final position.

The required strength of concrete at transfer of prestress shall be 4,000 psi, except in the cases of the 70 foot and 90 foot spans, 28 foot roadway, where it shall be 4,500 psi.

At transfer of prestress the sequence of release shall be: (a) the deflected strands, (b) the hold-down devices, and (c) the straight strands. An alternate procedure shall meet with the approval of the engineer.



ONE SPAN

Total Weight Lbs.	CONCRETE Volume Cu. Yd.	CONCRETE Weight of Beam Lbs.	BENDING DIAGRAM
616	9.2	37,300	All dimensions are out to out
681	10.6	43,100	
931	17.3	70,200	
1,005	19.4	78,400	
616	9.2	37,300	
681	10.6	43,100	
931	17.3	70,200	
1,005	19.4	78,400	Bar B2 is a straight bar.

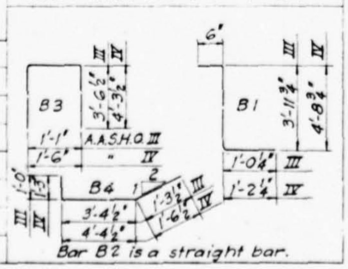
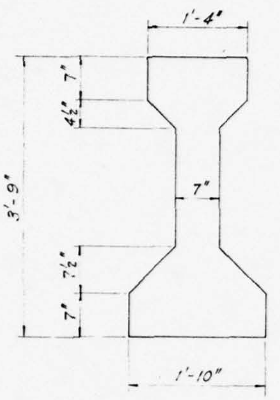
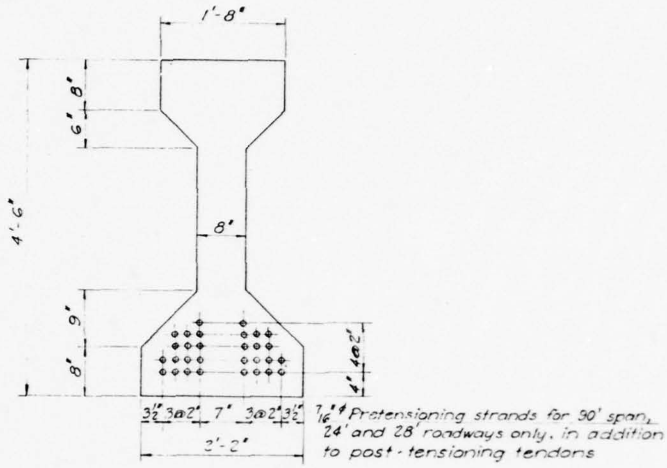


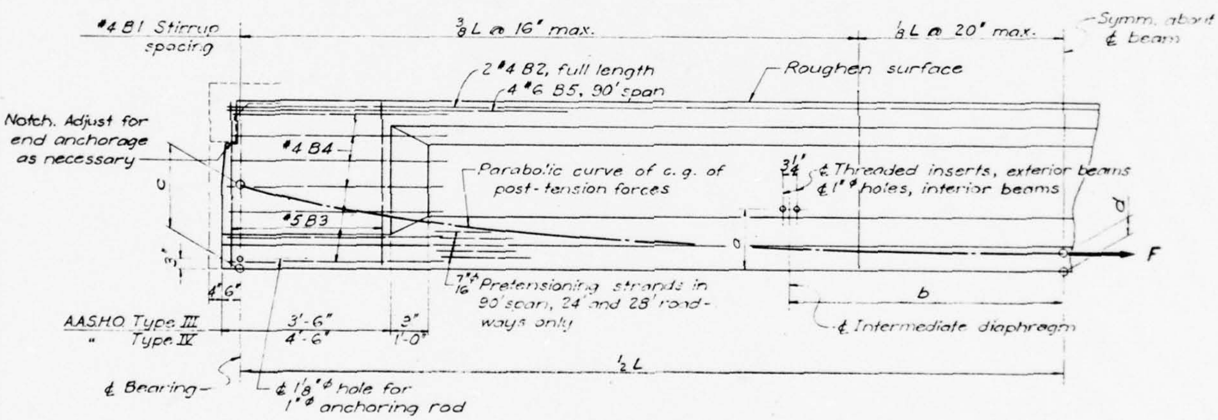
Figure G9. Beam sections and elevations (pretensioned-deflected strands) of standard precast I-girder bridges (spans 60 to 90 ft)



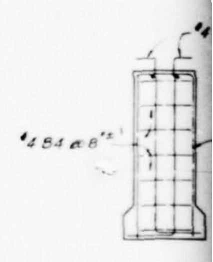
AASHO TYPE III BEAM



AASHO TYPE IV BEAM



ELEVATION



SUMMARY OF QUANTITIES FOR ONE BEAM

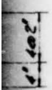
	SPAN IN FT.	AASHO BEAM TYPE	DIMENSION a	DIMENSION b	DIMENSION c	DIMENSION d	#4 B1 Length	#4 B1 No.	#4 B2 Length	#4 B2 No.	#5 B3 Length	#5 B3 No.	#4 B4 Length	#4 B4 No.	#6 B5 Length	#6 B5 No.	Total Weight Lbs.	Volu Cu. Y
24' RDWY.	60	III	1'-6"	10'-0"	15.20'	4.80"	5'-6"	88	30'-11"	4	8'-2"	14	5'-8"	24	-	-	616	9.
	70	III	"	11'-6"	14.43'	4.71"	"	102	35'-11"	"	"	"	"	"	-	-	681	10.6
	80	IV	1'-8½"	13'-6"	20.13'	5.25'	6'-5"	116	27'-8"	6	10'-1"	18	7'-2"	28	-	-	931	17.3
	90	IV	"	15'-0"	27.00"	7.25"	"	130	31'-0"	"	"	"	"	"	12'-0"	8	1,149	19.4
28' RDWY.	60	III	1'-6"	10'-0"	17.00"	6.00"	5'-6"	88	30'-11"	4	8'-2"	14	5'-8"	24	-	-	616	9.
	70	III	"	11'-6"	15.68"	5.25"	"	102	35'-11"	"	"	"	"	"	-	-	681	10.
	80	IV	1'-8½"	13'-6"	19.56'	6.33'	6'-5"	116	27'-8"	6	10'-1"	18	7'-2"	28	-	-	931	17.
	90	IV	"	15'-0"	27.00"	8.63'	"	130	31'-0"	"	"	"	"	"	12'-0"	8	1,149	19.

NOTES

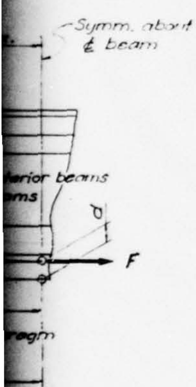
Pretensioning with straight strands shall be combined with post-tensioning only on the 90 foot span, 24 and 28 foot roadways. All pretensioning strands are $\frac{7}{16}$ inch in diameter and shall have a minimum ultimate strength of 27,000 lb. per strand. The initial tension applied shall be 18,900 lb. per strand.

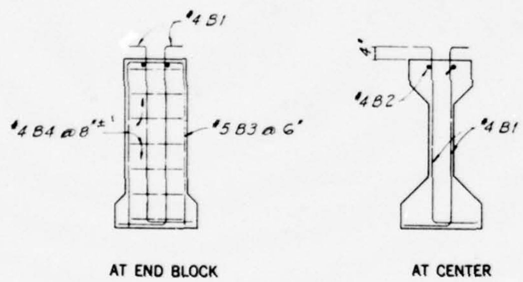
The required strength of concrete at transfer of prestress shall be 4,000 psi, except in the cases of the 70 foot span, 28 foot roadway, and 90 foot span, 24 and 28 foot roadways, where it shall be 4,500 psi.

A grid consisting of #3 bars @ 2 inch centers in both directions shall be placed near each anchorage of the post-tensioning system.

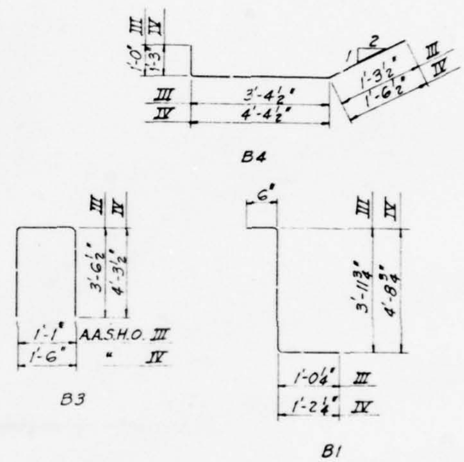


\# Pretensioning strands for 90' span, 24' and 28' roadways only, in addition to post-tensioning tendons





