PRESTRESSED PAVEMENT
VOL. 3, CONSTRUCTION MANUAL

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and Technology
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Research Center
6300 Georgetown Pike
McLean, Virginia 22101

Report No.
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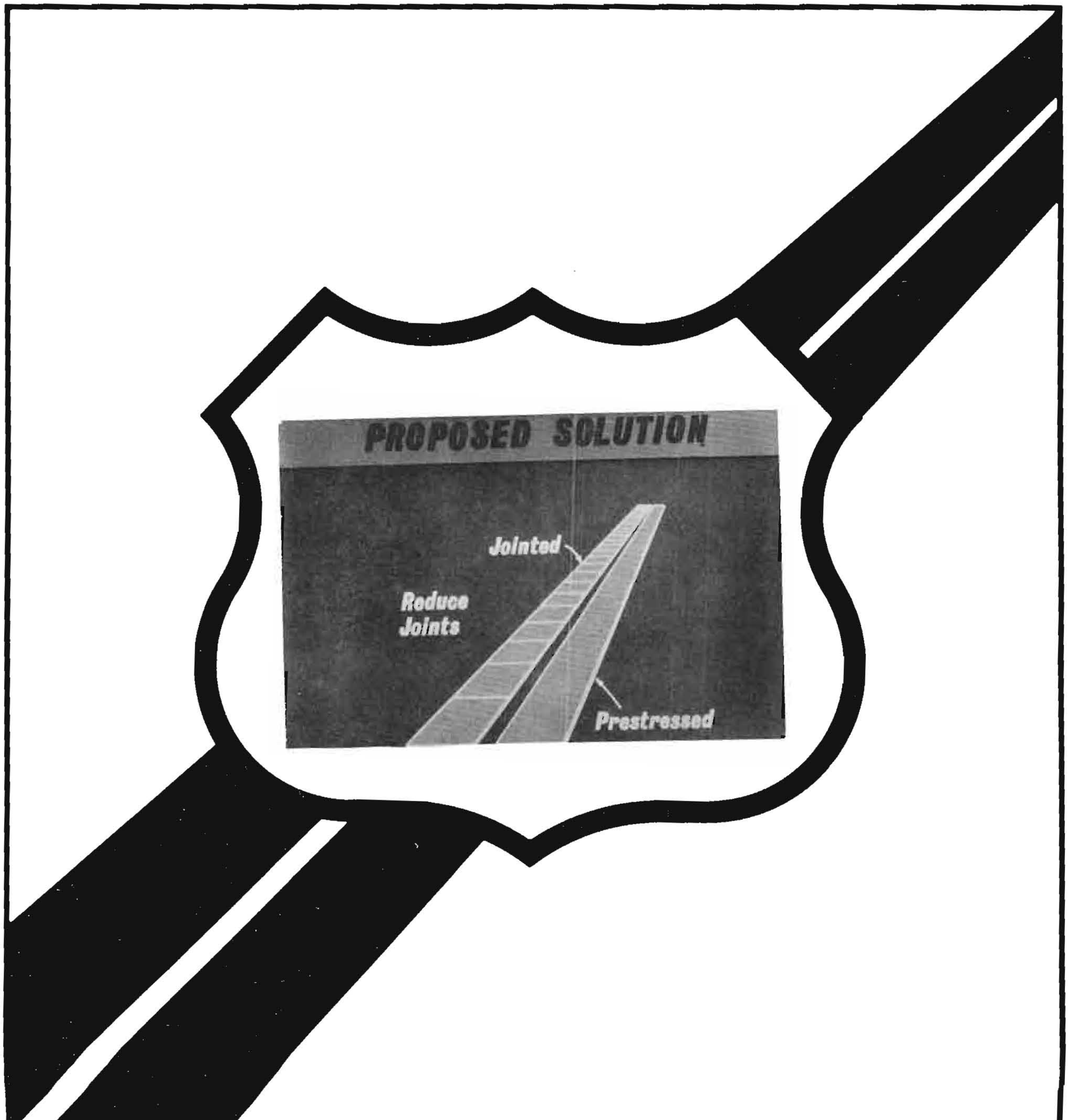
U.S. Department
of Transportation
**Federal Highway
Administration**

Final Report
June 1983



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FOREWORD

Highway administrators and engineers must select among alternative pavement investment and maintenance strategies. These decisions should be based upon economic analyses of the impacts expected for each pavement management strategy. Prestressed pavements offer an alternative type of strategy because of thinner slabs, fewer joints, and an expected reduction in maintenance costs.

Volume 3 is a manual which may be used to supplement standard specifications for concrete pavement construction. Information is provided on procedures and materials that differ significantly from those used with conventional pavements. The other volumes are:

FHWA/RD-82/090, Volume 1, "Joint Designs"
FHWA/RD-82/091, Volume 2, "Thickness Design"
FHWA/RD-82/115, Volume 4, "Prestressed Pavement Accelerated Testing Program" (available only from NTIS)
FHWA/RD-82/114, Volume 5, "Evaluation of Innovative Concepts Relating to Prestressed Concrete Pavements" (available only from NTIS).

Richard E. Hay, Director
Office of Engineering
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16. Abstract

This manual presents information on procedures and materials for prestressed pavement construction that differ significantly from those used with conventional pavements. Figures illustrate details of bulkhead construction, anchorage assemblies, jacking accessories, and joint hardware placement.

The manual may be used to supplement standard specifications for concrete pavement construction.

17. Key Words anchors, bulkheads, concrete, concrete pavement, construction, joints, prestressed pavement, prestress, steel, subbase

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METRIC CONVERSION FACTORS

APPROXIMATE CONVERSIONS FROM METRIC MEASURES

LENGTH

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km

AREA

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.6	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha

MASS (weight)

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t

VOLUME

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3

TEMPERATURE (exact)

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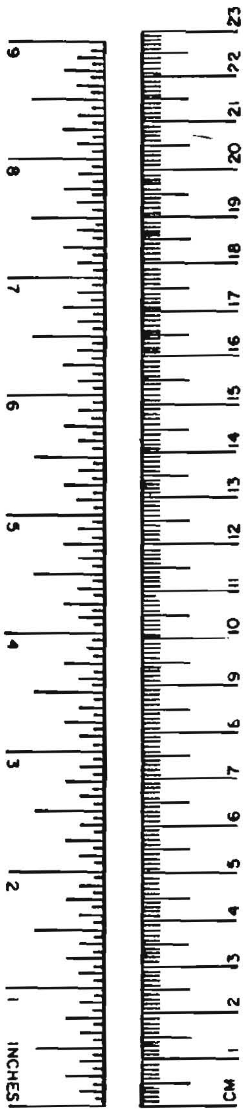
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS FROM METRIC MEASURES

LENGTH

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi

AREA

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	

MASS (weight)

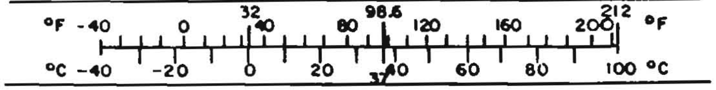
SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	

VOLUME

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3

TEMPERATURE (exact)

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

This report has been prepared as part of a contract between FHWA and the Construction Technology Laboratories, Division of the Portland Cement Association.

It is the third of a five-volume series concerning design of prestressed concrete pavements. The series consists of the following reports.

1. Prestressed Pavement Joint Designs
2. Prestressed Pavement Thickness Design
3. Prestressed Pavement Construction Manual
4. Prestressed Pavement Accelerated Testing Program
5. Evaluation of Innovative Concepts Relating to Prestressed Concrete Pavements

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INTRODUCTION

The objective of Federal Highway Administration's Research Project 5E, Premium Pavements for "Zero Maintenance" is to exploit modern materials and technology in developing "Zero Maintenance" pavements for warranted use.

As a portion of this research project, an investigation has been conducted by the Construction Technology Laboratories, a Division of the Portland Cement Association, to develop design and construction techniques for prestressed concrete pavements.

Prestressed pavement slabs are cast on cement or bituminous stabilized subbases. Concrete is deposited either with pavers riding on forms or by slip-form. Principal differences between conventional and prestressed pavements are that prestressed pavements are thinner, individual slabs are several hundred feet long, and friction reducing membranes are placed between slab and subbase.

Pavement widths are generally two lanes or wider with weakened plane longitudinal joints. A succession of prestressed slabs, separated by gap slab spaces are paved at one time. Gaps are provided between long slabs to facilitate main slab post-tensioning operations and placement of joint hardware. After hardware placement, these gaps are paved. Depending on anticipated pavement length changes, gap slab joints may consist of two active or one active and one construction type.

Concrete is subject to appreciable drying shrinkage during the first few days after casting. Therefore, prestressing is initiated as early as possible to prevent transverse cracking.

This manual presents information on procedures and materials for prestressed pavement construction that differ significantly from those used with conventional pavements. Discussion on bulkheads, anchors, and gap slab construction is presented for each of the four joint designs developed for work reported in "Prestressed Pavement Joint Designs."(1)

TENDONS AND REINFORCEMENT

Plastic encased seven-wire high-strength stress-relieved strands are recommended for prestressing main slabs. Gap slabs are either prestressed or conventionally reinforced. When prestressed, either strands or a combination of strands and rods are used. All prestressing is in the longitudinal direction. Transverse reinforcement is used near ends of main slabs and in all gap slabs. Details of tendons and reinforcement follow.

Plastic Encased Strands

Main slab tendons are seven-wire stress-relieved strand with strength of 270 ksi (1.86 GPa). Recommended strand stress at application of final tensioning is 70-80 percent of strength.

Each strand is covered with grease to reduce friction as it slides within a semi-rigid plastic encasement. These encasements should be strong enough to withstand unreeling and handling without splits or tears and without excessive shape deformation. The plastic should not bond to concrete. However, it should have sufficient elasticity to stretch at low temperatures across open pavement cracks without rupture or pinching at cracks upon closure.

Plastic tubing damaged for a limited length without damage to the strand, may be repaired in place. All repairs should be inspected and approved by the engineer. The strand should be regreased and encased in slip-on split plastic tubing of appropriate size and length. Split tubing, after application, should overlap by at least 1/4-in (6 mm). In addition, tubing should extend at least 3 in (76 mm) beyond damaged length. Tubing should be securely wrapped in place with not less than 2-in (51 mm) wide waterproof adhesive tape. Taping should extend beyond the tubing to prevent slipping and to assist in waterproofing.

Gap Slab Stress Rods

Gap slab stress rods are available in diameters from 3/4-in (19 mm) to 1-3/8-in (35 mm). Rods are hot rolled and cold stretched to meet ASTM Designation: A-722 "Uncoated High Strength Steel Bar for Prestressing Concrete."(2) Ends may be threaded or milled. Breaking strength is 150 ksi (1.1 GPa).

Gap slab rods are coated with grease and covered with split plastic tubing.

Deformed Reinforcing Steel

Deformed reinforcing bars are used near ends of main slabs in gap slabs, and as tie bars at longitudinal joints. Deformed bars should meet ASTM Designation: A615-76a "Deformed and Plain Billet-Steel Bars for Concrete Reinforcement."(3) Generally, Grade 60 reinforcement is specified for slab ends and gap slabs.

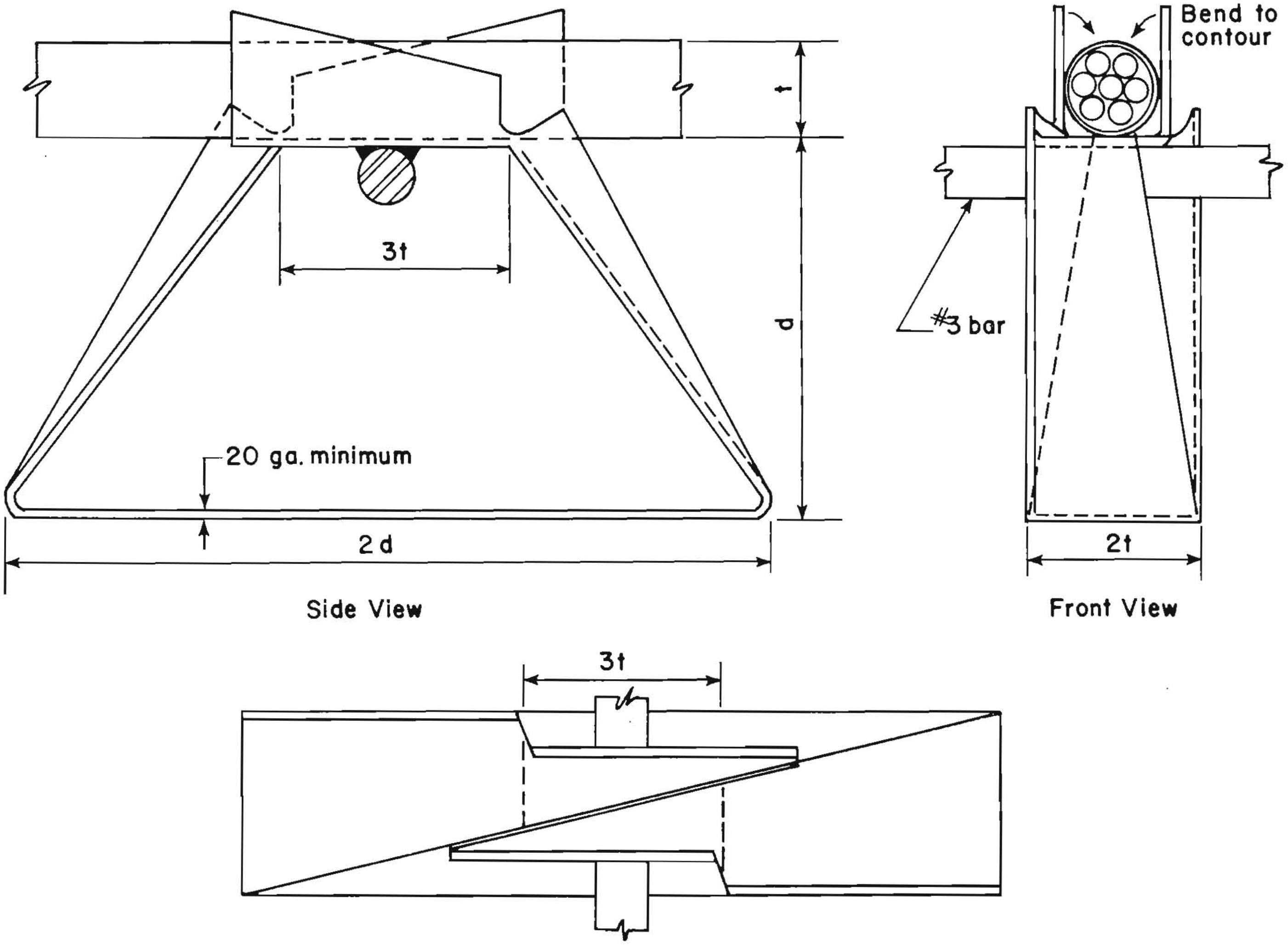
PLACEMENT OF TENDONS AND REINFORCEMENT

Tendons and reinforcement may be either preplaced on supports positioned on the subbase or they may be placed as part of slipforming operations. Recommended procedures for each placement method are discussed.

Preplaced Steel

Tendons and transverse reinforcement are supported on chairs placed on top of the friction reducing membrane. Supporting chairs should be free from sharp corners or edges that could tear the membrane. Support dimensions must be sufficient to keep tendons and bars stable during concrete placement. Near main slab ends where transverse reinforcement is placed, supports of the type shown in Figure 1 are recommended. If wire ties are used to position tendons on top of rebars, short sections of split tubing are inserted over the strand to prevent cutting of the encasement.

When steel is preplaced, tendons may be precut at each gap slab, and strand anchors slipped over the tendons and positioned at bulkheads before concreting. Sufficient strand lengths must



Side View

Front View

Top View: Strand removed

FIGURE 1 - Tendon Support

be left at main slab ends for post-tensioning jacks and for extending to permanent anchorages at active joints.

Slipped-in Steel

Tendons are slipped into the concrete and transverse reinforcement is vibrated into place in slip-form paving. Bulkheads provided with slots are preplaced to permit continuity of strand placement as the spreader passes. Tendons are unreeled and laid at approximate spacing on the friction reducing membrane for several slab lengths ahead of the paver. Tendons are pulled into the concrete through guides attached to the spreader.

Tendon placement guides may be pipes or J-shaped sections that are rigidly attached to the spreader frame work. Guides are positioned at correct spacing and elevation. They extend through the concrete spreader box and for a substantial distance into the previously placed concrete. Forward ends of guides are flared to prevent damage to plastic strand enclosures. Guides should have sufficient strength to resist displacement during concrete placing, but should not be so large as to cause excessive voids around the strand. Vibrators on the finisher consolidate concrete around the tendons. Vibrators are placed midway between strands so as not to force strands out of position.

Transverse rebars are vibrated into the concrete immediately above tendons. Care is necessary to properly position bars and to prevent their displacement.

BULKHEADS

Bulkheads are used to form ends of long slabs and block out gap slabs. Bulkheads are securely held in place by pinning to the subbase or by bracing across the gap slab space. Bulkhead details are presented for four designs to be used with slipped-in method of tendon placement. These designs were developed for work reported in "Prestress Pavement Joint Design."(1) Features of each design are listed in Table 1. Overall views

TABLE 1 - JOINT DESIGN FEATURES

Item	Design I	Design II	Design III	Design IV
Main Slab Length, ft	350	350	350	250
Main Slab Thickness, in	8	8	8	7
Gap Slab Length, in	59	59	59	59
Gap Slab Thickness, in	8	8	8	10
Concrete Shoulder Provision	None	None	None	Yes
Gap Slab Prestress Tendon	Strand	Rods	Rods	None
Number of Active Joints at Each Gap Slab	1	1	1	2
Infiltration Prevention Device	Strip Seal	Strip Seal	Cover Plate	Compression Seal

1 in = 25.4 mm
1 ft = 0.30 m

of hardware at gap slab joints for each design are shown in Figures 2, 3, 4, and 5.

Design I

Design I active joint and construction joint bulkheads are shown in Figures 6 and 7, respectively. The active joint bulkhead is provided with cutouts to accommodate passage of cylindrical guides attached to the paver used to locate tendons. Dowels are tied to semicircular sleeves which locate them accurately in the slab. Additional support for dowels may be provided with dowel baskets.

Concrete is left out for the first six inches of main slab length, allowing for placement of split plastic pocket formers, and sheet metal inserts to restrain concrete at bulkhead cutouts. Concrete is then hand-placed and consolidated with spud vibrators. Placement of joint hardware and concrete should be completed before onset of initial set of main slab concrete. Lower strip seal holders are embedded in the plastic concrete.

The construction joint bulkhead (Figure 7) is slotted to allow passage of the paver. After concrete placement, cutouts are sealed with sheet metal inserts.

Design II

Both active joint and construction joint bulkheads for Design II are identical to those for Design I. However, due to the different anchors used in the Design II active joint, different split pocket formers and sheet metal inserts are required. These are shown in Figures 8 and 9. The construction sequence at both bulkheads is identical to that in Design I.

Design III

The active joint bulkhead for Design III is shown in Figure 10. This bulkhead is designed to allow passage of the paver and to support the steel angle to which the cover plate will be attached.