SECTIONS



Bars B2 and B5 are straight bars

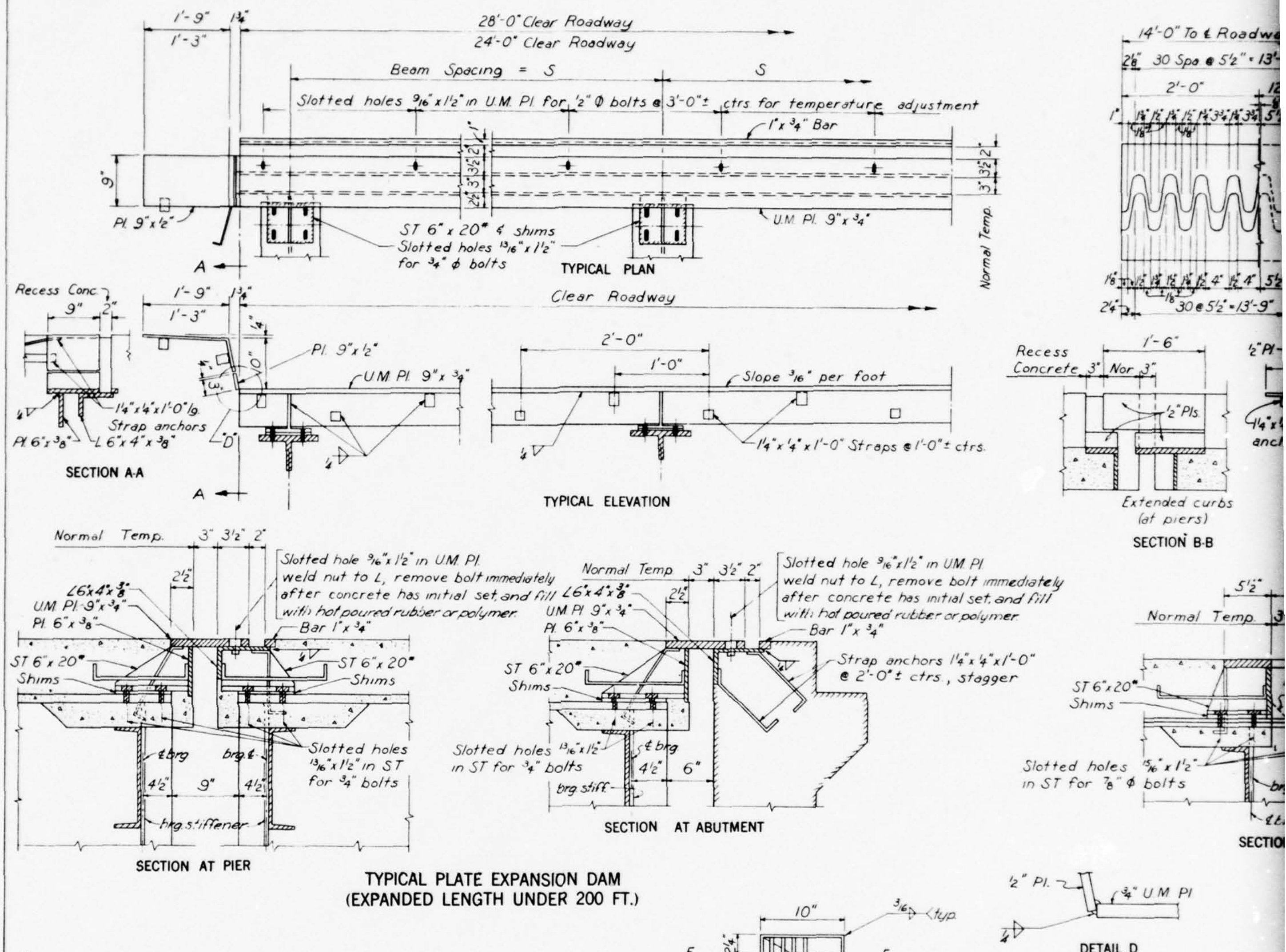
BENDING DIAGRAM

All dimensions are out to out

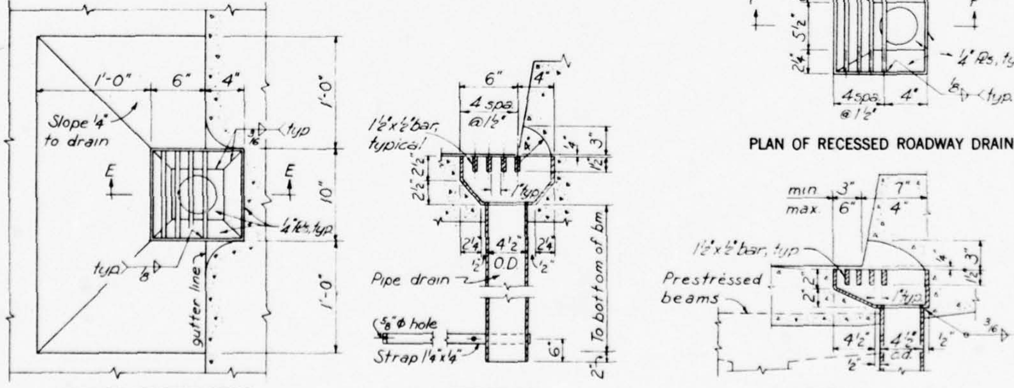
FOR ONE BEAM

...DULE					CONCRETE		F
B4	#6 B5		Total Weight		Volume	Weight of Beam	Total post-tension force at ℄ span after relaxation
No.	Length	No.	Lbs.		Cu. Yd.	Lbs.	Lbs.
24	-	-	616		9.2	37,300	404,600
"	-	-	681		10.6	43,100	566,500
28	-	-	931		17.3	70,200	647,400
"	12'-0"	8	1,149		19.4	78,400	404,600
24	-	-	616		9.2	37,300	485,500
"	-	-	681		10.6	43,100	647,400
28	-	-	931		17.3	70,200	726,300
"	12'-0"	8	1,149		19.4	78,400	485,500

Figure G10. Beam sections and elevations of standard precast posttensioned I-girder bridges (spans 60 to 90 ft)



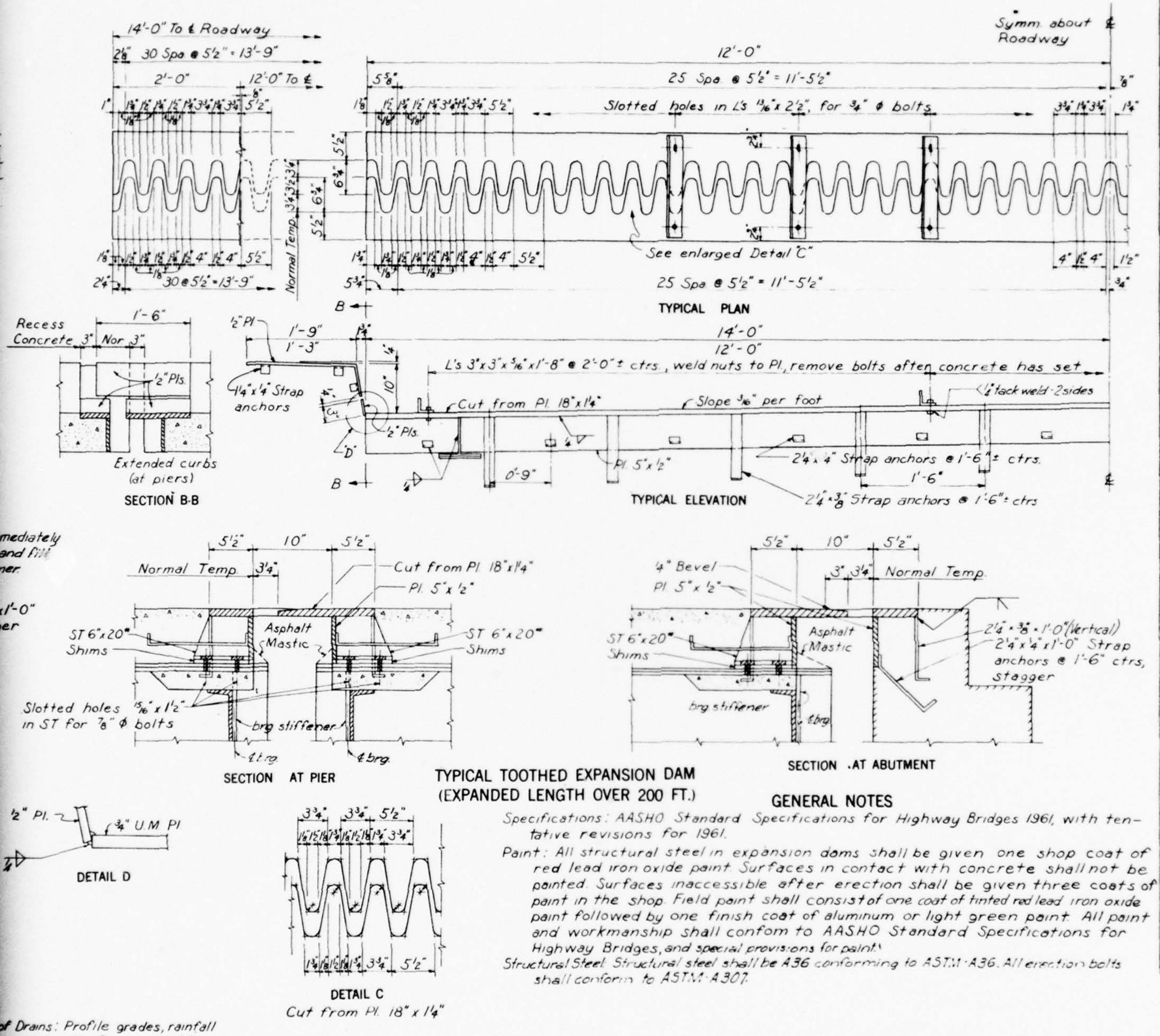
TYPICAL PLATE EXPANSION DAM
(EXPANDED LENGTH UNDER 200 FT.)



DETAILS OF RECOMMENDED ROADWAY DRAINS

Location of Drains: Profile grades, rainfall intensity and length of span should govern the location and spacing of drains. Considerati should be given to deleting deck drains on continuous structures if it is feasable to handle all the water with a suitable dra on the approach embankment as indicate on the layout of typical continuous bridg

Note: Galvanize drains after welding.



GENERAL NOTES

Specifications: AASHO Standard Specifications for Highway Bridges 1961, with tentative revisions for 1961.

Paint: All structural steel in expansion dams shall be given one shop coat of red lead iron oxide paint. Surfaces in contact with concrete shall not be painted. Surfaces inaccessible after erection shall be given three coats of paint in the shop. Field paint shall consist of one coat of tinted red lead iron oxide paint followed by one finish coat of aluminum or light green paint. All paint and workmanship shall confom to AASHO Standard Specifications for Highway Bridges, and special provisions for paint.

Structural Steel: Structural steel shall be A36 conforming to ASTM A36. All erection bolts shall conform to ASTM A307.

of Drains: Profile grades, rainfall
ty and length of span should govern
ation and spacing of drains. Consideration
be given to deleting deck drains on
uous structures if it is feasable to
all the water with a suitable drain
approach embankment as indicated
layout of typical continuous bridges.

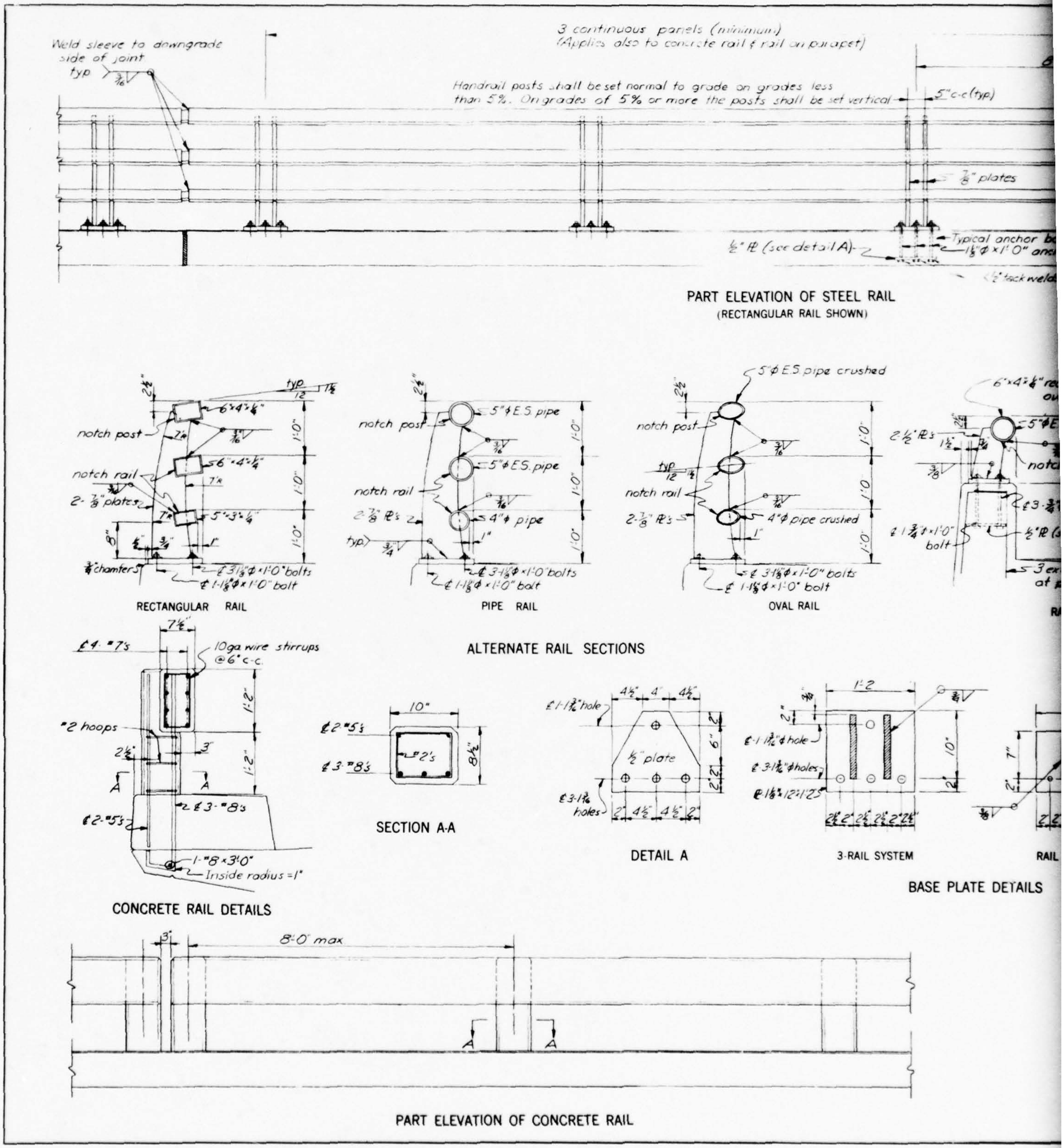
alvanize drains after welding.

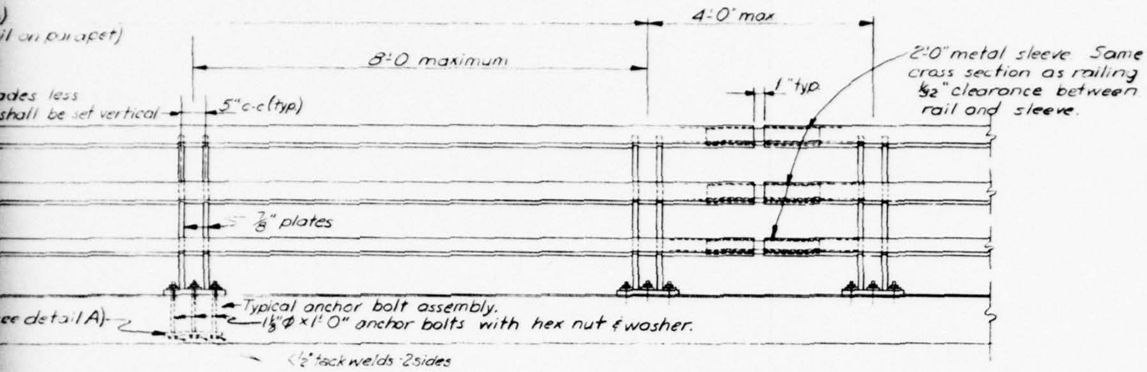
SUMMARY OF QUANTITIES FOR STRUCTURAL STEEL * (LBS.)

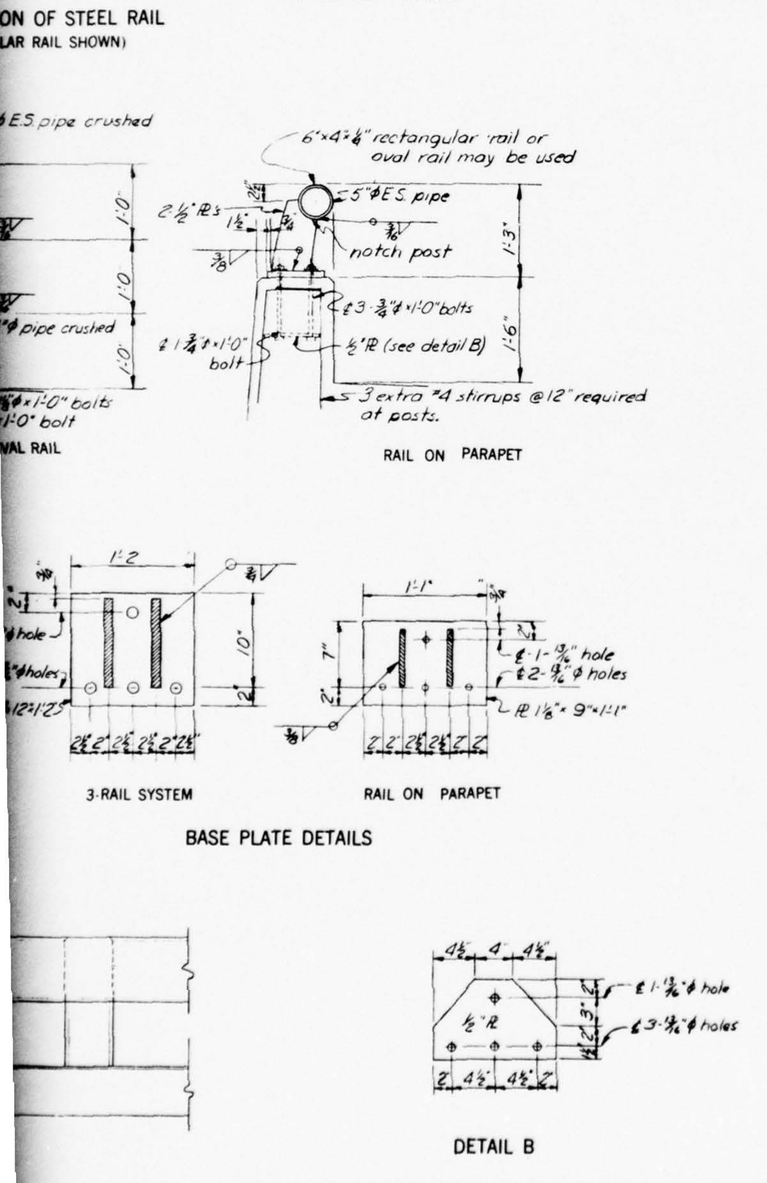
TYPE OF SUPERSTRUCTURE	24 FT R'DY. ABUT	24 FT R'DY. PIER	28 FT R'DY. ABUT	28 FT R'DY. PIER
CONCRETE	1170		1380	
I-BEAM	1330	1420	1570	1690
PLATE GIRDER	2740	2800	3210	3290

* Weights listed are for one expansion dam.

Figure G11. Typical details for expansion dams and recommended roadway drains


3 continuous panels (minimum)
(Applies also to concrete rail ¢ rail on parapet)
Weld sleeve to downgrade side of joint
typ
Handrail posts shall be set normal to grade on grades less than 5%. On grades of 5% or more the posts shall be set vertical
5" c-c (typ)
7/8" plates
Typical anchor bo
1 1/8" ø × 1'-0" anc
1/2" ℞ (see detail A)
1/2" tack weld
PART ELEVATION OF STEEL RAIL
(RECTANGULAR RAIL SHOWN)
notch post
notch rail
2-7/8" plates
6"×4"×1/4"
5"×3"×1/4"
3/4" chamfer
¢ 3-1 1/8" ø × 1'-0" bolts
¢ 1-1 1/8" ø × 1'-0" bolt
RECTANGULAR RAIL
5" ø E.S. pipe
4" ø pipe
PIPE RAIL
5" ø E.S. pipe crushed
4" ø pipe crushed
OVAL RAIL
ALTERNATE RAIL SECTIONS
¢ 4-#7's
10 ga. wire stirrups @ 6" c-c.
#2 hoops
2 ¢ 3-#8's
¢ 2-#5's
1-#8 × 3'-0"
Inside radius = 1"
CONCRETE RAIL DETAILS
¢ 2-#5's
¢ 3-#8's
#2's
SECTION A-A
¢ 1-1 3/16" hole
1/2" plate
¢ 3-1 3/16" holes
DETAIL A
¢ 1-1 3/16" ø hole
¢ 3-1 3/16" ø holes
℞ 1 1/8" × 12" × 1'-2"
3-RAIL SYSTEM
RAIL
BASE PLATE DETAILS
8'-0" max
PART ELEVATION OF CONCRETE RAIL





GENERAL NOTES

Design Specifications: See following sheet for design procedures and specifications.

Loading: See following sheet for loadings of types C, F & H railing systems.

Structural Steel: All structural steel shall conform to ASTM specification A36 and A53, grade B (grade A for oval rails).

Concrete: Concrete cast-in-place rail & posts shall be Class Y(AE). Air entraining agents shall meet with the approval of the engineer.

Reinforcing Steel: Reinforcing shall be deformed intermediate grade steel conforming to ASTM spec. A15. Dimensions relating to spacing of reinforcing steel are to centers of bars.

Anchor Bolts: Anchor bolts shall conform to ASTM spec. A325. All anchor bolt assemblies shall be galvanized. All anchor bolts shall have a final tensile force equal to 70% of the minimum proof load applied to them. This may be done by applying approximately 250 ft-lbs of torque to 3/4"φ bolts and 750 ft-lbs of torque to 1 1/8"φ bolts.

Paint: All structural steel shall be given one shop coat of red lead iron oxide paint. Inside of railings shall be given one coat of paint in the shop. Field paint shall consist of one coat of tinted red lead iron oxide paint followed by one finish coat of aluminum or light green paint. All paint and workmanship shall conform to the AASHO Standard Specifications for Highway Bridges and the special provisions for paint.