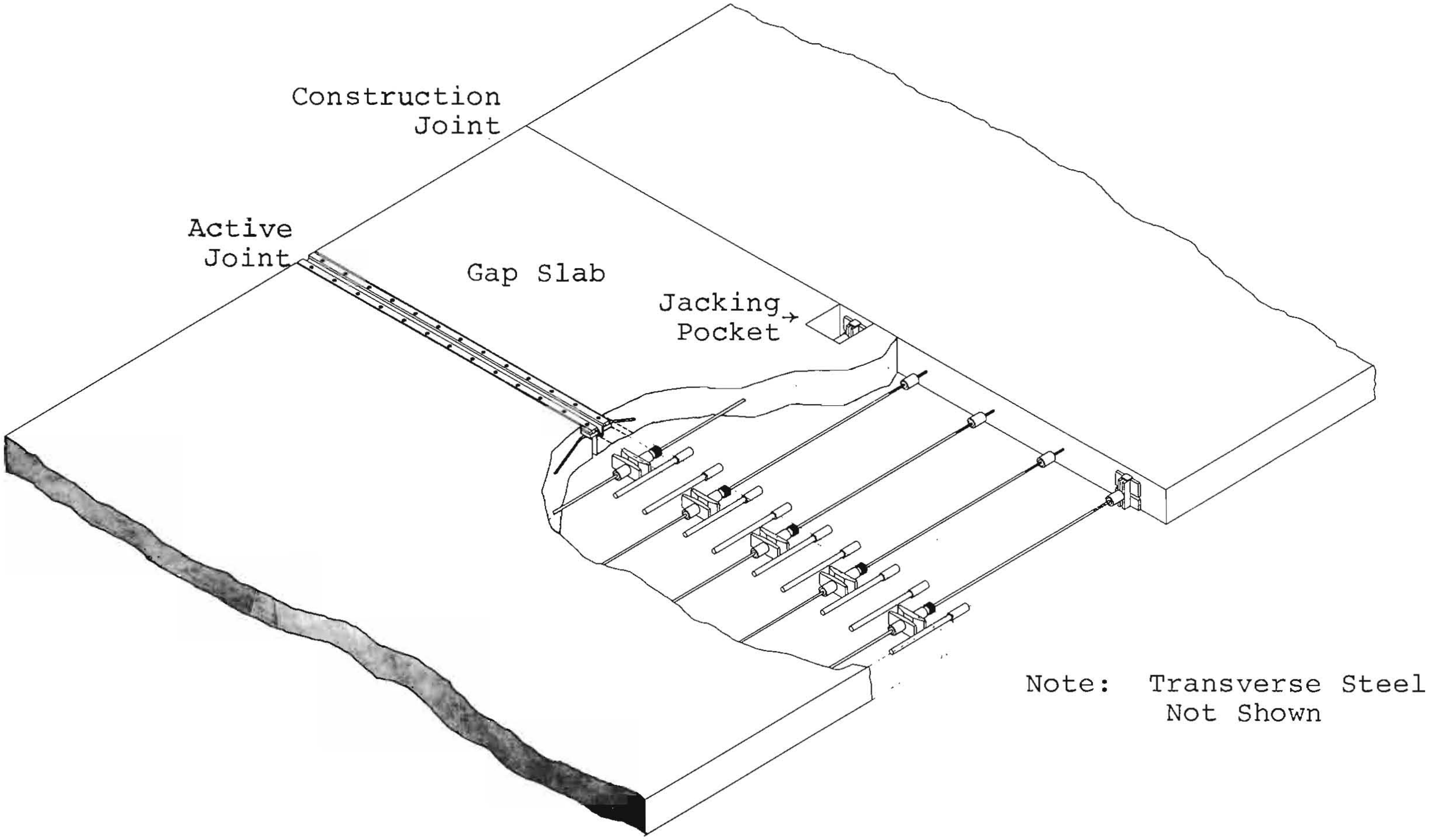


Figure 2 - Overall View Design I

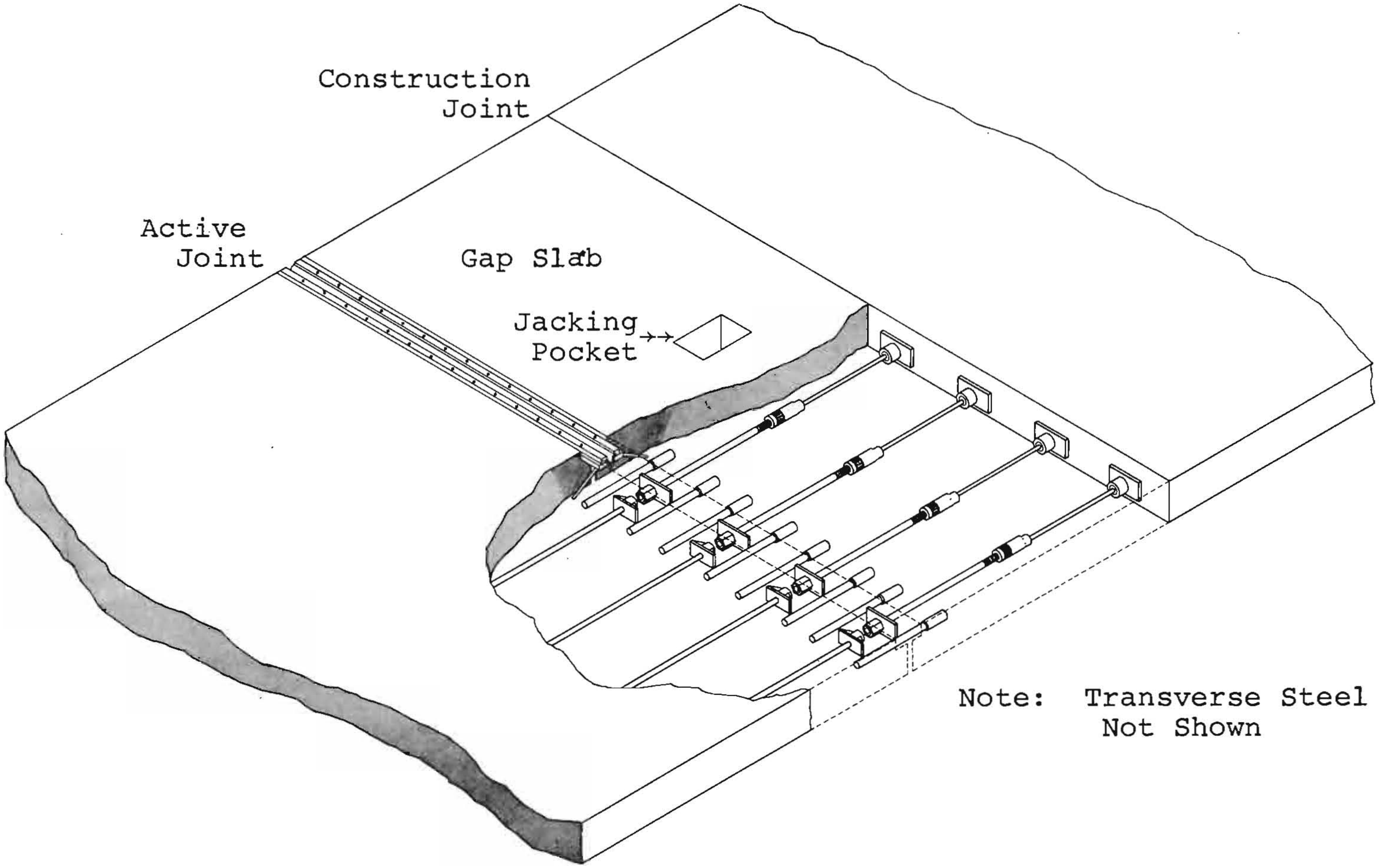
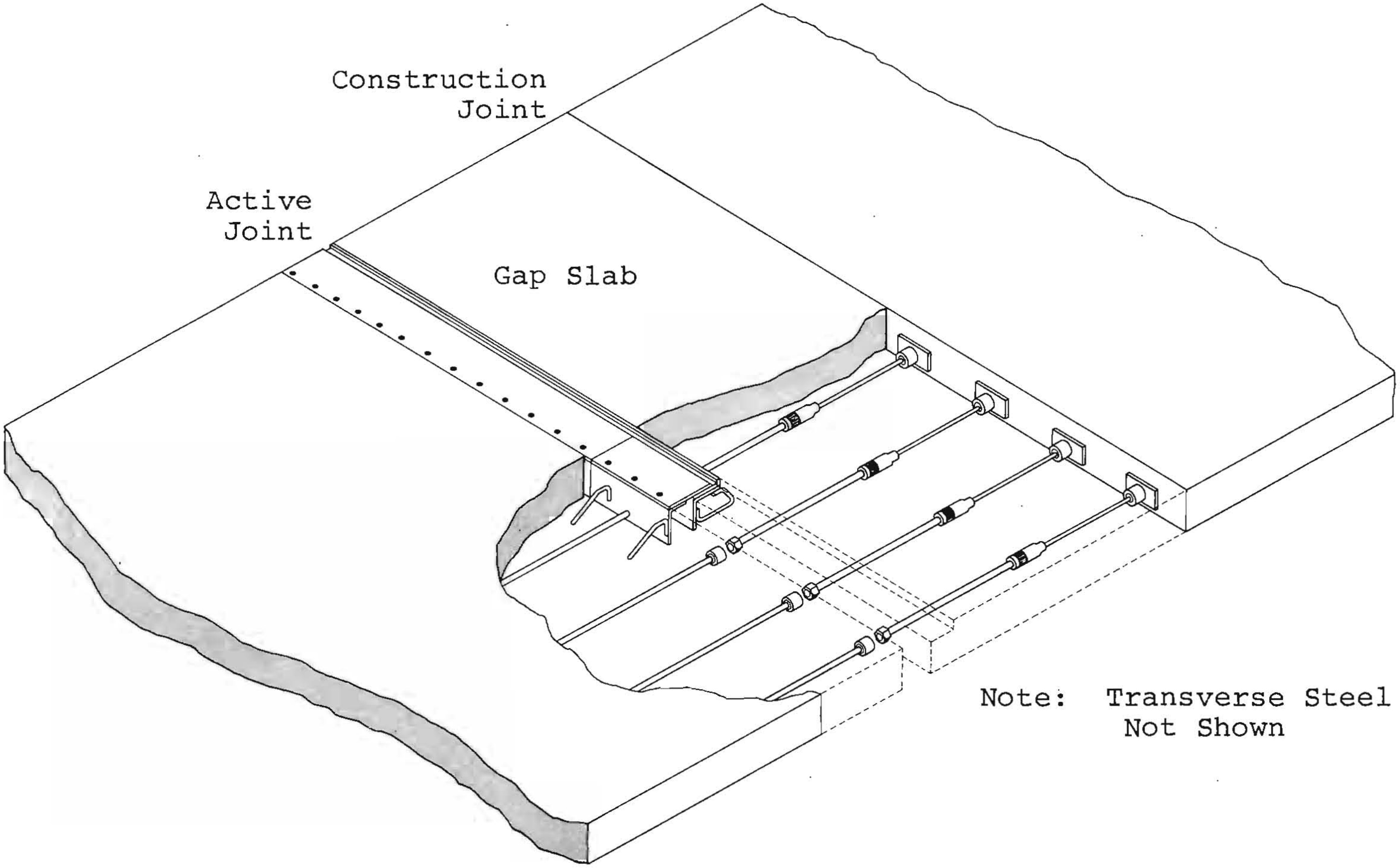


Figure 3 - Overall View Design II



Note: Transverse Steel Not Shown

Figure 4 - Overall View Design III

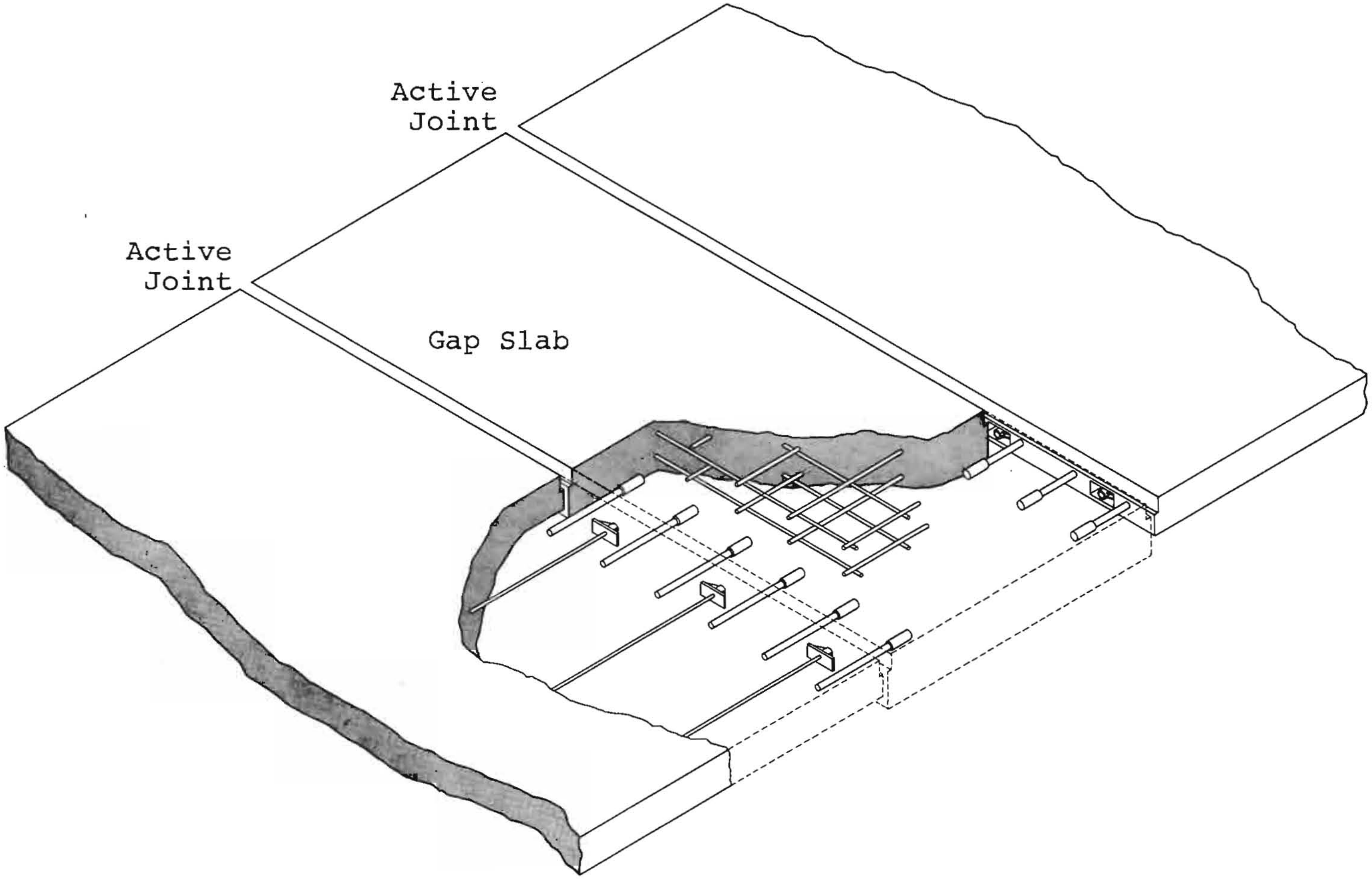


Figure 5 - Overall View Design IV

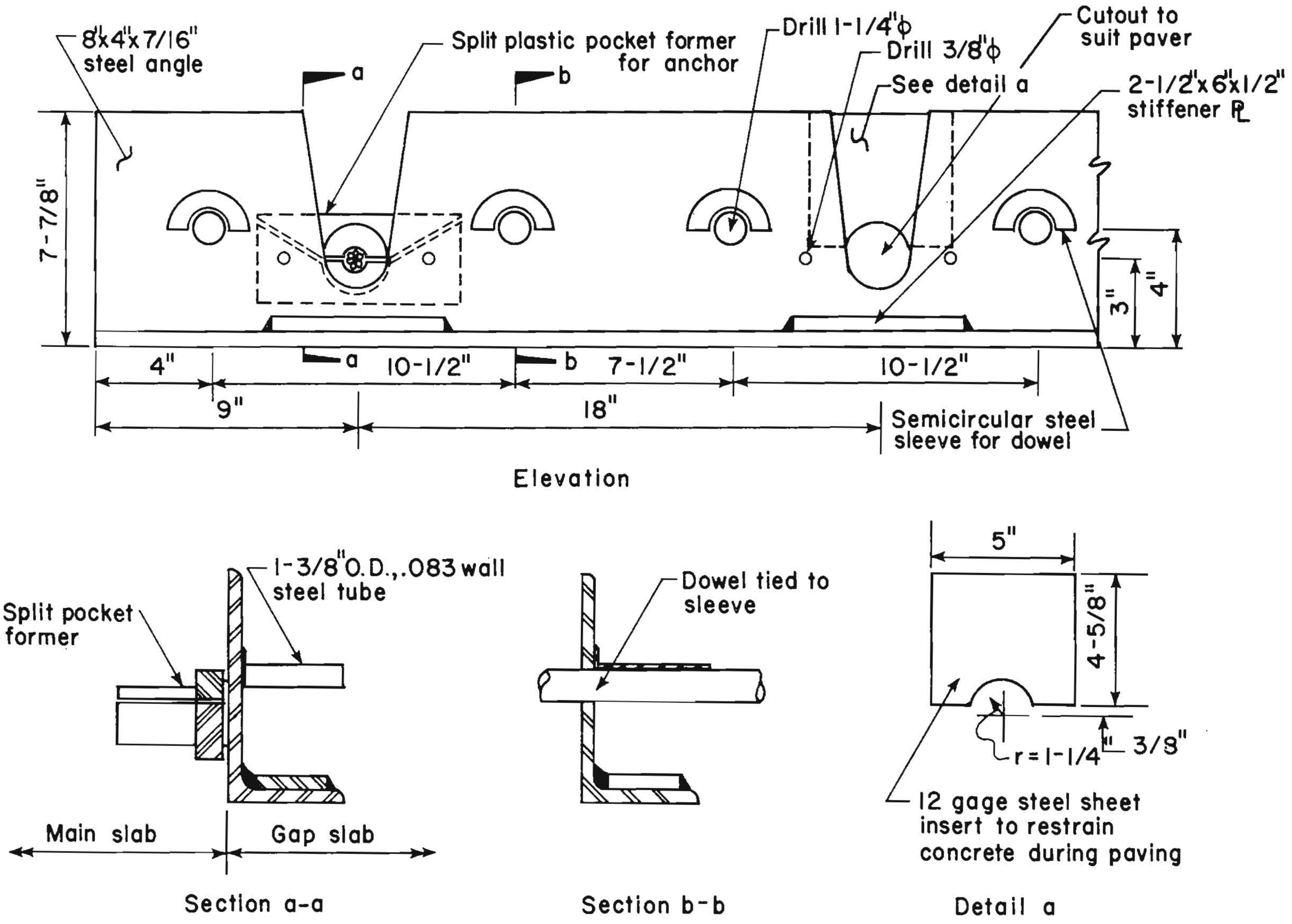
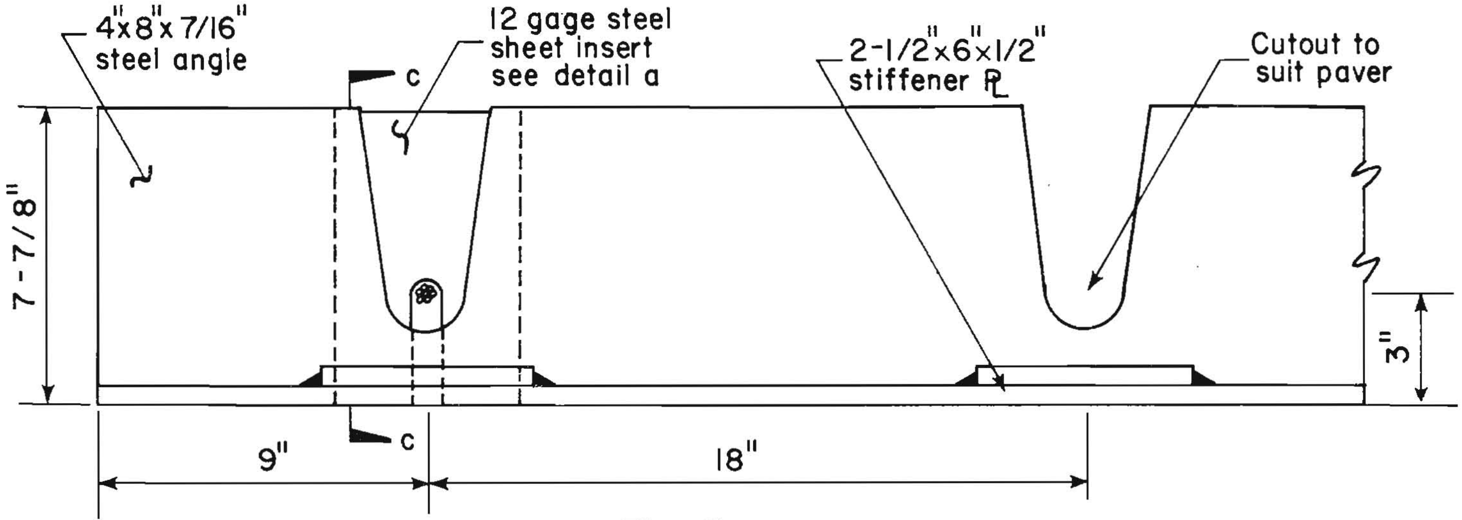
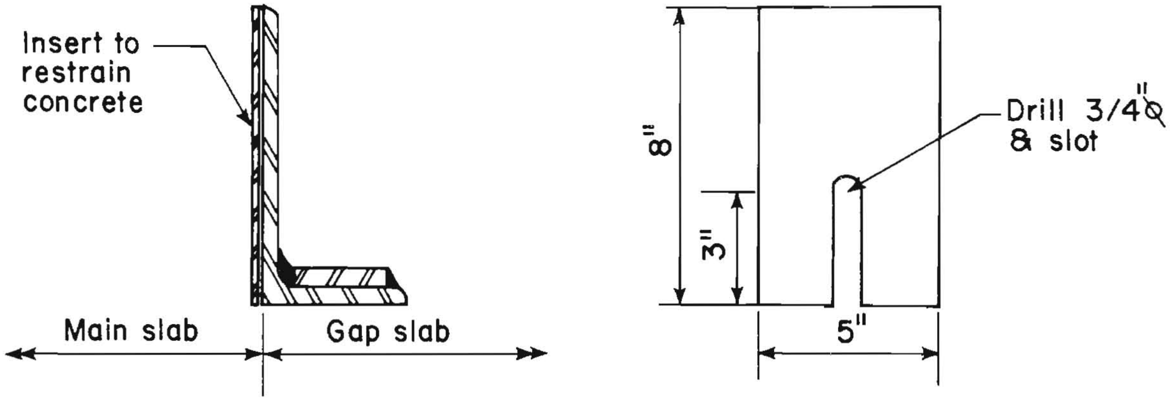


Figure 6 - Design I - Active Joint Bulkhead



Elevation



Section a-a

Detail a

Note:
Bulkhead pinned to subbase or braced against opposite bulkhead.

Figure 7 - Design I - Construction Joint Bulkhead

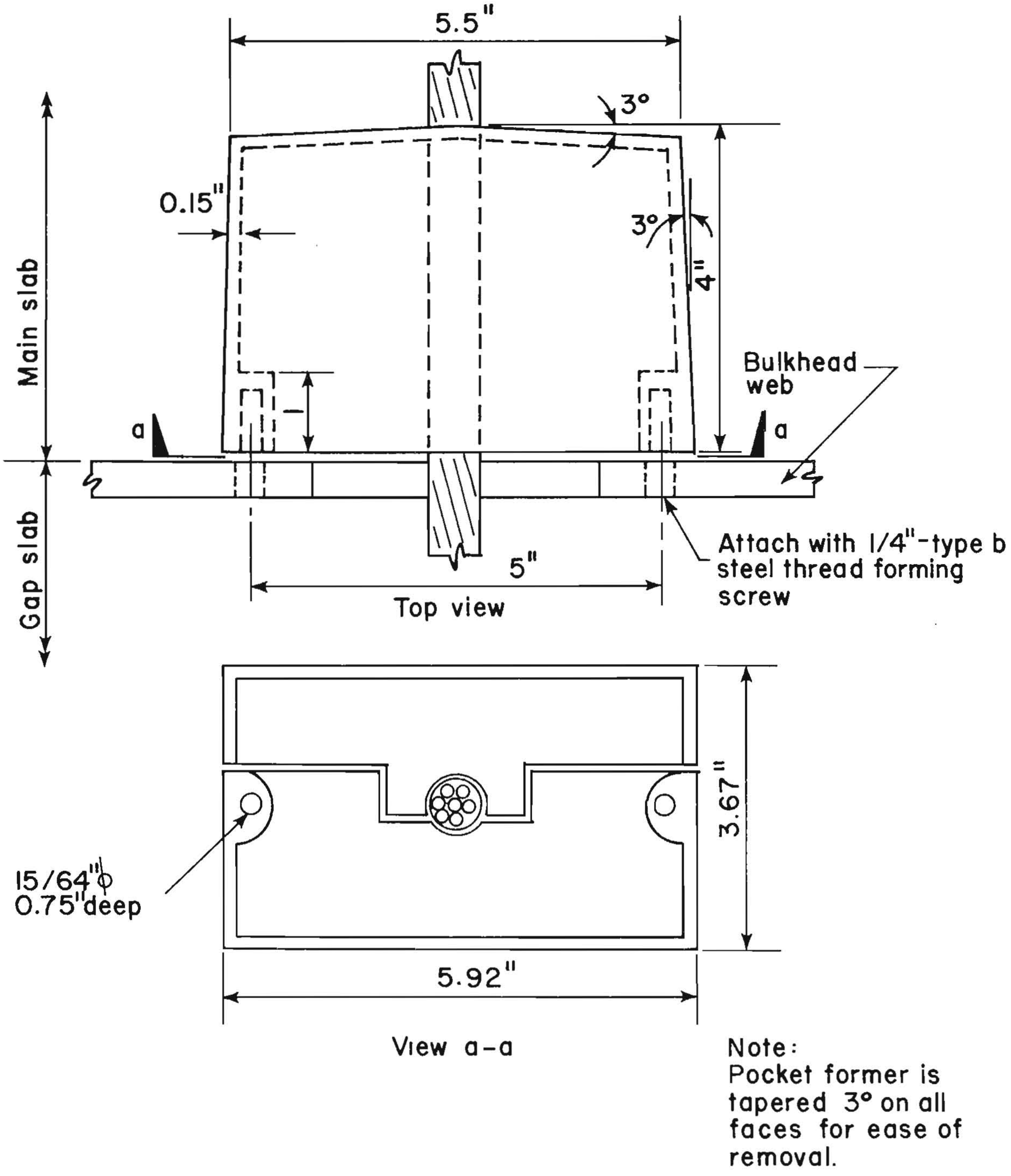
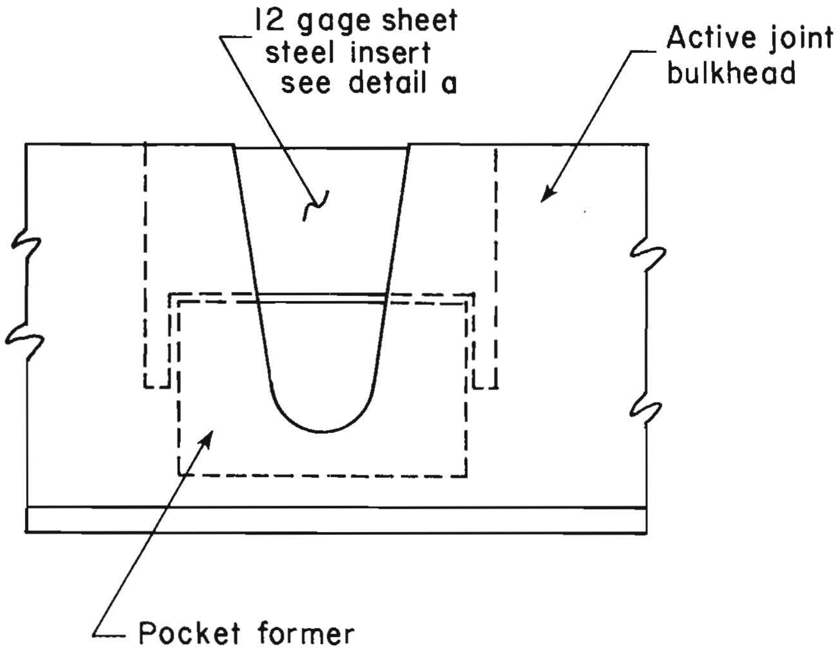
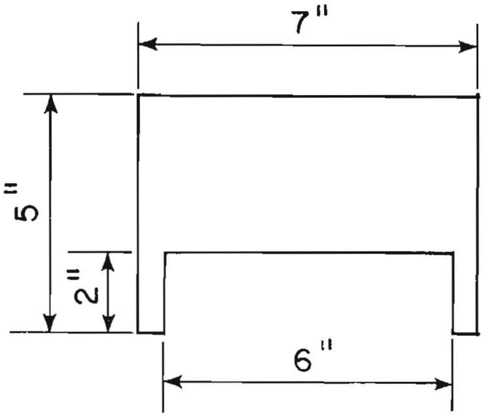


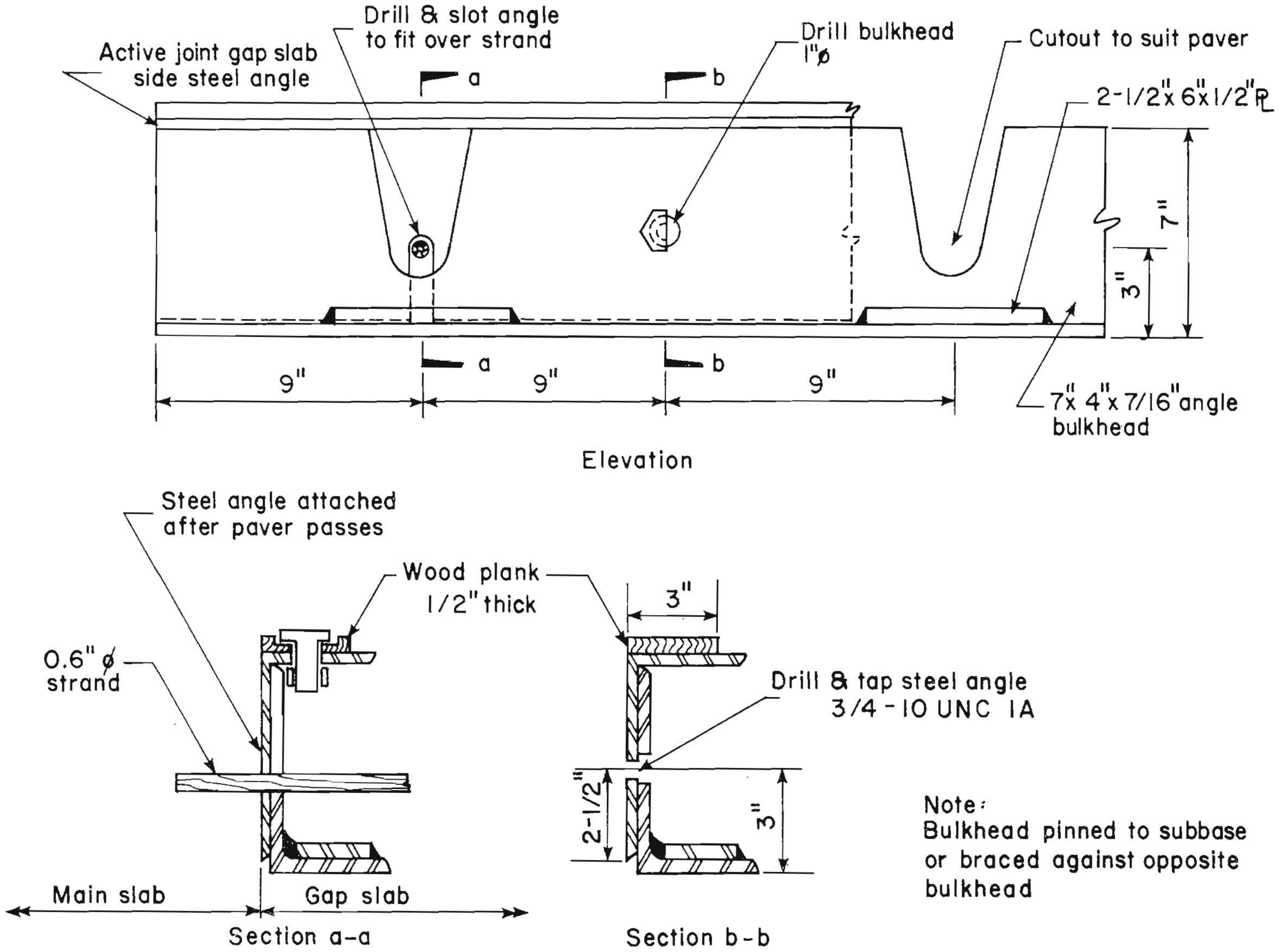
Figure 8 - Split Plastic Pocket Former Design II - Active Joint





Detail a

Figure 9 - Sheet Metal Insert Design II - Active Joint



Note:
Bulkhead pinned to subbase
or braced against opposite
bulkhead

Figure 10 - Design III - Active Joint Bulkhead

The first six inches of concrete are left out on the main slab side of the active bulkhead as the paver passes. The steel angle, slotted at tendon locations, is then attached to the bulkhead using bolts. Wood plank spacers are attached to the angle in place of the coverplate, allowing accurate concrete finishing behind the bulkhead. Concrete is then placed and vibrated in back of the steel angle before initial set of the main slab concrete.

The construction joint is formed using the same bulkhead as shown in Figure 7 for Design I.