Figure G12. Typical details for bridge railings

APPENDIX H: TYPICAL PROPERTIES AND DETAILS OF PRESTRESSED CONCRETE PILES[64]

Pile Size Diameter* in.	Shape**	Solid or Hollow†	A_c†† $in.^2$	Weight (plf)‡ lb	Number of Strands per Pile‡‡	Effective Prestress§ (to Nearest 5 psi) psi	I $in.^4$	I/c $in.^3$	Perimeter in.	Allowable Moment§§ 300-psi Tension kip in.	Allowable Moment§§ 600-psi Tension kip in.	Allowable Loads# Based on f'_c 6000 psi tons	Allowable Loads# Based on f'_c 7000 psi tons
						Bearing Piles							
10	Square	Solid	98	105	4--7/16 in.	720	790	158	38	161	209	59	69
12	Square	Solid	142	152	6--7/16 in.	745	1,664	277	46	290	373	85	100
14	Square	Solid	194	209	8--7/16 in.	725	3,112	445	54	456	589	116	135
16	Square	Solid	254	273	11--7/16 in.	765	5,344	668	62	711	912	152	178
18	Octagonal	Solid	268	288	11--7/16 in.	720	5,705	634	60	647	837	161	188
18	Square	Solid	322	346	14--7/16 in.	765	8,597	955	70	1,017	1,303	193	225
20	Square	Solid	398	428	13--1/2 in.	770	13,146	1,315	78	1,407	1,801	239	279
20	Square	11-in. H. C.	303	326	10--1/2 in.	775	12,427	1,243	78	1,336	1,709	182	212
24	Square	14-in. H. C.	418	450	13--1/2 in.	730	25,490	2,124	94	2,188	2,825	250	292
36	Round	26-in. H. C.	487	524	17--1/2 in.	820	60,016	3,334	113	3,734	4,735	292	341
48	Round	38-in. H. C.	675	726	24--1/2 in.	835	158,222	6,593	151	7,483	9,460	405	472
54	Round	44-in. H. C.	770	829	28--1/2 in.	855	233,409	8,645	170	9,985	12,578	462	539
12	TRICON	Solid	62	66	3--3/8 in.	645	348	57	34	53	70	37	43
14	TRICON	Solid	84	90	3--7/16 in.	630	626	87	40	81	107	50	59
16	TRICON	Solid	110	118	3--1/2 in.	640	1,091	130	46	123	162	66	77

(Continued)

* Nominal pile size is measured through the center of the pile, except for TRICON piles, which are measured along the side of the triangle.

** Circular piles with comparable properties may be used in lieu of octagonal piles shown.

† Holes for hollow core piles are circular.

†† Reduction in area for chamfers on square piles has been taken into account.

‡ Tables are based on regular concrete of 155 lb/cu ft density. The use of high strength lightweight concrete in piles for certain specific applications, such as fender piles, should be considered, when available, because its lower E value gives greater deflection and energy absorption characteristics. With lightweight concrete, an f'_c of 5000 psi should be used, and the values in the table should be adjusted accordingly.

‡‡ Based on 1/2-, 7/16-, and 3/8-in.-diameter high strength strands with ultimate strengths of 41,300, 31,000, and 23,000 lb, respectively. If different diameter or regular strength strand is used, the number of strands per pile should be increased or decreased, in accordance with strand manufacturers' tables, to provide approximately the same minimum effective prestress shown in the table.

§ Effective prestress assumes a uniform distribution of strands resulting in a uniform prestress. For special applications of sheet piles, eccentric prestress may be desirable and economical. Experience has shown that such eccentricity may be safely used provided the effective compression on the face with minimum prestress is above 400 psi.

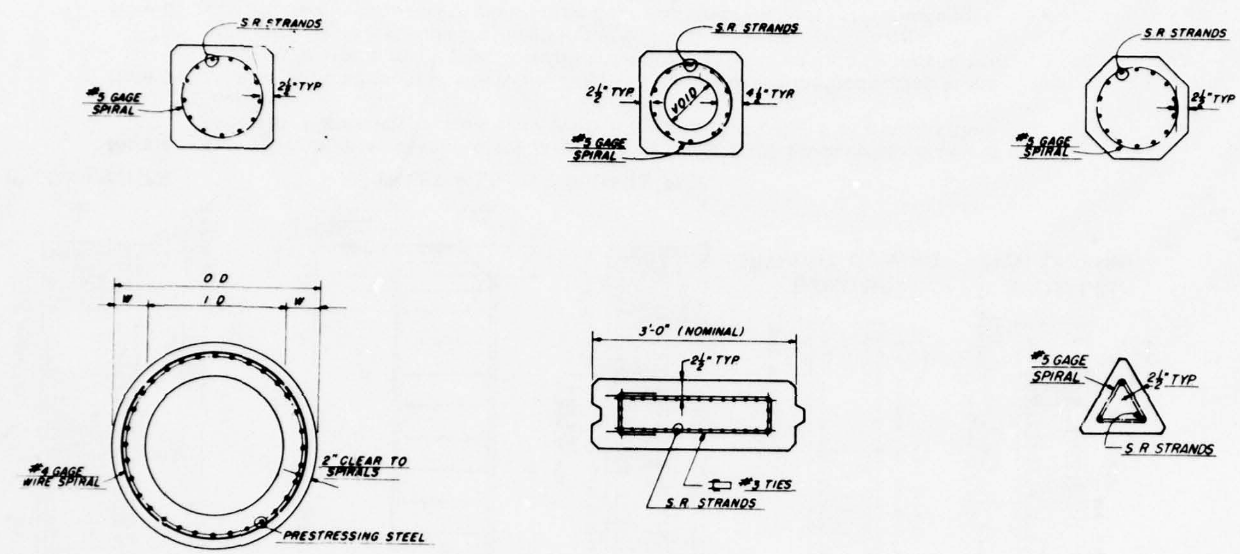
§§ Allowable bending moments are listed for a permissible tensile stress of 300 psi with an effective prestress as given in the table, f'_c = 6000 psi, and assuming a modulus of rupture of 600 psi. Allowable moments for earthquake or similar transient loads are based on a tension of 600 psi. Where bending resistance is critical, the allowable moment may be increased by using more strands to raise the effective prestress to a maximum of 0.2 f'_c psi.

\# Allowable design loads are based on the accepted formula of $N = 0.2\ f'_c \times A_c$ and are computed for f'_c = 6000 and 7000 psi. Concrete strengths in excess of this may be used to increase allowable design loads whenever driving and soil conditions are favorable.

Figure H1. Properties of pretensioned prestressed concrete piles (sheet 1 of 2)

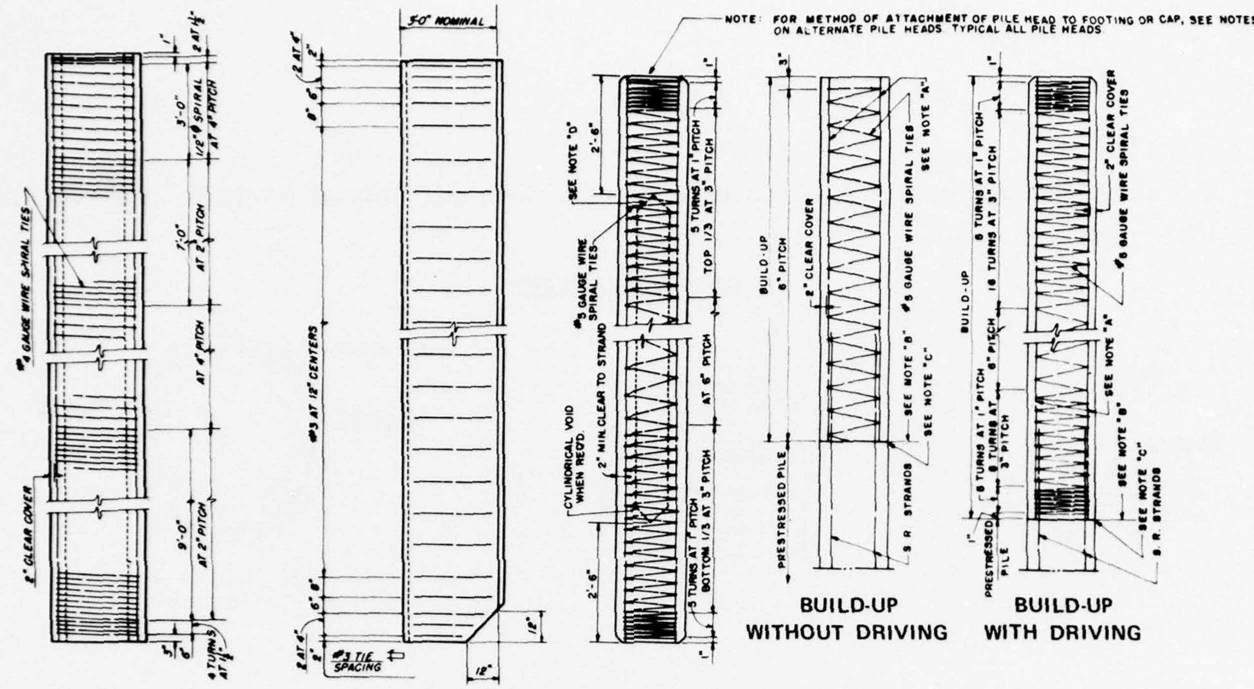
Pile Size in.	Shape	Solid or Hollow	A_c in.^{2}	Weight (plf) lb	Number of Strands per Pile	Effective Prestress (to Nearest 5 psi) psi	I in.^{4}	I/c Per Pile in.^{3}	I/c Per foot of Wall in.^{3}	Perimeter in.	Allowable Moment (per Foot of Wall) 300-psi Tension kip in.	Allowable Moment (per Foot of Wall) 600-psi Tension kip in.
						Sheet Piles						
9 × 36	Rectangular	Solid	324	348	14--1/2 in.	1,020	2,187	486	162	90	214	262
12 × 36	Rectangular	Solid	432	465	20--1/2 in.	1,090	5,184	864	288	96	400	487
18 × 36	Rectangular	W/2--10-in. H. C.	491	528	24--1/2-in.	1,150	16,515	1,835	612	108	887	1,071
						Fender Piles						
14	Square	Solid	194	209	12--7/16 in.	1,090	3,112	445	N/A	54	618	752
16	Square	Solid	254	273	12--1/2 in.	1,115	5,344	668	N/A	62	945	1,145

Figure H1 (sheet 2 of 2)



CROSS SECTIONS

Figure H2. Typical details for pretensioned prestressed concrete piles (sheet 1 of 3)



CYLINDER PILE SHEET PILE SQUARE PILE

Note A: The minimum area of reinforcing steel shall be 1½% of the gross cross-section of concrete. Placement of bars shall be in a symmetrical pattern of not less than four bars.

Note B: Method of attachment of pile to build-up may be any of the methods given in the notes on Alternate Pile Heads. If mild reinforcing steel is used for attachment, the area shall be no less than that used in the build-up.

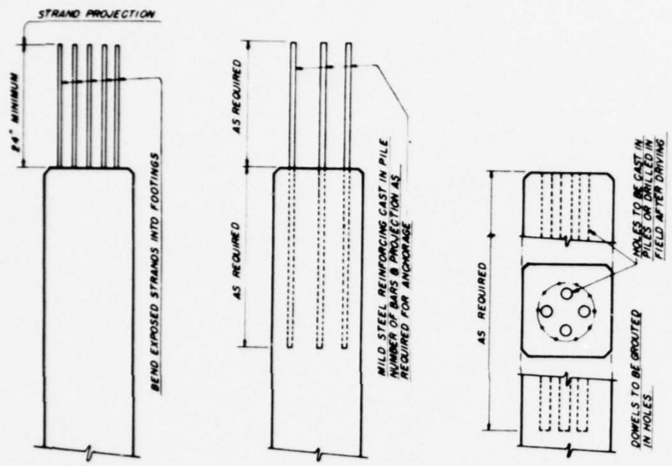
Note C: Concrete around top half of pile shall be bush-hammered to prevent feather edges.