Design IV

Due to the double active joint used in Design IV, a construction joint bulkhead is not required. Instead, two active joint bulkheads as shown in Figure 11 are used. The bulkheads have sleeves for holding dowels and cutouts to allow passage of the paver. Split pocket formers are positioned after passage of the paver and a wood block cut to shape is used to form the compression seal space on the main slab side of the joint. Concrete is then hand-placed and finished.

Construction Comments

Tendons can be cut soon after the paving train has passed. However, cathead clamps should be attached to tendons at the forward bulkhead to prevent them from slipping into the freshly placed concrete.

Bulkhead removal is facilitated by application of sufficient form release agent prior to concreting. Easily accessible bolts should be used for holding hardware items to bulkheads. These are removed before moving bulkheads. Restraints to slab ends should be minimized because bulkheads are removed as soon as possible after concrete hardening. This is done to prepare slab ends for initial applications of prestress and to permit re-use of bulkhead forms.

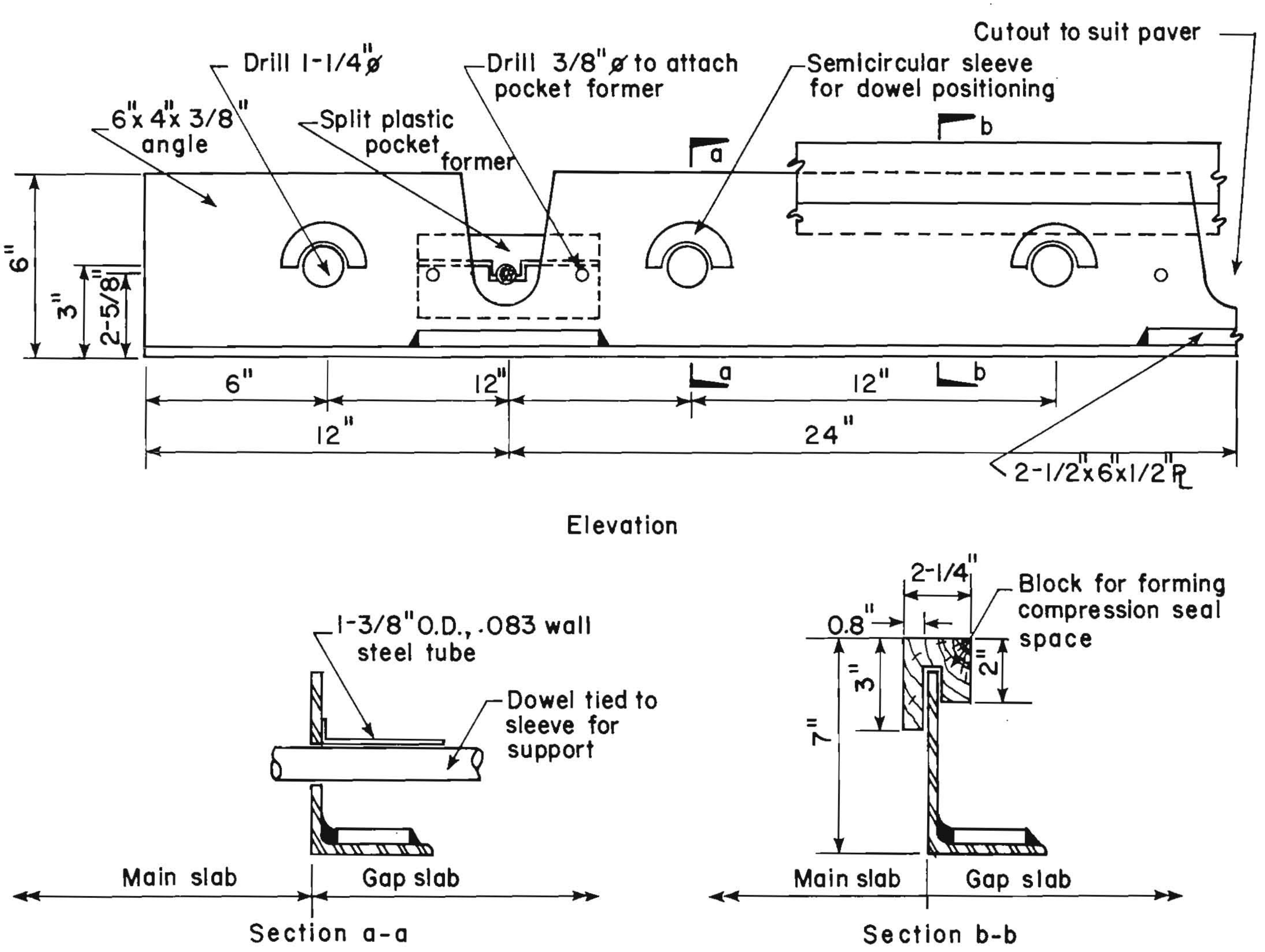


Figure 11 - Design IV Bulkhead

Permanent anchors may then be entered onto strand ends and set into voids formed by pocket formers at the joint face concrete.

Mechanical spreading equipment must permit distribution of concrete over the pavement width without laterally displacing tendons. During paving around curves, it has been observed that strands may displace sideways toward the inside. Care must be used to prevent excessive pull on strands. Tendons should be slack ahead of feeder guides and have a minimum of friction in guides. Concrete should not pile up in the spreader or ahead of the finisher. To assure proper strand positioning, strand locations through curves should be checked with pachometers early during the progress. In sharp curves, the strands should be preplaced and supported on chairs welded to transverse rebars spaced at less than 3 ft (0.8 m).

Vibrators should be spaced between each tendon and should be capable of properly densifying the concrete. They should be kept at least 1/2 in (13 mm) above the tendons.

Sliding forms should be long enough to prevent edge slumping on the friction reducing membrane. Paving equipment should spread, consolidate, screed, and finish the concrete in one complete pass. A well consolidated and homogeneous concrete slab should be obtained. Intermediate construction joints should be avoided.

Special bulkheads are required for the special case of equipment breakdown. These should be designed for each project to accommodate strand placement methods. A split bulkhead form may meet requirements of emergency construction joints. These would be placed by manually removing plastic concrete, placing the form and then replacing concrete, vibrating, and surface finishing. Concrete ahead of the bulkhead is then removed from the grade.

Normal curing methods may be adequate to prevent early length changes due to concrete drying shrinkage and temperature variations, except for extreme conditions. However, the last 20 ft (6.1 m) of slabs should be moist cured and protected until gap slabs are completed. This is recommended to prevent end of main slab curling and warping deformations.

PRESTRESS OPERATIONS

Initial prestress is generally applied in three steps. The first step consisting of approximately one-third of final strand tension is applied as soon as concrete strength allows, preferably before midnight following concrete placement. Early application is desired to counteract development of tensile restraint stresses during night-time slab cooling and contraction.

Concrete strength for the initial application of prestress is generally from 700 to 1,000 psi (4.8 to 6.9 MPa). Care is required to protect the young concrete during this stressing step. Stress under bearing plates must be evenly distributed.

Second and third steps, to full initial prestress, should follow as concrete compressive strength increases. Full initial prestress may be applied after a concrete strength of 2,500 psi (17.2 MPa) has been reached.

Concrete strength for step stressing is determined from tests on cylinders cured under job conditions. A sufficient number of cylinders must be taken at both ends of each long slab, especially if paving progress is slow.

Strands should be tensioned from both slab ends at about the same time. However, if there is a substantial difference between concrete strengths at slab ends, first step tension at the forward slab end may be delayed. Full length strand friction losses should be considered for determining forward end stress magnitudes. Concrete placed during the earlier part of the day is normally subject to more critical first night tension. It should be prestressed even if effective prestress at the forward end must be delayed.

Final restressing is done after approximately 28 days of curing, but in any case prior to concreting gap slabs. Final stressing consists of retensioning tendons to specified stress magnitudes. Both strand ends should be simultaneously tensioned. If gap slabs are to be normally reinforced, strand ends are cut and epoxy grouts are applied to prevent corrosion of anchors and strands.

Strand cutting and grouting are delayed if prestressed gap slabs are used. In this case strands are extended to a coupler or to an anchor at the active joint. Gap slab stressing procedures are discussed later in the report.

Post-Tensioning Safety

While post-tensioning is a simple and fast operation, the large energy stored in tensioned long strands requires that safety precautions for jacking crews be observed. Although very rare, tendons may fail prematurely. Anchors have been known to fail if wedges are seated incorrectly. Concrete strength, although carefully checked may be insufficient for pressure concentrations at bearings. This could lead to local failure and flying pieces of concrete.

Only men directly occupied with post-tensioning should be near slab ends. During strand elongation, no one should be in direct line with strands at the jack. Pumps should be located a safe distance to the side of pressing alignment. Safety helmets should be worn during post-tensioning operations.

Strand failure away from slab ends will normally result in loss of the strand with correspondingly lower prestress in the slab. Strand failure near ends can be repaired by uncovering the strand and connecting a new strand end with a splice chuck. A space or groove is left in the concrete to permit splice chuck movement during restressing. Failure of an anchor, or local failure of concrete at an anchor, may be repaired with quick-setting concrete. Usually, a sufficient strand length is available to advance the unstressed strand toward the failed end and to place a new anchor on clean or unkinked strand.

Post-tensioning jacks are provided with head fittings to center jacks on the strand anchor. As pressure is applied, the jack will automatically align with the strand anchor. During the first step of initial post-tensioning, the jack is in a cantilevered position. To prevent eccentric anchor loading, post-tensioning jacks should be supported.

ANCHORS

Tendon anchors consist of castings that provide bearing against the concrete and chucks that accommodate wedges for gripping strand. Anchors transmit strand tension through the anchor bearing as compression to the concrete. Anchors for the four designs were selected to provide adequate concrete bearing area. Other criteria for selection included corrosion protection and applicability to prestressing procedure employed.

Design I

Three types of anchors are required for prestressing main and gap slabs for this design. Figure 12 shows the anchor used at the main slab side of the active joint. The stressing end of this anchor has a threaded collar for attaching an end cap. Prior to attaching the end cap, the anchor body is filled with epoxy.

An automatic seating anchor used at the gap slab side of the active joint is shown in Figure 13. This anchor accommodates gap slab stressing operations. It consists of separate bearing and chuck bodies. The chuck is threaded into the anchor body, allowing fine adjustments in strand position during gap slab construction. During gap slab stressing, a helical compression spring inside the anchor seats wedges as the strand is advanced.

At the construction joint, a temporary anchor is installed during main slab prestressing. It consists of a 2-3/4-in (69.9 mm) diameter by 2-in (51 mm) long machined steel chuck with 3-jaw wedges bearing on an alignment of bearing plates. These plates drop out during gap slab prestressing when the strand force is taken by the jack advancing the strand in

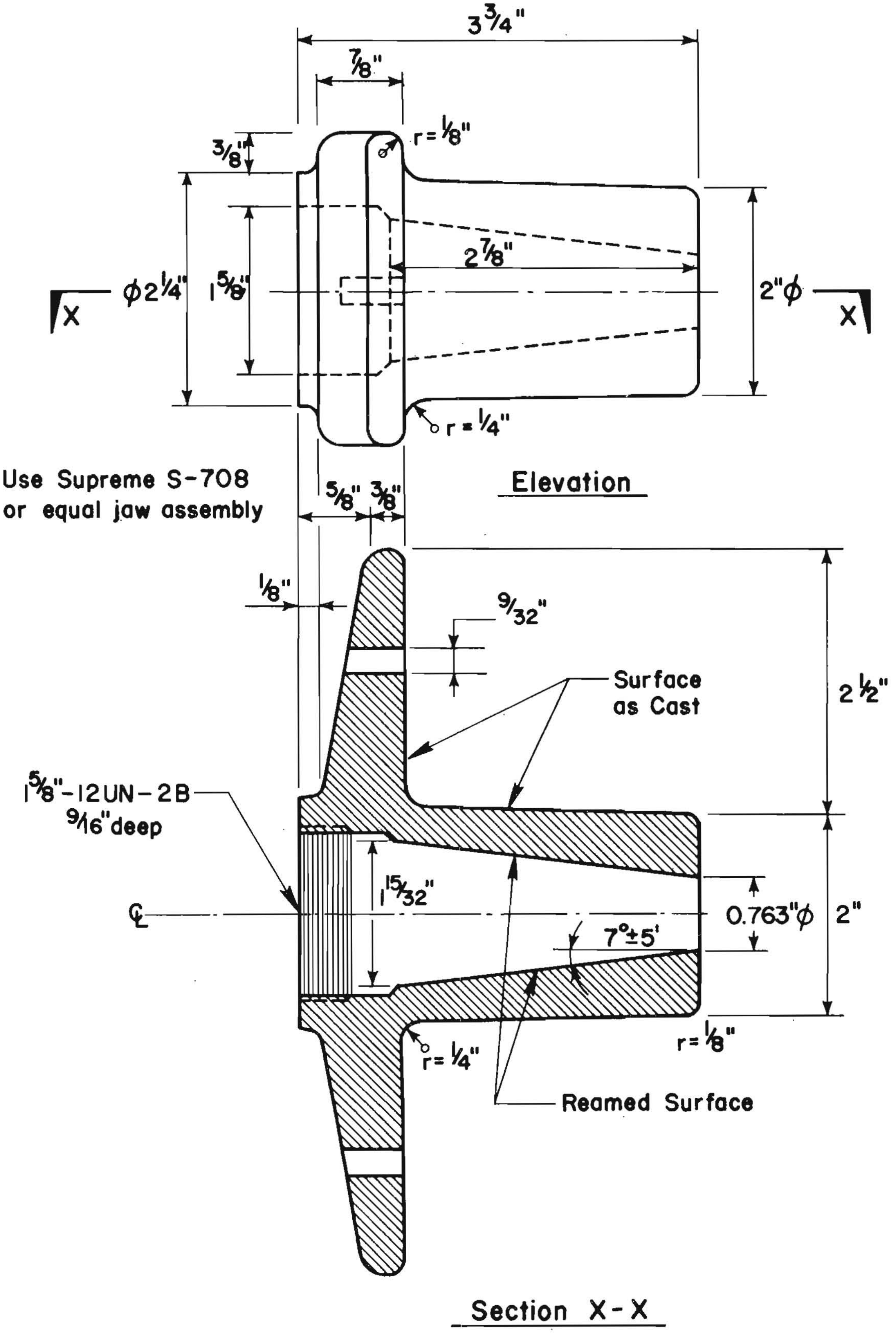


Figure 12 - Main Slab Anchor - Design I

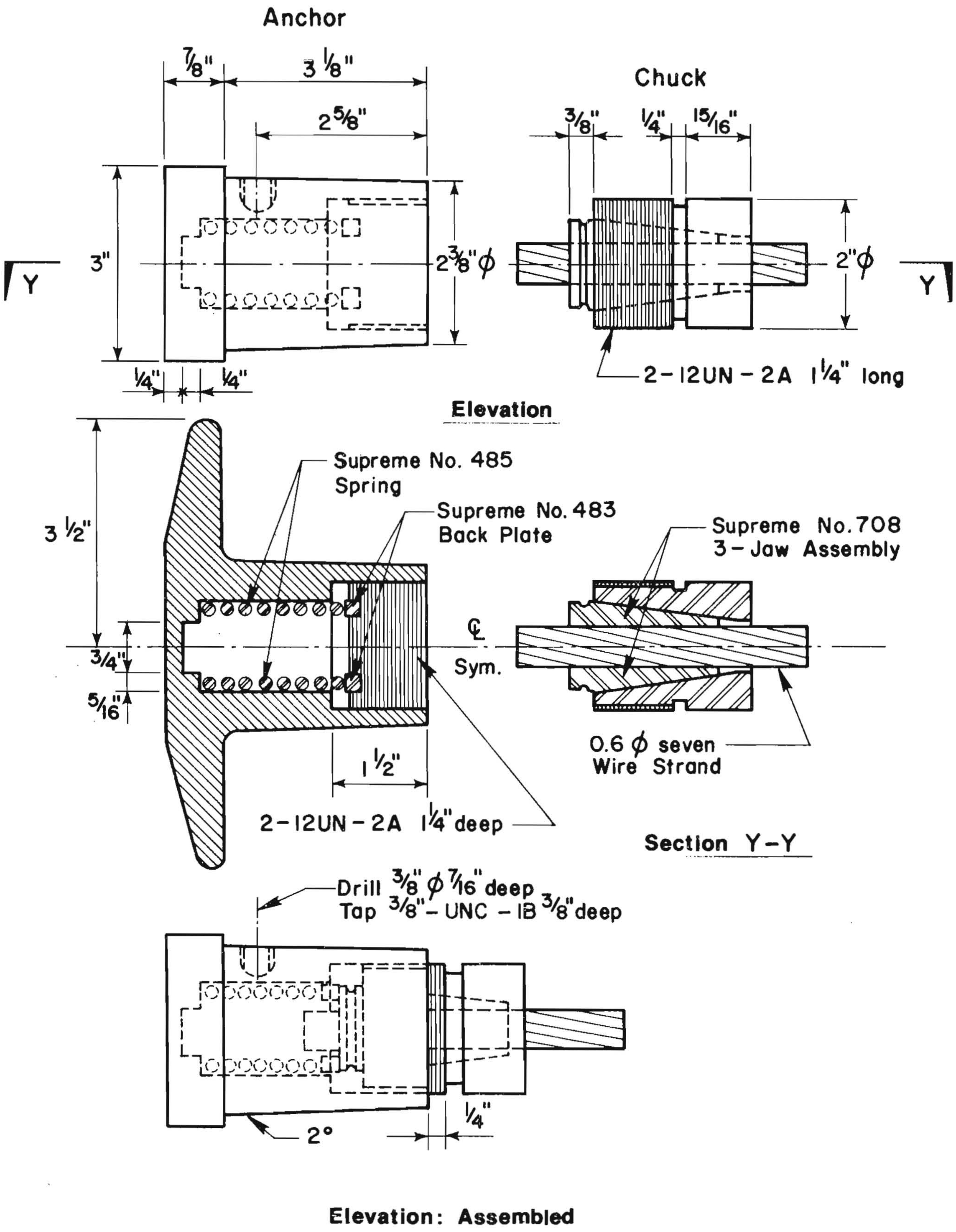


Figure 13 - Automatic Seating Anchor

automatic seating anchor located at the other end of the gap slab.

Design II

The anchor used at the main slab side of the active joint is shown in Figure 14. This anchor is set inward from the slab end in a pocket. After stressing operations are completed the pocket is grouted to provide corrosion protection.

At the gap slab side of the active joint, a Stressteel® nut and thread anchor is used. This assembly consists of a 1-5/8-in (41 mm) long nut and 1/2-in (12 mm) thick plate threaded onto the 1-in (25 mm) diameter Stressteel® bar extending from the gap slab. This anchorage is also set inward in a pocket allowing unhindered movement at the active joint.

At the construction joint, main slab prestress is transmitted to the concrete using a 2-3/4-in (70 mm) diameter by 2-in (50 mm) long machined steel chuck with three jaw wedges. The chuck bears on a 7x4x1/2-in (178x100x12 mm) steel plate. This assembly remains in the concrete following gap slab prestressing.

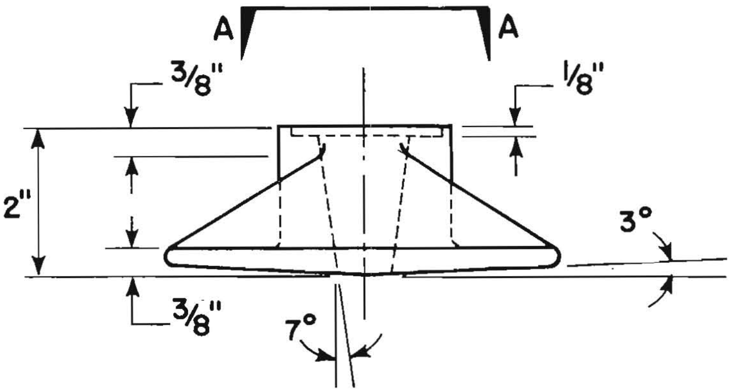
Design III

Steel angles at the active joint of the coverplate design act as bearing plates for anchorage as shown in Figure 15. On the main slab side of the active joint, a 2-3/4-in (70 mm) diameter machined chuck is used to anchor the 0.60-in (15 mm) strand. On the gap slab side of the joint, a Stressteel® nut anchors a 1.0-in (25 mm) diameter rod against a steel angle bearing on concrete.

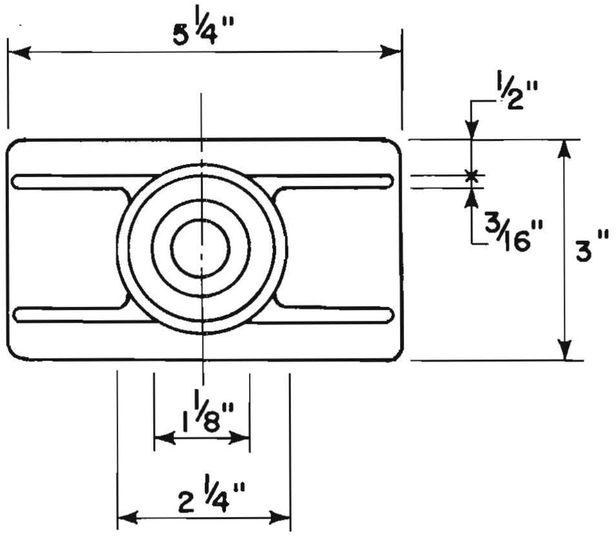
Anchors at the construction joint are the same as those used in Design II.

Design IV

The anchor used at main slab side of both active joints is shown in Figure 14. This anchor is set in a preformed pocket. After prestressing operations, the pocket is filled with grout.



Top View



View A-A

Figure 14 - Anchor for 0.60 in Strand

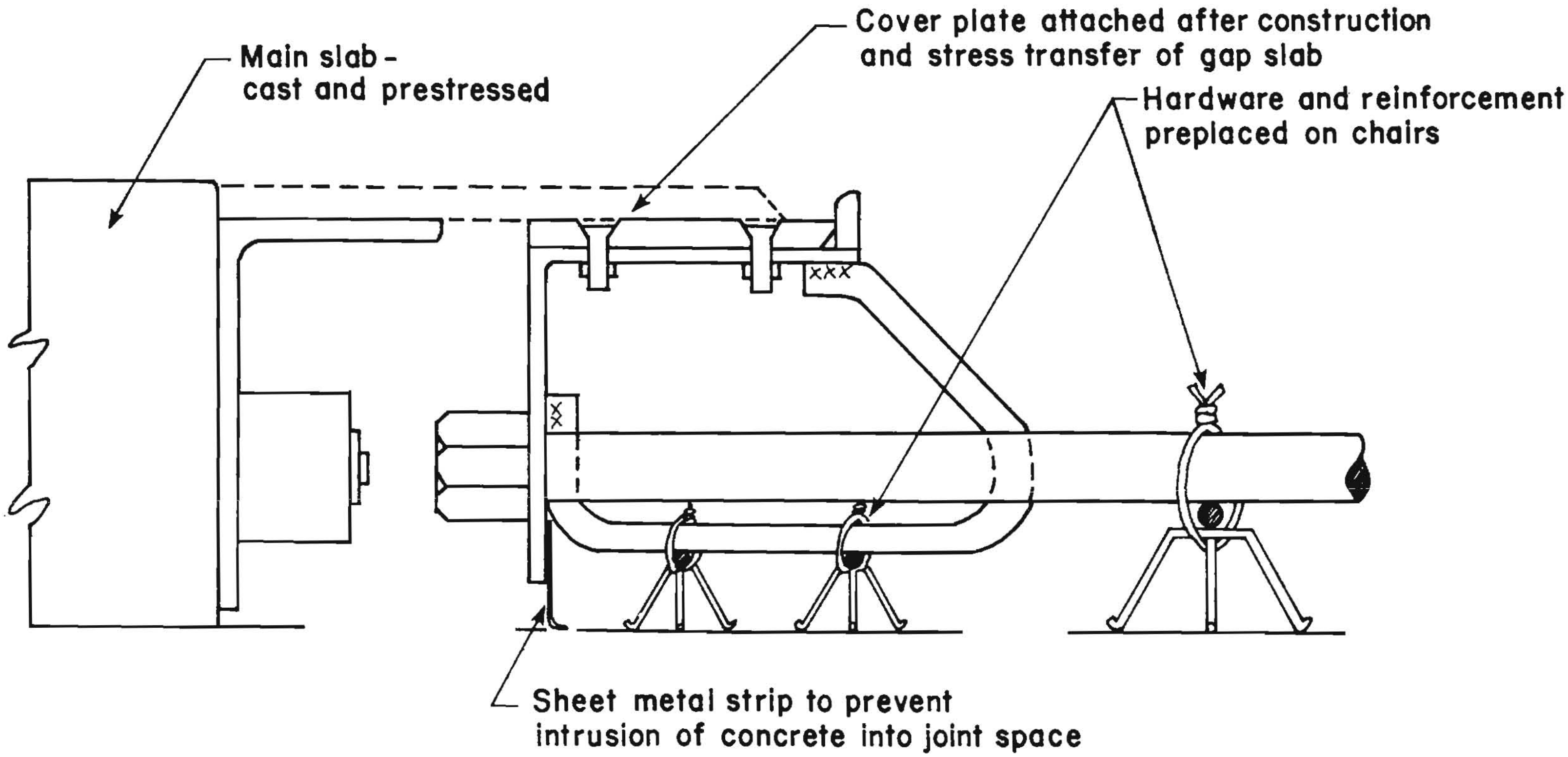


Figure 15 - Active Joint Anchors - Design III

This anchor uses a three-jaw seating wedge sized for 0.60-in (15 mm) diameter strand.

JACKS

Jacks for main slab prestressing are of the open-throat monostrand type widely used in structural post-tensioning. They are suitable for rapid application and accurate control of tension with a minimum of seating loss in wedging strands in anchors. They are generally 20 to 30 in (51 to 76 mm) in length and depending on details and stroke, weigh from 30 to 80 lbs (133 to 356 N).

Essential parts of a post-tensioning jack are shown in Figure 16. Jacks have self-centering devices built in. Jack heads are brought to bear against rims of strand chucks, anchors, or bearing plates. Sliding strand grippers connected to rams hold strands during elongation. Supplementary small hydraulic or spring loaded rams seat wedges in strand anchors after completing jacking strokes.

Post-tensioning jacks are connected to hydraulic pumps with sufficient hose length to reach all strands at one slab end. Pumps are equipped with gages and controls to set pressure to specified strand force.

Due to unique requirements for stressing gap slabs in Designs I and II, special jacks are required. Figure 17 shows the gap slab prestressing rams and a cast ductile iron double-C fitting used for Design I. Two 30 ton 1-in stroke jacks are positioned over bearing plates at the construction joint jacking pocket. The jacks straddle the existing barrel chuck. The double-C fitting slips over the two rams. Legs at the back of the fitting bear on each side of the spacer against the strand chucks. As rams advance, strand tension is carried by C-fittings. Spacers are then lifted out. Strand forces are transferred to the active joint by automatic seating anchors as the rams retract.