Note D: Conical end fitting or form may be rounded, flat or tapered with proper taping to prevent leakage.

ELEVATION

Figure H2 (sheet 2 of 3)

Reinforcement may be specified to project from the pile into the cap or footing. If so required, attachment of the pile to the cap or footing may be made by any one of the following methods unless otherwise specified:

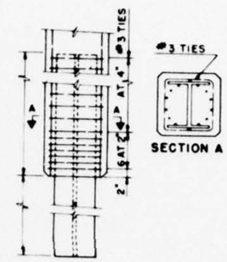


TYPE A　　TYPE B　　TYPE C

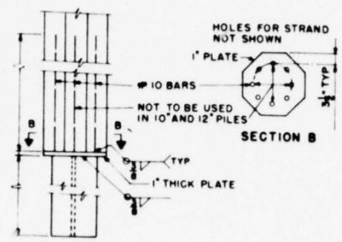
If mild reinforcing steel is used for projection into the cap or footing, the minimum area of steel required shall be 1½% of the gross cross-section of concrete pile, with not less than four bars being used for piles up to 24" in diameter, and not less than eight bars being used for piles greater than 24" in diameter. Arrangement of bars shall be in a symmetrical pattern with bars as close as practical to the sides of the pile. Anchorage of bars shall be sufficient to develop strength of bar, but not less than 20 bar diameters.

ALTERNATE PILE HEADS

When driving into rock or hard strata, either Type I or Type II alternate tips may be used in lieu of the standard flat tip. Size and length of steel section used shall be as determined by Engineer for adequate penetration. Type I or Type II tips may be used for either square or octagonal piles.



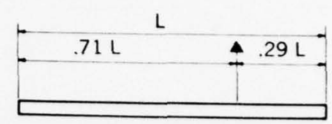
TYPE I



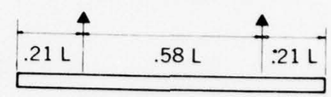
TYPE II

ALTERNATE PILE TIPS

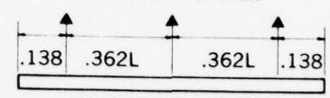
Maximum lengths for pick-up are determined by using the following stress assumptions: Loading = 1.5 x full dead load (to allow for impact). Allowable tensile stress = $6.0\sqrt{f'c}$. These stress and loading criteria are based on normal care in handling of the pile.



ONE-POINT PICK
$M = .043\ wL^2$ max



TWO-POINT PICK
$M = .0214\ wL^2$ max



THREE-POINT PICK
$M = .0095\ wL^2$ max

PICKING POINTS

Figure H2 (sheet 3 of 3)

APPENDIX I: TYPICAL DESIGN REQUIREMENTS FOR REINFORCED CONCRETE LOW-HEAD PRESSURE PIPE

1. The typical design requirements (e.g. diameter, wall thickness, compressive strength of the concrete, and the amount of circumferential reinforcement) for reinforced concrete low-head pressure pipes[65] are given in Table I1. The class of pipe given in this table for combined external and hydrostatic head is based on a field installation procedure at least comparable to one of those described in ASTM C 361-76.[65] Where the designer does not expect to attain such an installation, a detailed design analysis of the pipe should be made taking into consideration the anticipated external loading, hydrostatic head, and installation procedure.

Table I1

Design Requirements for Reinforced Concrete Low-Head Pressure Pipe, Concrete Design Strength 4500 psi

Circumferential reinforcement, in.^{2}/linear ft of pipe

Internal Designated Dia, in.	12		15		18				21			
Type of Reinforcement	Circular		Circular		Circular		Elliptical		Circular		Elliptical	
Wall Thickness, in.	2	3	2	3	2¼	3	2¼	3	2⅜	3	2⅜	3
Layers of Reinforcement	Single	Single	Single	Single	Single	Single	Single	Single	Single	Single	Single	Single
Class*												
A-25	0.07	0.06	0.10	0.08	0.12	0.11	0.12	0.12	0.15	0.13	0.14	0.14
B-25	0.10	0.08	0.14	0.11	0.18	0.15	0.16	0.12	0.23	0.19	0.20	0.14
C-25	0.13	0.09	0.19	0.14	0.25	0.19	0.22	0.14	0.32	0.26	0.27	0.19
D-25	0.16	0.11	0.25	0.17	0.32	0.24	0.28	0.17	0.42	0.33	0.37	0.23
A-50	0.11	0.10	0.14	0.13	0.18	0.16	0.24	0.24	0.21	0.19	0.28	0.28
B-50	0.13	0.11	0.19	0.15	0.23	0.20	0.24	0.24	0.29	0.26	0.28	0.28
C-50	0.16	0.13	0.24	0.18	0.30	0.25	0.26	0.24	0.38	0.32	0.32	0.28
D-50	0.19	0.15	0.29	0.21	0.37	0.29	0.33	0.24	0.48	0.39	0.42	0.28
A-75	0.17	0.17	0.21	0.21	0.26	0.26	...	...	0.30	0.30	...	...
B-75	0.17	0.17	0.23	0.21	0.29	0.26	...	...	0.35	0.32	...	...
C-75	0.20	0.17	0.28	0.23	0.35	0.30	...	...	0.44	0.38	...	...
D-75	0.23	0.18	0.34	0.26	0.43	0.35	...	...	0.55	0.45	...	...
A-100	0.25	0.25	0.32	0.32	0.38	0.38	...	...	0.44	0.44	...	...
B-100	0.25	0.25	0.32	0.32	0.38	0.38	...	...	0.44	0.44	...	...
C-100	0.25	0.25	0.32	0.32	0.41	0.38	...	...	0.50	0.44	...	...
D-100	0.26	0.25	0.38	0.32	0.48	0.40	...	...	0.61	0.51	...	...
A-125	0.32	0.32	0.39	0.39	0.47	0.47	...	...	0.55	0.55	...	...
B-125	0.32	0.32	0.39	0.39	0.47	0.47	...	...	0.55	0.55	...	...
C-125	0.32	0.32	0.39	0.39	0.47	0.47	...	...	0.57	0.55	...	...
D-125	0.32	0.32	0.42	0.39	0.53	0.47	...	...	0.67	0.57	...	...

Internal Designated Dia, in.	24				27							
Type of Reinforcement	Circular		Elliptical		Circular						Elliptical	
Wall Thickness, in.	2½	3	2½	3	2⅝	3⅛	3¼		4¼		2⅝	3¼
Layers of Reinforcement	Single	Single	Single	Single	Single	Single	Inner	Outer	Inner	Outer	Single	Single
Class*												
A-25	0.18	0.16	0.16	0.16	0.21	0.19	0.13	0.09	0.11	0.07	0.18	0.18
B-25	0.29	0.25	0.23	0.18	0.35	0.30	0.20	0.11	0.15	0.08	0.27	0.20
C-25	0.40	0.33	0.32	0.24	0.49	0.41	0.27	0.14	0.20	0.09	0.39	0.27
D-25	0.54	0.43	0.44	0.30	...	0.54	0.35	0.16	0.24	0.10	0.51	0.35
A-50	0.25	0.23	0.32	0.32	0.29	0.27	0.19	0.15	0.16	0.12	0.36	0.36
B-50	0.36	0.32	0.32	0.32	0.43	0.38	0.26	0.17	0.20	0.13	0.36	0.36
C-50	0.47	0.40	0.39	0.32	0.57	0.49	0.32	0.19	0.25	0.14	0.45	0.36
D-50	0.61	0.50	0.50	0.37	...	0.61	0.41	0.22	0.29	0.15	0.58	0.41
A-75	0.34	0.34	...	...	0.38	0.38	0.25	0.20	0.21	0.17	...	...
B-75	0.43	0.39	...	...	0.50	0.46	0.31	0.23	0.25	0.18	...	...
C-75	0.54	0.47	...	...	0.65	0.57	0.39	0.25	0.30	0.19	...	...
D-75	0.68	0.57	...	...	...	0.69	0.46	0.27	0.35	0.20	...	...
A-100	0.50	0.50	...	...	0.57	0.57	0.31	0.26	0.29	0.24	...	...
B-100	0.50	0.50	...	...	0.58	0.57	0.38	0.28	0.31	0.23	...	...
C-100	0.61	0.55	...	...	0.73	0.65	0.45	0.30	0.35	0.24	...	...
D-100	0.75	0.64	...	...	...	0.77	0.52	0.33	0.40	0.25	...	...
A-125	0.63	0.63	...	...	0.71	0.71	0.40	0.31	0.38	0.32	...	...
B-125	0.63	0.63	...	...	0.71	0.71	0.44	0.35	0.40	0.31	...	...
C-125	0.68	0.63	...	...	0.81	0.72	0.50	0.37	0.41	0.30	...	...
D-125	0.82	0.71	...	...	...	0.85	0.57	0.40	0.45	0.30	...	...

* DESIGNATIONS A, B, C, AND D, FOR CLASS OF PIPE, DENOTE 5, 10, 15, AND 20 FT OF EARTH COVER OVER TOP OF PIPE. FIGURES 25, 50, 75, ETC., FOR CLASS OF PIPE, DENOTE HYDROSTATIC PRESSURE HEADS IN FEET (KILOPASCALS) MEASURED TO CENTER LINE OF PIPE.