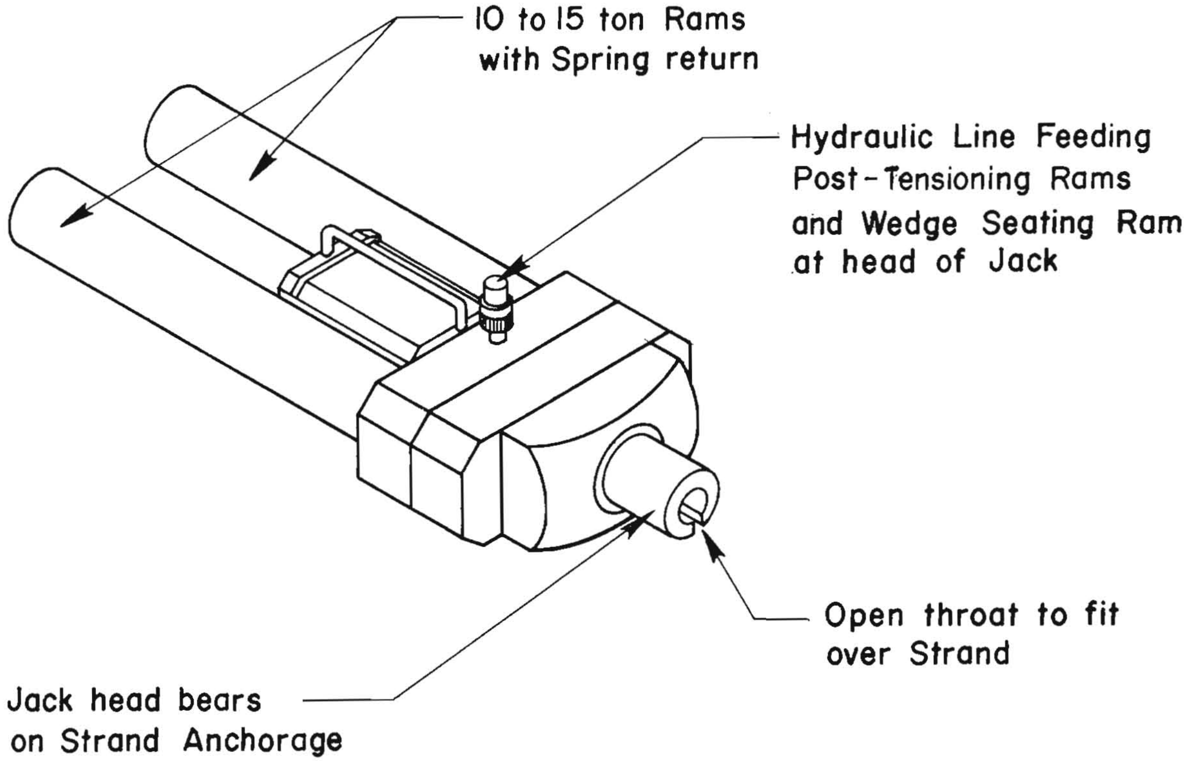


Figure 16 - Main Slab Post-Tensioning Jack

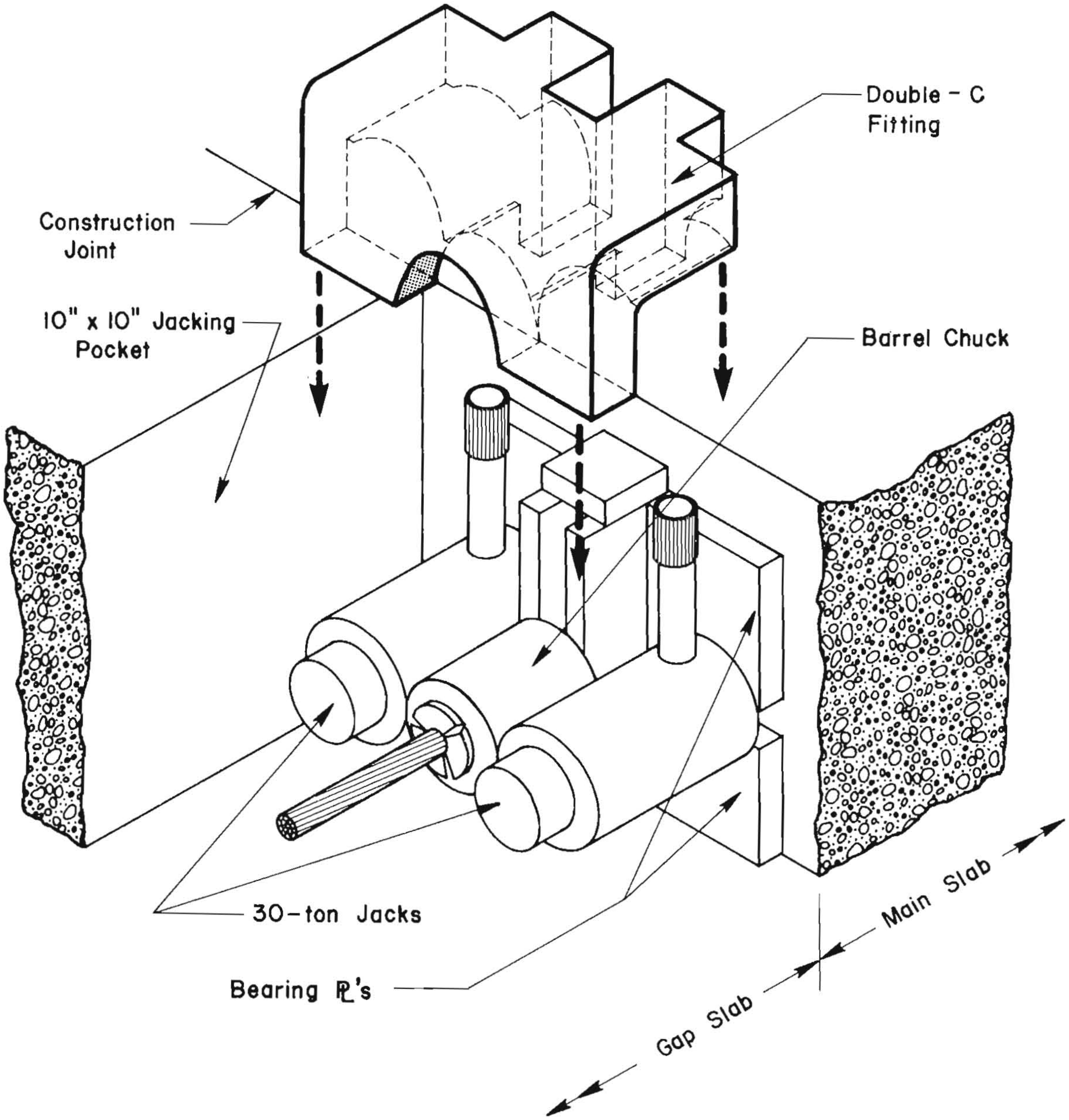


Figure 17 - Design I Gap Slab Prestressing Jack

Figure 18 shows jack requirements for prestressing the gap slab in Design II. Two short stroke ENERPAC® JMC-200 or equal "pancake" cylinders attached to a slotted 2-in (50 mm) thick plate are positioned straddling a splice chuck on the construction joint side. As the rams advance, the threaded rod in the active joint advances about 0.25 in (12 mm). Nuts may then be turned manually inside the active joint before retracting the jack.

For gap slab prestressing of Design III, calibrated torque wrenches are used at the active joint.

All jacks and pumps should be carefully calibrated before use to assure compliance between recorded and actual jacking force throughout the pressure range. Each pump and jack should carry its own calibration information and identifying designation, so that jacking pressure control, and strand force may be checked in the field.

Jacking is normally handled by two men. One man operates the jacks and one the pumps. Strand elongations should be measured at both ends of each slab as a control of strand performance. Elongation data should be recorded by the engineer.

GAP SLAB CONSTRUCTION

Gap slabs are built following prestressing of main slabs. Prior to gap slab paving, hardware and reinforcement are preplaced, side forms set, and shoulder drains installed at active joints. For three designs, gap slabs are post-tensioned. The gap slab of Design IV is conventionally reinforced. The following discussion provides detailed gap slab construction procedures for each design.

Design I

Prior to concreting, side forms are set and hardware and reinforcement are preplaced on chairs. Strand is extended from construction joint to active joint and positioned in automatic seating anchors, leaving space inside the anchor for strand

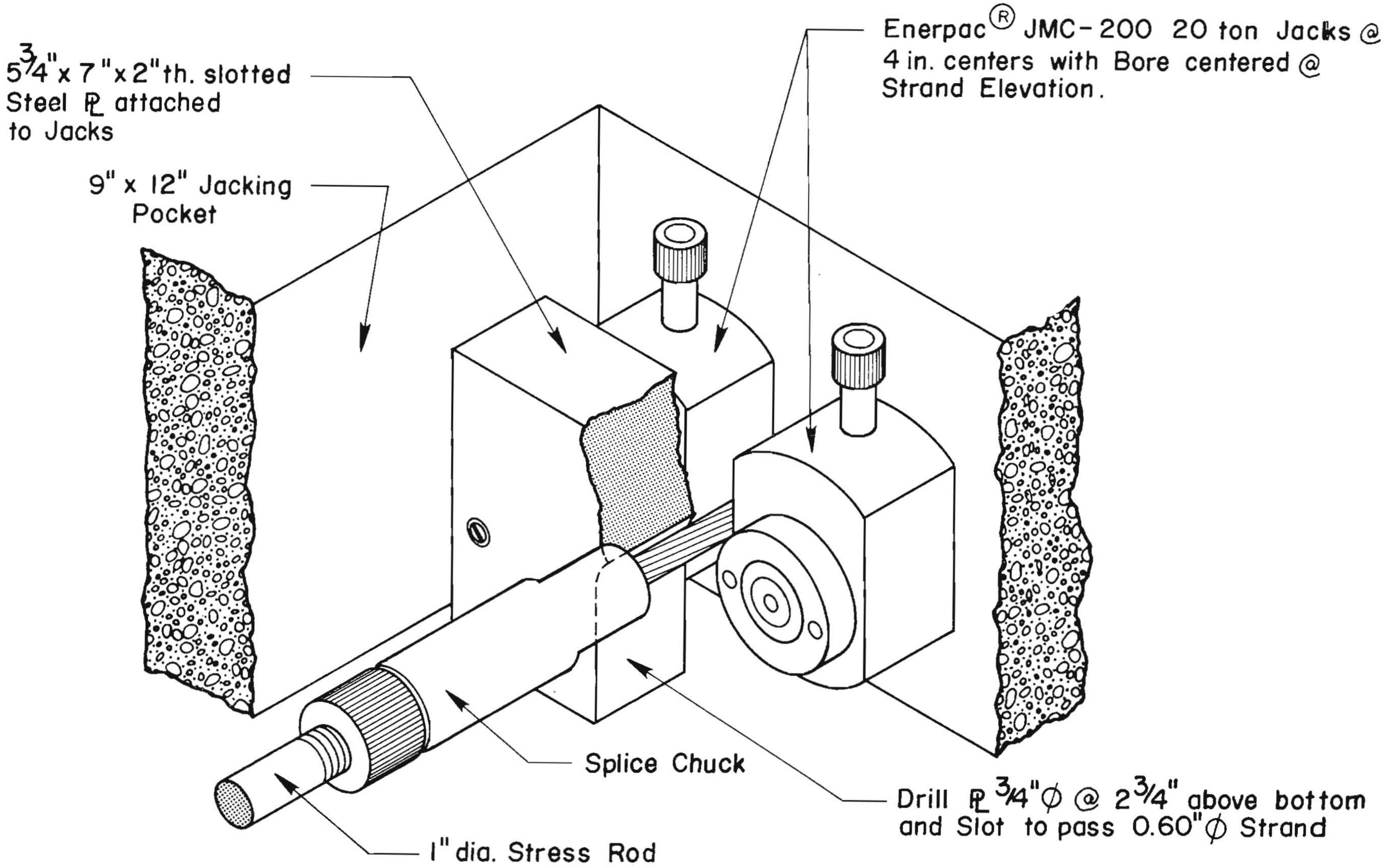


Figure 18 - Design II Gap Slab Prestressing Jack

elongation. An active joint space commensurate with construction temperature is formed with styrofoam insulation board. Dowels extending across the active joint are provided with sleeves for slab movements. At the construction joint, box-outs are formed around temporary anchorages to accommodate jacking equipment.

Gap slab concrete is hand placed and finished. Strip seal holders at the active joint are embedded in the plastic concrete. Following adequate curing, the gap slab is prestressed using the jack shown in Figure 17.