(Continued)

(Sheet 1 of 8)

Table I1 (Continued)

Circumferential reinforcement, in.²/linear ft of pipe																				
Internal Designated Dia, in.	30										33									
Type of Reinforcement	Circular								Elliptical		Circular								Elliptical	
Wall Thickness, in.	2¾	3⅛	3¼		3½		4¾		2¾	3½	2⅞	3⅛	3¼		3¾		4¾		2⅞	3¾
Layers of Reinforcement	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single
Class																				
A-25	0.24	0.23	0.16	0.10	0.15	0.10	0.12	0.08	0.20	0.20	0.28	0.26	0.18	0.12	0.16	0.11	0.13	0.09	0.22	0.22
B-25	0.41	0.37	0.25	0.14	0.22	0.13	0.17	0.09	0.31	0.22	0.48	0.44	0.29	0.17	0.25	0.14	0.19	0.10	0.36	0.25
C-25	0.60	0.51	0.33	0.17	0.30	0.15	0.21	0.10	0.45	0.30	...	0.64	0.41	0.22	0.33	0.17	0.25	0.12	0.50	0.33
D-25	...	0.69	0.43	0.21	0.39	0.19	0.26	0.11	0.59	0.39	...	...	0.53	0.27	0.43	0.21	0.32	0.14	0.71	0.43
A-50	0.33	0.31	0.22	0.17	0.21	0.16	0.17	0.13	0.39	0.39	0.37	0.36	0.25	0.19	0.23	0.17	0.19	0.15	0.43	0.43
B-50	0.50	0.45	0.31	0.20	0.28	0.19	0.22	0.14	0.39	0.39	0.58	0.54	0.37	0.24	0.31	0.20	0.25	0.16	0.43	0.43
C-50	0.68	0.60	0.40	0.24	0.37	0.21	0.26	0.15	0.51	0.39	...	0.73	0.48	0.28	0.40	0.24	0.32	0.18	0.57	0.43
D-50	...	0.78	0.49	0.27	0.45	0.24	0.32	0.16	0.69	0.45	...	...	0.62	0.33	0.49	0.27	0.37	0.20	0.78	0.49
A-75	0.42	0.42	0.28	0.23	0.27	0.22	0.23	0.19	...	...	0.47	0.46	0.32	0.26	0.29	0.24	0.25	0.20	...	...
B-75	0.59	0.54	0.38	0.26	0.35	0.25	0.27	0.20	...	...	0.67	0.64	0.44	0.31	0.38	0.27	0.32	0.22	...	...
C-75	0.77	0.69	0.46	0.30	0.43	0.27	0.32	0.20	...	...	...	0.83	0.55	0.36	0.46	0.30	0.38	0.24	...	...
D-75	...	0.86	0.56	0.33	0.51	0.30	0.37	0.21	...	...	...	...	0.69	0.41	0.55	0.33	0.43	0.25	...	...
A-100	0.63	0.63	0.36	0.29	0.35	0.29	0.32	0.27	...	...	0.69	0.60	0.40	0.33	0.39	0.31	0.35	0.29	...	...
B-100	0.67	0.63	0.44	0.33	0.41	0.31	0.33	0.25	...	...	0.77	0.73	0.51	0.39	0.45	0.33	0.38	0.29	...	...
C-100	0.86	0.78	0.53	0.37	0.49	0.33	0.38	0.26	...	...	...	0.93	0.63	0.43	0.53	0.37	0.44	0.30	...	...
D-100	...	0.95	0.64	0.41	0.57	0.37	0.43	0.27	...	...	...	...	0.75	0.48	0.63	0.40	0.49	0.31	...	...
A-125	0.78	0.78	0.43	0.36	0.44	0.35	0.42	0.36	...	...	0.86	0.86	0.47	0.40	0.47	0.39	0.47	0.39	...	...
B-125	0.78	0.78	0.51	0.40	0.48	0.38	0.44	0.34	...	...	0.87	0.86	0.58	0.46	0.52	0.41	0.48	0.38	...	...
C-125	0.95	0.86	0.59	0.43	0.55	0.40	0.45	0.33	...	...	...	1.02	0.70	0.50	0.61	0.44	0.50	0.37	...	...
D-125	...	1.04	0.70	0.47	0.64	0.43	0.48	0.32	...	...	...	...	0.82	0.55	0.70	0.47	0.55	0.38	...	...

(Continued)

(Sheet 2 of 8)

Table I1 (Continued)

Circumferential reinforcement, in.²/linear ft of pipe																										
Internal Designated Dia, in.	36									39*									42							
Type of Reinforcement	Circular							Elliptical		Circular						Elliptical		Circular						Elliptical	
Wall thickness, in.	3 1/8	3 1/4		4		5		3 1/8	4	3 1/2		4 1/4		5 1/4		3 1/2	4 1/4	3 3/4		4 1/2		5 1/2		3 3/4	4 1/2
Layers of Reinforcement	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single
Class																									
A-25	0.31	0.21	0.14	0.17	0.12	0.15	0.10	0.24	0.24	0.22	0.15	0.19	0.13	0.16	0.11	0.26	0.26	0.24	0.16	0.20	0.14	0.17	0.12	0.28	0.28
B-25	0.53	0.36	0.20	0.27	0.15	0.22	0.12	0.38	0.27	0.38	0.22	0.29	0.17	0.24	0.13	0.38	0.29	0.40	0.23	0.31	0.18	0.26	0.14	0.40	0.31
C-25	...	0.49	0.26	0.37	0.19	0.28	0.14	0.52	0.37	0.52	0.28	0.40	0.21	0.31	0.15	0.52	0.40	0.54	0.30	0.43	0.22	0.34	0.17	0.54	0.43
D-25	...	0.67	0.33	0.46	0.23	0.35	0.16	0.72	0.46	0.70	0.36	0.50	0.25	0.39	0.18	0.70	0.50	0.73	0.38	0.54	0.27	0.43	0.20	0.73	0.54
A-50	0.41	0.29	0.22	0.24	0.19	0.21	0.16	0.47	0.47	0.30	0.23	0.26	0.20	0.23	0.18	0.51	0.51	0.32	0.24	0.28	0.21	0.25	0.19	0.55	0.55
B-50	0.64	0.43	0.28	0.35	0.22	0.29	0.18	0.47	0.47	0.45	0.29	0.37	0.24	0.31	0.20	0.51	0.51	0.48	0.31	0.40	0.26	0.33	0.22	0.55	0.55
C-50	...	0.56	0.33	0.43	0.26	0.35	0.20	0.62	0.47	0.59	0.36	0.47	0.28	0.38	0.22	0.59	0.51	0.64	0.38	0.50	0.30	0.42	0.24	0.64	0.55
D-50	...	0.74	0.41	0.53	0.29	0.41	0.22	0.80	0.53	0.77	0.43	0.57	0.32	0.46	0.24	0.77	0.57	0.81	0.46	0.63	0.35	0.50	0.27	0.81	0.63
A-75	0.52	0.37	0.29	0.31	0.26	0.28	0.22	...	...	0.39	0.31	0.34	0.27	0.30	0.24	...	...	0.41	0.33	0.36	0.29	0.33	0.26	...	...
B-75	0.74	0.51	0.36	0.41	0.29	0.35	0.25	...	...	0.53	0.38	0.45	0.31	0.38	0.27	...	...	0.56	0.40	0.47	0.33	0.41	0.29	...	...
C-75	...	0.66	0.42	0.50	0.32	0.41	0.26	...	...	0.69	0.44	0.54	0.36	0.45	0.29	...	...	0.72	0.46	0.58	0.38	0.50	0.32	...	...
D-75	...	0.81	0.49	0.61	0.37	0.49	0.29	...	...	0.84	0.51	0.66	0.40	0.53	0.32	...	...	0.88	0.54	0.70	0.43	0.58	0.34	...	...
A-100	0.75	0.45	0.38	0.42	0.34	0.38	0.32	...	...	0.47	0.40	0.46	0.36	0.42	0.34	...	...	0.50	0.42	0.49	0.40	0.45	0.37	...	...
B-100	0.85	0.58	0.44	0.48	0.37	0.42	0.31	...	...	0.63	0.46	0.52	0.39	0.45	0.34	...	...	0.66	0.48	0.55	0.42	0.48	0.37	...	...
C-100	...	0.73	0.49	0.57	0.40	0.48	0.33	...	...	0.77	0.52	0.63	0.43	0.52	0.36	...	...	0.80	0.55	0.67	0.46	0.56	0.39	...	...
D-100	...	0.88	0.56	0.68	0.44	0.54	0.35	...	...	0.92	0.59	0.73	0.47	0.59	0.38	...	...	0.99	0.63	0.78	0.50	0.65	0.42	...	...
A-125	0.94	0.53	0.45	0.52	0.43	0.51	0.43	...	...	0.56	0.47	0.56	0.47	0.55	0.47	...	...	0.60	0.50	0.60	0.50	0.59	0.50	...	...
B-125	0.95	0.68	0.51	0.56	0.44	0.52	0.41	...	...	0.71	0.54	0.61	0.47	0.57	0.45	...	...	0.74	0.57	0.64	0.50	0.61	0.48	...	...
C-125	...	0.81	0.57	0.66	0.47	0.54	0.40	...	...	0.84	0.62	0.70	0.50	0.59	0.43	...	...	0.88	0.64	0.75	0.54	0.65	0.47	...	...
D-125	...	0.99	0.65	0.75	0.51	0.62	0.42	...	...	1.03	0.68	0.80	0.54	0.67	0.45	...	...	1.07	0.71	0.86	0.58	0.72	0.49	...	...

(Continued)

Table I1 (Continued)

Circumferential reinforcement, in.²/linear ft of pipe

Internal Designated Dia, in.	45*							
Type of Reinforcement	Circular						Elliptical	
Wall thickness, in.	3 7/8		4 3/4		5 3/4		3 7/8	4 3/4
Layers of Reinforcement	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single
Class								
A-25	0.26	0.18	0.22	0.15	0.19	0.13	0.30	0.30
B-25	0.43	0.25	0.33	0.19	0.28	0.15	0.43	0.33
C-25	0.62	0.33	0.46	0.24	0.37	0.19	0.62	0.46
D-25	0.80	0.42	0.58	0.29	0.47	0.22	0.80	0.58
A-50	0.35	0.26	0.30	0.23	0.27	0.21	0.59	0.59
B-50	0.51	0.33	0.42	0.27	0.36	0.23	0.59	0.59
C-50	0.70	0.42	0.54	0.32	0.46	0.27	0.70	0.59
D-50	0.88	0.50	0.67	0.38	0.55	0.30	0.88	0.67
A-75	0.44	0.36	0.39	0.31	0.35	0.28	...	...
B-75	0.61	0.43	0.50	0.36	0.44	0.31	...	...
C-75	0.78	0.51	0.63	0.41	0.54	0.34	...	...
D-75	0.99	0.59	0.75	0.46	0.62	0.37	...	...
A-100	0.53	0.45	0.52	0.43	0.48	0.40	...	...
B-100	0.70	0.52	0.58	0.44	0.52	0.39	...	...
C-100	0.87	0.59	0.71	0.49	0.61	0.42	...	...
D-100	1.08	0.69	0.83	0.54	0.70	0.45	...	...
A-125	0.65	0.53	0.64	0.54	0.63	0.54	...	...
B-125	0.79	0.62	0.67	0.54	0.66	0.51	...	...
C-125	0.98	0.70	0.80	0.57	0.69	0.50	...	...
D-125	1.16	0.77	0.91	0.63	0.78	0.53	...	...

Internal Designated Dia, in.	48							
Type of Reinforcement	Circular						Elliptical	
Wall thickness, in.	4 1/8		5		5 3/4		4 1/8	5
Layers of Reinforcement	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single
Class								
A-25	0.28	0.19	0.24	0.16	0.21	0.14	0.32	0.32
B-25	0.45	0.27	0.36	0.21	0.32	0.18	0.45	0.36
C-25	0.66	0.36	0.50	0.27	0.44	0.22	0.66	0.50
D-25	0.86	0.45	0.65	0.32	0.54	0.26	0.86	0.65
A-50	0.38	0.28	0.32	0.25	0.30	0.23	0.63	0.63
B-50	0.55	0.36	0.45	0.30	0.40	0.26	0.63	0.63
C-50	0.75	0.45	0.59	0.36	0.52	0.30	0.75	0.63
D-50	0.97	0.54	0.73	0.41	0.62	0.34	0.97	0.73
A-75	0.47	0.38	0.42	0.34	0.39	0.31	...	...
B-75	0.65	0.46	0.54	0.39	0.49	0.35	...	...
C-75	0.84	0.54	0.68	0.44	0.60	0.39	...	...
D-75	1.06	0.64	0.81	0.50	0.72	0.43	...	...
A-100	0.57	0.48	0.55	0.45	0.51	0.42	...	...
B-100	0.75	0.55	0.64	0.48	0.57	0.44	...	...
C-100	0.95	0.65	0.77	0.53	0.69	0.47	...	...
D-100	1.15	0.73	0.90	0.58	0.79	0.51	...	...
A-125	0.69	0.56	0.68	0.57	0.67	0.57	...	...
B-125	0.84	0.66	0.73	0.57	0.70	0.55	...	...
C-125	1.05	0.74	0.86	0.63	0.77	0.56	...	...
D-125	1.24	0.83	1.00	0.68	0.87	0.59	...	...

Internal Designated Dia, in.	51*							
Type of Reinforcement	Circular						Elliptical	
Wall thickness, in.	4 1/4		5 1/4		6		4 1/4	5 1/4
Layers of Reinforcement	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single
Class								
A-25	0.30	0.20	0.25	0.17	0.23	0.15	0.34	0.34
B-25	0.49	0.29	0.38	0.22	0.34	0.19	0.49	0.38
C-25	0.72	0.40	0.53	0.28	0.47	0.24	0.72	0.53
D-25	0.97	0.50	0.69	0.35	0.58	0.28	...	0.69
A-50	0.41	0.30	0.35	0.26	0.32	0.25	0.67	0.67
B-50	0.58	0.39	0.48	0.31	0.43	0.28	0.67	0.67
C-50	0.81	0.49	0.63	0.38	0.55	0.33	0.81	0.67
D-50	1.06	0.59	0.77	0.44	0.68	0.37	...	0.77
A-75	0.50	0.41	0.44	0.36	0.42	0.33	...	...
B-75	0.69	0.49	0.57	0.41	0.52	0.37	...	...
C-75	0.90	0.58	0.72	0.47	0.65	0.42	...	...
D-75	1.14	0.70	0.86	0.53	0.76	0.46	...	...
A-100	0.62	0.51	0.59	0.48	0.54	0.45	...	...
B-100	0.79	0.59	0.67	0.50	0.61	0.46	...	...
C-100	1.02	0.70	0.81	0.56	0.73	0.50	...	...
D-100	1.24	0.79	0.97	0.63	0.84	0.54	...	...
A-125	0.74	0.60	0.73	0.60	0.72	0.61	...	...
B-125	0.89	0.70	0.76	0.61	0.74	0.58	...	...
C-125	1.12	0.79	0.91	0.66	0.82	0.59	...	...
D-125	1.33	0.89	1.06	0.72	0.94	0.64	...	...

(Continued)

(Sheet 4 of 8)

Table I1 (Continued)

Circumferential reinforcement, in.²/linear ft of pipe																								
Internal Designated Dia, in.	54								57[b]								60							
Type of Reinforcement	Circular						Elliptical		Circular						Elliptical		Circular						Elliptical	
Wall thickness, in.	4½		5½		6¼		4½	5½	4¾		5¼		6½		4¾	5¼	5		6		6¾		5	6
Layers of Reinforcement	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single
Class																								
A-25	0.31	0.21	0.27	0.18	0.25	0.16	0.36	0.36	0.33	0.22	0.28	0.19	0.26	0.17	0.38	0.38	0.35	0.23	0.30	0.20	0.28	0.18	0.39	0.39
B-25	0.50	0.30	0.40	0.23	0.36	0.20	0.50	0.40	0.52	0.31	0.43	0.25	0.38	0.22	0.52	0.43	0.54	0.32	0.45	0.26	0.41	0.23	0.54	0.45
C-25	0.75	0.41	0.57	0.30	0.50	0.26	0.75	0.57	0.78	0.43	0.61	0.32	0.53	0.28	0.78	0.61	0.81	0.45	0.64	0.35	0.56	0.29	0.81	0.64
D-25	1.00	0.52	0.73	0.37	0.63	0.30	...	0.73	1.03	0.54	0.77	0.40	0.67	0.33	...	0.77	1.07	0.56	0.81	0.42	0.71	0.35	...	0.81
A-50	0.42	0.32	0.37	0.28	0.34	0.26	0.71	0.71	0.44	0.33	0.39	0.29	0.36	0.28	0.75	0.75	0.46	0.35	0.41	0.31	0.38	0.29	0.78	0.78
B-50	0.62	0.41	0.50	0.33	0.46	0.30	0.71	0.71	0.64	0.42	0.52	0.35	0.48	0.32	0.75	0.75	0.66	0.44	0.55	0.37	0.51	0.33	0.78	0.78
C-50	0.84	0.51	0.67	0.40	0.59	0.35	0.85	0.71	0.87	0.53	0.71	0.42	0.64	0.37	0.90	0.75	0.91	0.55	0.74	0.45	0.67	0.39	0.96	0.78
D-50	1.09	0.63	0.82	0.46	0.72	0.39	...	0.82	1.13	0.65	0.86	0.49	0.77	0.43	...	0.88	1.16	0.67	0.91	0.52	0.81	0.45	...	0.94
A-75	0.53	0.43	0.47	0.38	0.44	0.35	...	...	0.55	0.44	0.49	0.40	0.47	0.37	...	...	0.57	0.46	0.52	0.42	0.49	0.39	...	...
B-75	0.72	0.51	0.60	0.43	0.55	0.39	...	...	0.74	0.53	0.63	0.45	0.58	0.42	...	...	0.77	0.55	0.66	0.47	0.61	0.44	...	...
C-75	0.96	0.62	0.76	0.50	0.69	0.45	...	...	1.00	0.64	0.80	0.52	0.73	0.47	...	...	1.03	0.67	0.85	0.55	0.77	0.50	...	...
D-75	1.18	0.72	0.91	0.56	0.81	0.49	...	...	1.22	0.75	0.97	0.59	0.86	0.52	...	...	1.26	0.78	1.02	0.63	0.92	0.55	...	...
A-100	0.64	0.53	0.62	0.51	0.58	0.47	...	...	0.67	0.55	0.66	0.54	0.61	0.50	...	...	0.70	0.57	0.70	0.56	0.64	0.53	...	...
B-100	0.82	0.62	0.70	0.53	0.65	0.49	...	...	0.85	0.64	0.74	0.55	0.68	0.52	...	...	0.88	0.67	0.77	0.58	0.72	0.54	...	...
C-100	1.06	0.72	0.86	0.59	0.78	0.54	...	...	1.10	0.75	0.90	0.63	0.82	0.57	...	...	1.14	0.78	0.96	0.66	0.87	0.60	...	...
D-100	1.28	0.82	1.02	0.66	0.89	0.58	...	...	1.32	0.85	1.07	0.69	0.96	0.62	...	...	1.39	0.88	1.12	0.73	1.01	0.65	...	...
A-125	0.77	0.64	0.77	0.64	0.76	0.64	...	...	0.82	0.67	0.82	0.68	0.80	0.67	...	...	0.86	0.71	0.85	0.72	0.85	0.71	...	...
B-125	0.92	0.73	0.80	0.64	0.78	0.62	...	...	0.97	0.75	0.83	0.68	0.82	0.65	...	...	1.01	0.78	0.86	0.72	0.87	0.69	...	...
C-125	1.16	0.82	0.97	0.70	0.87	0.64	...	...	1.20	0.85	1.02	0.73	0.92	0.67	...	...	1.25	0.89	1.07	0.77	0.98	0.71	...	...
D-125	1.40	0.92	1.11	0.76	1.00	0.68	...	...	1.45	0.97	1.17	0.79	1.06	0.72	...	...	1.50	1.00	1.22	0.83	1.11	0.76	...	...

(Continued)

(Sheet 5 of 8)

Table I1 (Continued)

Circumferential reinforcement, in.²/linear ft of pipe																								
Internal Designated Dia, in.	63*								66										69*					
Type of Reinforcement	Circular						Elliptical		Circular						Elliptical		Circular						Elliptical	
Wall Thickness, in.	5¼		6¼		7		5¼	6¼	5½		6½		7¼		5½	6½	5¾		6¾		7½		6¾	7½
Layers of Reinforcement	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single
Class																								
A-25	0.37	0.25	0.32	0.22	0.30	0.20	0.41	0.41	0.39	0.26	0.34	0.23	0.32	0.21	0.43	0.43	0.41	0.27	0.36	0.24	0.33	0.22	0.45	0.45
B-25	0.57	0.35	0.48	0.28	0.43	0.25	0.57	0.48	0.59	0.36	0.50	0.29	0.45	0.26	0.60	0.50	0.62	0.37	0.52	0.31	0.48	0.28	0.63	0.53
C-25	0.85	0.47	0.68	0.37	0.60	0.31	0.85	0.68	0.87	0.49	0.71	0.38	0.63	0.33	0.87	0.71	0.89	0.50	0.73	0.40	0.66	0.35	0.90	0.73
D-25	1.13	0.59	0.87	0.45	0.76	0.38	...	0.87	1.17	0.63	0.91	0.47	0.81	0.41	...	0.91	1.20	0.65	0.97	0.50	0.85	0.43	...	0.97
A-50	0.49	0.37	0.44	0.33	0.41	0.31	0.82	0.82	0.51	0.39	0.46	0.35	0.43	0.33	0.86	0.86	0.53	0.40	0.48	0.36	0.46	0.34	0.90	0.90
B-50	0.69	0.46	0.58	0.39	0.54	0.36	0.82	0.82	0.72	0.48	0.62	0.41	0.57	0.37	0.86	0.86	0.74	0.49	0.64	0.43	0.59	0.39	0.90	0.90
C-50	0.97	0.58	0.79	0.47	0.71	0.42	1.01	0.83	1.00	0.61	0.82	0.49	0.74	0.44	1.05	0.87	1.02	0.63	0.85	0.51	0.77	0.47	1.10	0.92
D-50	1.23	0.71	0.98	0.55	0.87	0.49	...	1.01	1.27	0.74	1.03	0.58	0.92	0.51	...	1.07	1.31	0.76	1.08	0.62	0.97	0.54	...	1.14
A-75	0.62	0.49	0.55	0.44	0.52	0.42	...	...	0.64	0.51	0.58	0.46	0.55	0.44	...	...	0.67	0.53	0.61	0.48	0.58	0.46	...	...
B-75	0.81	0.57	0.70	0.50	0.66	0.47	...	...	0.84	0.60	0.73	0.52	0.69	0.49	...	...	0.86	0.62	0.76	0.55	0.72	0.52	...	...
C-75	1.08	0.70	0.89	0.58	0.82	0.53	...	...	1.11	0.73	0.94	0.61	0.85	0.56	...	...	1.14	0.75	0.97	0.64	0.90	0.58	...	...
D-75	1.36	0.82	1.09	0.67	0.98	0.59	...	...	1.40	0.85	1.14	0.70	1.03	0.63	...	...	1.45	0.88	1.19	0.73	1.08	0.66	...	...
A-100	0.74	0.61	0.73	0.59	0.68	0.55	...	...	0.76	0.63	0.77	0.62	0.71	0.57	...	...	0.79	0.66	0.80	0.64	0.74	0.60	...	...
B-100	0.92	0.70	0.81	0.62	0.76	0.57	...	...	0.97	0.73	0.85	0.65	0.79	0.61	...	...	1.00	0.75	0.88	0.68	0.83	0.64	...	...
C-100	1.20	0.82	1.01	0.70	0.92	0.64	...	...	1.23	0.84	1.05	0.73	0.97	0.67	...	...	1.26	0.87	1.09	0.76	1.01	0.70	...	...
D-100	1.47	0.95	1.19	0.77	1.08	0.70	...	...	1.51	0.98	1.25	0.81	1.13	0.73	...	...	1.56	1.01	1.30	0.85	1.19	0.77	...	...
A-125	0.90	0.74	0.90	0.75	0.89	0.75	...	...	0.95	0.78	0.94	0.79	0.93	0.78	...	...	0.99	0.82	0.98	0.82	0.97	0.82	...	...
B-125	1.06	0.82	0.93	0.75	0.91	0.72	...	...	1.09	0.85	0.96	0.79	0.95	0.76	...	...	1.13	0.88	1.00	0.82	1.00	0.79	...	...
C-125	1.31	0.95	1.13	0.81	1.04	0.75	...	...	1.37	0.98	1.17	0.84	1.08	0.78	...	...	1.40	1.01	1.21	0.88	1.12	0.82	...	...
D-125	1.58	1.06	1.30	0.88	1.18	0.81	...	...	1.62	1.09	1.38	0.92	1.24	0.84	...	...	1.68	1.13	1.43	0.97	1.30	0.88	...	...