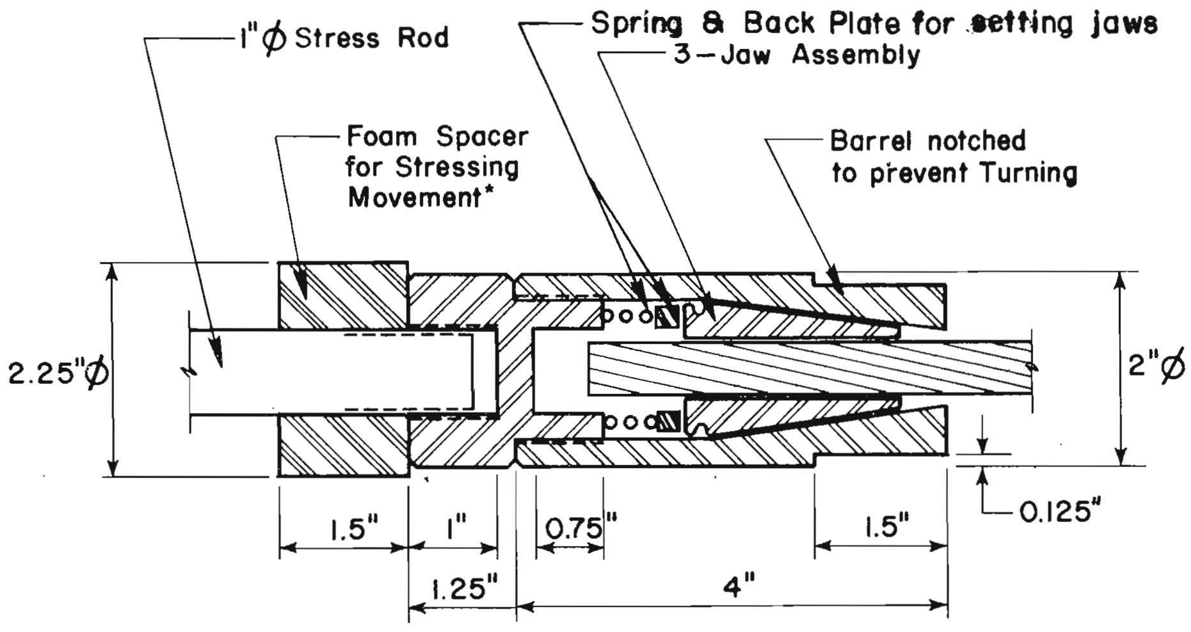
Construction joints may open between casting and stressing of the gap slab. If this occurs a grout is placed in the opening prior to stressing the gap slab. Following gap slab prestressing strip seals are installed and jacking pockets are grouted.

Design II

Dowel sleeves and transverse reinforcement are preplaced. Strand protruding from the construction joint is coupled to an appropriate length of 1-in (25 mm) diameter stress rod by the splice chuck shown in Figure 19.

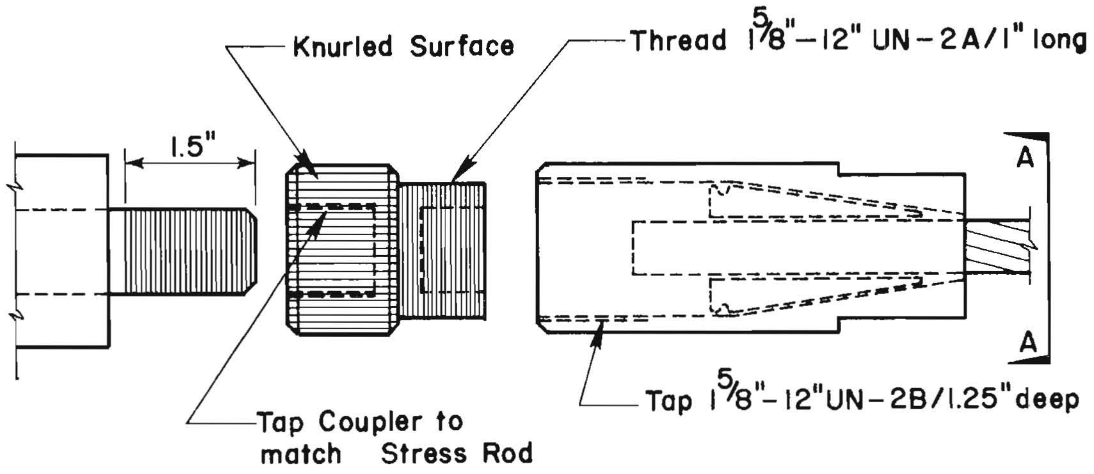
At the active joint, a bearing plate and Stressteel® nut are threaded over the stress rod, and positioned on chairs at the proper location. An appropriate joint space is formed with styrofoam insulation boards. Cutouts are provided in the board for dowels and nuts. Cylindrical waxed cardboard caps are slipped over nuts to prevent concrete intrusion. Box-outs are formed around splice chucks to accommodate jacking equipment.

Following casting, installation of strip-seal holders, finishing, and curing, the gap slab is prestressed. The jack assembly shown in Figure 18 is positioned in the jacking pocket. As the rams advance, the threaded rod moves forward at the active joint. The nut at the active joint is then manually tightened. As the rams retract, stress is transferred to the gap slab. Following prestressing, strip seals are installed and jacking pockets are grouted.

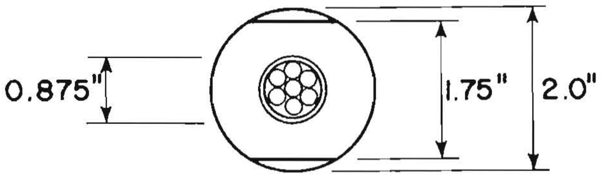


Section

*Note: Design III only



Elevation



View A-A

Figure 19 - Splice Chuck - Designs II and III

Design III

Figure 15 shows gap slab hardware preplacement for a cover plate design. A 1-in (25 mm) diameter stress rod is coupled to the strand at gap slab midlength using a splice chuck. At the active joint, the steel angle and nut are threaded over the rod and positioned on the subbase with chairs. Transverse reinforcement is preplaced and side forms are set.

After casting, finishing, and curing, the gap slab is prestressed from the active joint using calibrated torque wrenches. A foam rubber spacer installed over the stress rod end of the splice chuck prevents the concrete from restraining splice chuck movement during stressing. Teflon coated washers are used between nuts and steel angles to reduce torquing resistance. Cover plates are bolted into place following prestressing.

Design IV

Gap slab thickness for Design IV is 10 in (254 mm). Therefore, 3 in (76 mm) of subbase must be removed prior to reinforcement placement unless subbase grade was changed at time of subbase construction. Transverse and longitudinal reinforcing steel is then placed on chairs at proper elevation. Sleeves are positioned on dowels protruding from the main slab. Joint space and compression seal spaces are formed with styrofoam insulation board. Following casting and curing, compression seal spaces are cleaned and seals are installed.

SUBBASES

Prestressed concrete pavements have been placed successfully on cement treated base courses (CTB), on lean concrete base course (LCB), and on bituminous base courses with sand-asphalt surface. Subbase surface should be at correct grade, slope, and within a tolerance of not more than 1/4 in (6 mm) below a 10-ft (3 m) straight edge in any direction. In addition, there should be no ridges in the transverse direction.

Subbases should extend not less than 2 ft (0.6 m) beyond slab edges on each side. Extra width provides support for edge loadings and stable support for construction equipment.

Subbases are placed on existing embankments or roadbeds after cleaning, shaping, and compacting to correct and uniform grade. Stabilized subbases provide support for the pavements at a modulus of reaction of about 500 pci (136 MPa/m).

If used for construction traffic, subbases must be protected from overloads, rutting, and abrasion. Immediately before paving, subbases should be cleaned, surface voids filled, and level and surface smoothness restored.

Cement Treated Subbases

Cement treated subbases are generally produced with Type A-1, A-2, or A-3 soils, using enough cement to obtain a compressive strength of 300 psi (2.1 MPa) at 7 days. In addition, the CTB must meet criteria of ASTM-AASHTO freeze-thaw and wet-dry test. CTB may be mixed in place or be plant mixed. The mixture should be placed at optimum moisture in accordance with ASTM Designation: D558-76 "Moisture-Density Relations of Soil-Cement Mixtures"(4) and compacted to not less than 95 percent of maximum density.

Lean Concrete Subbases

Use of lean concrete subbases (LCB) under concrete pavements is a more recent innovation.

For LCB construction, the cement content should be not less than 250 lb/cy (1.45 kN/m^3) of concrete. The water-cement ratio may be greater than 1 and the slump 2 to 3 in (50 to 75 mm), as measured at the slip-form paver. Concrete compressive strength should be 750 to 1500 psi (5.2 to 10.3 MPa) at 28 days. These strengths give a subbase suitable for heavy duty pavements. Air entrainment in LCB is above 3 percent. A minimum of 4.5 percent is recommended for freeze-thaw areas.

The LCB mix may be deposited by haul units directly in front of the slip-form paver, or may be placed by spreader. Damage to the top of the embankment, or seal must be repaired by the contractor. LCB is placed and finished in one pass.

Bituminous Subbases

Bituminous subbases may perform as barriers to water inflow into subgrade soils in addition to providing a stiff subbase. They may be constructed as one or two layers. One layer construction consists of a high stability dense graded mix placed and compacted to form a smooth subbase surface. For two-layer construction, a conventional, more open graded, base course mix is placed first. This is followed by a sand-asphalt layer. Total bituminous base course thickness is about 5 to 6 in (125 to 150 mm), including where applicable a 1-in (25 mm) sand asphalt surface.

A high stability hot mix should be used with Marshall stability values of not less than 1000 lbs (4.450 kN) and flow values of 12 or less. ASTM Designation: D1559-76 "Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus"(5) methods are applicable for mix design.

Hot mix base course material should be placed with an asphalt paver that provides screed control for construction of a smooth and level subbase surface. Materials should be mixed in a pug mill at 225 to 300°F (107 to 150°C) and placed at not less than 200°F (93°C). Initial compaction is accomplished by the tamping action of the asphalt paver. Steel wheel and rubber tired equipment are used for rolling and kneading compaction. Desired smooth and dense surfaces are obtained by final compaction with steel wheeled roller.

Subbase Curing

All CTB and LCB must be effectively protected against frost and loss of moisture for not less than 7 days. Curing should be water spray and/or membrane curing. Liquid membrane curing compound is applied at a rate of at least one gallon per 200 sq ft (or a 0.2 mm depth).

Bituminous emulsions or liquid applications cure are not suitable for prestressed pavement construction. They pick up and partially bond materials to the base. Bituminous material also interferes with squeegeed application of sand.

FRICTION REDUCING MEMBRANES

Friction reducing membranes (FRM) are required between prestressed pavement slabs and subbases to reduce slab to subbase interface friction.

Sand Squeegee

Application of sand to fill holes and discontinuities in subbase surface immediately before placing the friction reducing layers contributes to obtaining low friction values. Large holes in which the sand cannot remain level and provide firm support for pavement concrete should be filled with cement grout. Overfilling with sand should be avoided as this may form ridges and waves ahead of plastic pavement concrete.

A fine, uniform size sand with a No. 40 (0.42 mm) maximum size is recommended.

The squeegee blade should have sufficient rigidity to bridge across depressions.

Polyethylene Film

Two layers of polyethylene film are recommended for use as FRM. Polyethylene film is available in rolls 100-ft (30 m) long and 24, 28, 32, and 40-ft (7, 8, 10 and 12 m) widths. Each layer should be full width, without laps in longitudinal direction, and wide enough to extend not less than 1 ft (0.3 m) beyond the width of construction. It is recommended that a low friction polyethylene as specified by ASTM Designation: D2103-80 Type I "Polyethelene Film and Sheeting,"(6) with a specified friction coefficient of less than 0.20, when tested in accordance with ASTM Designation: D1894-78 "Static and Kinetic Coefficients of Friction of Plastic Film and Sheeting,"(7) be used. Recommended thickness of each film is 0.006 in (0.15 mm) minimum. Transverse laps between successive rolls should be not less than 94 in (2.4 mm).

Friction reducing membranes must be held in place, without folds or ridges. All edges must be held down against wind. Weight of prestressing tendons and the transverse rebars is not sufficient to keep the FRM in place during high winds. Nailing in place through wood slats or weighting blocks have been used. Particular care must be taken to prevent folds into the concrete.

SUMMARY

Information on construction procedures and materials for prestressed concrete pavement construction is presented. This information is presented in detail for tendons, reinforcement, tendon placement, bulkheads at joints, prestress operations, anchors, post-tensioning jacks, and gap slab construction. This manual may be used to supplement standard specifications for concrete pavement construction.

REFERENCES

1. Nussbaum, P.J., Tayabji, S.D., and Ciolko, A.T., "Prestressed Pavement Joint Designs," A report prepared for Federal Highway Administration, December 1980.

2. "Uncoated High Strength Steel Bar for Prestressing Concrete" (ASTM A722-75), 1978 Annual Book of ASTM Standards, Part 4, American Society for Testing and Materials, pp. 750-754.

3. "Deformed and Plain Billet-Steel Bars for Concrete Reinforcement" (ASTM A615-76a), 1978 Annual Book of ASTM Standards, Part 4, American Society for Testing and Materials, pp. 579-584.

4. "Moisture-Density Relations of Soil-Cement Mixtures" (ASTM D558-76), 1977 Annual Book of ASTM Standards, Part 19, American Society for Testing and Materials, pp. 101-105.

5. "Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus" (ASTM D1559-76), 1977 Annual Book of ASTM Standards, Part 15, American Society for Testing and Materials, pp. 417-425.

6. "Polyethelene Film and Sheeting" (ASTM D2103-80 Type I), 1980 Annual Book of ASTM Standards, Part 36, American Society for Testing and Materials, pp. 288-293.

7. "Static and Kinetic Coefficients of Friction of Plastic Film and Sheeting" (ASTM D1894-78), 1980 Annual Book of ASTM Standards, Part 35, American Society for Testing and Materials, pp. 599-604.