(Continued)

(Sheet 6 of 8)

Table I1 (Continued)

Circumferential reinforcement, in.²/linear ft of pipe

Internal Designated Dia, in.*	72								78						84					
Type of Reinforcement	Circular						Elliptical		Circular						Circular					
Wall thickness, in.	6		7		7¾		6	7	6½		7½		8¼		7		8		8¾	
Layers of Reinforcement	Inner	Outer	Inner	Outer	Inner	Outer	Single	Single	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer
Class																				
A-25	0.45	0.30	0.40	0.26	0.37	0.24	0.48	0.47	0.49	0.32	0.43	0.29	0.41	0.27	0.53	0.35	0.47	0.31	0.45	0.29
B-25	0.68	0.41	0.57	0.34	0.52	0.30	0.68	0.57	0.72	0.44	0.62	0.37	0.57	0.33	0.77	0.46	0.67	0.40	0.62	0.36
C-25	1.00	0.55	0.80	0.44	0.72	0.38	1.00	0.80	1.04	0.58	0.86	0.47	0.78	0.42	1.09	0.62	0.91	0.51	0.84	0.45
D-25	1.37	0.72	1.07	0.55	0.95	0.47	...	1.07	1.44	0.76	1.15	0.61	1.04	0.52	1.51	0.81	1.23	0.65	1.11	0.57
A-50	0.59	0.44	0.53	0.40	0.50	0.37	0.94	0.94	0.64	0.47	0.57	0.43	0.55	0.41	0.68	0.50	0.63	0.46	0.59	0.44
B-50	0.81	0.54	0.70	0.47	0.65	0.43	0.94	0.94	0.86	0.57	0.76	0.50	0.71	0.47	0.92	0.62	0.82	0.54	0.77	0.51
C-50	1.12	0.69	0.92	0.56	0.84	0.51	1.15	0.96	1.17	0.72	1.00	0.61	0.92	0.55	1.23	0.76	1.06	0.65	0.99	0.59
D-50	1.48	0.84	1.18	0.68	1.07	0.59	...	1.20	1.57	0.89	1.28	0.74	1.16	0.66	1.64	0.96	1.38	0.79	1.26	0.71
A-75	0.73	0.58	0.66	0.53	0.63	0.51	...	...	0.78	0.62	0.72	0.57	0.69	0.55	0.84	0.66	0.78	0.62	0.75	0.59
B-75	0.96	0.68	0.83	0.60	0.78	0.56	...	...	1.02	0.73	0.90	0.65	0.85	0.61	1.08	0.77	0.97	0.70	0.92	0.66
C-75	1.25	0.82	1.06	0.70	0.98	0.64	...	...	1.31	0.86	1.13	0.75	1.05	0.69	1.39	0.91	1.21	0.80	1.13	0.74
D-75	1.60	0.98	1.31	0.80	1.19	0.72	...	...	1.69	1.04	1.43	0.87	1.31	0.79	1.78	1.10	1.52	0.94	1.40	0.85
A-100	0.87	0.72	0.83	0.68	0.77	0.63	...	...	0.94	0.77	0.90	0.73	0.83	0.68	1.00	0.82	0.97	0.79	0.90	0.73
B-100	1.10	0.82	0.97	0.73	0.90	0.69	...	...	1.16	0.87	1.05	0.79	0.98	0.74	1.23	0.92	1.12	0.84	1.06	0.80
C-100	1.40	0.96	1.19	0.82	1.09	0.76	...	...	1.47	1.01	1.27	0.88	1.17	0.82	1.54	1.07	1.36	0.95	1.26	0.88
D-100	1.73	1.11	1.45	0.94	1.30	0.84	...	...	1.85	1.18	1.56	1.01	1.42	0.91	1.94	1.24	1.65	1.08	1.52	0.99
A-125	1.04	0.85	1.03	0.85	1.02	0.85	...	...	1.12	0.91	1.12	0.92	1.11	0.91	1.20	0.99	1.21	0.99	1.19	0.98
B-125	1.23	0.97	1.11	0.87	1.04	0.82	...	...	1.31	1.03	1.19	0.94	1.13	0.89	1.40	1.09	1.27	1.00	1.21	0.96
C-125	1.53	1.10	1.32	0.97	1.22	0.89	...	...	1.61	1.16	1.42	1.03	1.31	0.96	1.68	1.22	1.51	1.10	1.42	1.03
D-125	1.89	1.24	1.57	1.07	1.43	0.97	...	...	1.98	1.31	1.69	1.15	1.55	1.05	2.08	1.40	1.79	1.22	1.66	1.13

(Continued)

(Sheet 7 of 8)

Table I1 (Concluded)

Internal Designated Dia, in.	90				96				102				108			
Type of Reinforcement	Circular				Circular				Circular				Circular			
Wall thickness, in.	$7^1/_2$		8		8		$8^1/_2$		$8^1/_2$		9		9		$9^1/_2$	
Layers of Reinforcement	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer
Class																
A-25	0.57	0.38	0.54	0.36	0.62	0.41	0.58	0.39	0.66	0.44	0.63	0.42	0.71	0.47	0.68	0.45
B-25	0.82	0.49	0.77	0.46	0.87	0.53	0.82	0.49	0.92	0.56	0.87	0.52	0.99	0.59	0.94	0.56
C-25	1.14	0.65	1.06	0.59	1.20	0.68	1.12	0.63	1.26	0.72	1.18	0.67	1.32	0.76	1.24	0.71
D-25	1.57	0.84	1.43	0.76	1.62	0.88	1.49	0.80	1.69	0.92	1.56	0.84	1.75	0.97	1.64	0.89
A-50	0.73	0.54	0.70	0.52	0.78	0.57	0.75	0.55	0.84	0.62	0.81	0.59	0.89	0.65	0.86	0.63
B-50	0.98	0.66	0.92	0.62	1.04	0.70	0.99	0.66	1.10	0.74	1.05	0.70	1.16	0.78	1.11	0.74
C-50	1.29	0.80	1.20	0.74	1.37	0.84	1.27	0.79	1.44	0.89	1.35	0.83	1.50	0.94	1.43	0.88
D-50	1.70	1.00	1.57	0.90	1.77	1.04	1.64	0.96	1.86	1.09	1.72	1.01	1.93	1.14	1.80	1.06
A-75	0.89	0.71	0.86	0.68	0.96	0.75	0.92	0.73	1.02	0.80	0.99	0.77	1.08	0.84	1.05	0.82
B-75	1.14	0.81	1.08	0.78	1.21	0.86	1.15	0.82	1.27	0.91	1.22	0.87	1.36	0.97	1.29	0.92
C-75	1.46	0.96	1.37	0.90	1.53	1.01	1.44	0.96	1.60	1.07	1.52	1.01	1.68	1.12	1.60	1.07
D-75	1.87	1.15	1.71	1.06	1.94	1.20	1.79	1.12	2.02	1.25	1.89	1.17	2.10	1.31	1.98	1.23
A-100	1.07	0.87	1.04	0.84	1.13	0.92	1.11	0.90	1.20	0.98	1.17	0.96	1.27	1.04	1.24	1.01
B-100	1.30	0.99	1.24	0.94	1.39	1.04	1.32	1.00	1.46	1.10	1.41	1.06	1.54	1.15	1.49	1.12
C-100	1.61	1.12	1.52	1.06	1.69	1.18	1.60	1.12	1.77	1.24	1.69	1.18	1.87	1.30	1.78	1.25
D-100	2.01	1.30	1.88	1.21	2.09	1.37	1.96	1.28	2.18	1.43	2.05	1.35	2.27	1.49	2.15	1.42
A-125	1.29	1.06	1.29	1.06	1.38	1.13	1.38	1.13	1.47	1.19	1.47	1.19	1.56	1.26	1.55	1.26
B-125	1.48	1.15	1.42	1.11	1.56	1.21	1.50	1.17	1.64	1.28	1.58	1.24	1.73	1.35	1.67	1.30
C-125	1.77	1.28	1.68	1.22	1.87	1.36	1.77	1.29	1.96	1.43	1.88	1.37	2.05	1.49	1.97	1.44
D-125	2.16	1.47	2.02	1.38	2.25	1.53	2.12	1.45	2.34	1.60	2.22	1.52	2.46	1.67	2.32	1.60

Circumferential reinforcement, in²/linear ft of pipe

(Sheet 8 of 8)

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McDonald, James E
Precast concrete elements for structures in selected theaters of operations / by James E. McDonald, Tony C. Liu. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.
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