CHAPTER 3

JOINTED REINFORCED CONCRETE (JRC) PAVEMENT DESIGN

3-1. Uses. JRC pavement may be used as slabs on grade or as overlay pavement for any traffic area of the airfield. Reinforcement may be used to reduce the required thickness and permit greater spacing between joints. Its selection should be based upon the materials available and time element involved. In certain instances, reinforcement will be required to control cracking that may occur in the JC pavements without any reduction in thickness requirements.

3-2. Reduced thickness design. The thickness of JRC pavement can be less than the thickness of JC pavements. The design procedure presented herein yields the thickness of JRC pavement and the percentage of steel reinforcement S required to provide the same performance as a predetermined thickness of JC pavement contructed on the same foundation condition. The greatest use of reinforcement to reduce the required JC pavement thickness will probably be to provide a uniform thickness for the various traffic areas and to meet surface grade requirements. This is especially true for rigid overlays where it is necessary to provide different thicknesses for the various types of traffic areas or different structural conditions of the base pavement. Since these changes in thickness cannot be made at the surface, reinforcement can be used to reduce the required thickness and thereby obviate the necessity for removal and replacement of pavements or overdesigns. There are other instances in which reinforcement to reduce the pavement thickness may be warranted and must be regarded. The design procedure consists of determining the percentage of steel required, the thickness of the JRC pavement, and the maximum allowable length of slabs.

a. Determination of required percent steel and required thickness of JRC pavement. It is first necessary to determine the required thickness h_{dc} of JC pavement using the design loading and physical properties of the pavement and foundation (chap 2). When the JRC pavement is to be used on nonstabilized bases or subgrades, the procedure outlined in paragraph 2-2a will be used to determine h_{dc}; whereas, when the JRC pavement is to be used on stabilized layers of material, the procedure outlined in 2-3b will be used. The thickness, h_{dc} or h_{doc}, is then used to enter the nomograph (fig 3-1) to determine the required percent steel, S, and required thickness h_{dr} or h_{dor} of JRC pavement. Since the thickness h_{dr} and S are interrelated, it will be necessary to establish a desired value of one and determine the other. The resulting values of h_{dr} and S will represent a JRC pavement that will provide the same performance as the required thickness of concrete pavement, h_{dc} or h_{doc}. In all cases, when the required thickness h_{dc} is reduced by the addition of reinforcing steel, the design percentage of steel will be placed in each of two directions (transverse and longitudinal) in the slab. For construction purposes,

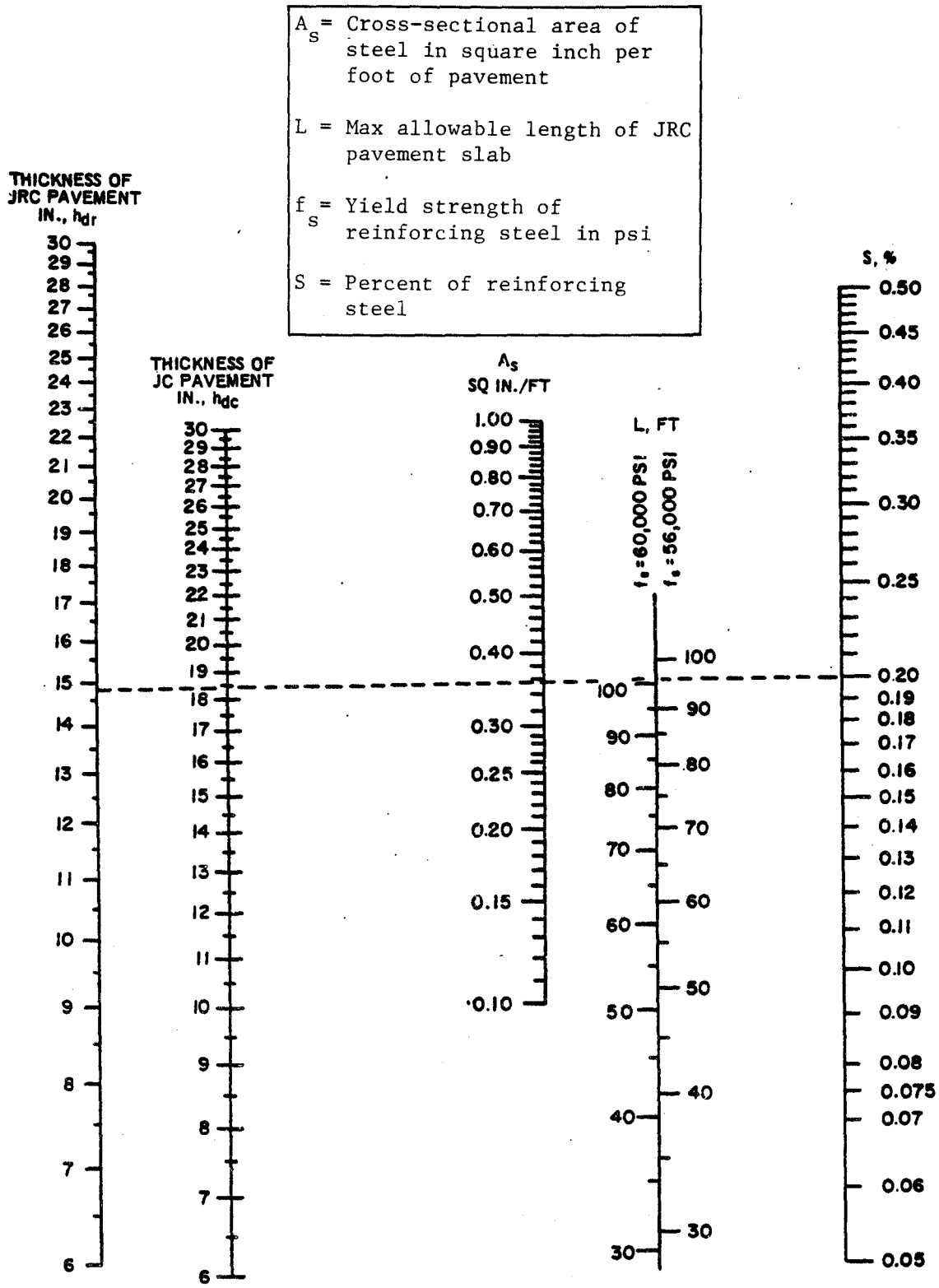

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FIGURE 3-1. JOINTED REINFORCED CONCRETE PAVEMENT DESIGN

the required thickness h_{dr} must be rounded to the nearest full- or half-inch increment. When the indicated thickness is midway between full- and half-inch or half and full increments, the thickness will be rounded upward.

b. Determination of maximum JRC pavement slab size. The maximum length or width of JRC pavement slab is dependent largely upon the resistance to movement of the slab on the underlying material and the yield strength of the reinforcing steel. The latter factor can be easily determined; however, very little reliable information is available regarding the sliding resistance of concrete on the various foundation materials. For this design procedure, the sliding resistance has been assumed to be constant for a JRC pavement cast either directly on the subgrade, on a stabilized or nonstabilized base course, or on an existing flexible pavement. The maximum allowable width W or length L of JRC pavement slab will be determined from the following equation:

$$W \text{ or } L = 0.0777\sqrt[3]{h_{dr}(f_s S)^2}$$

The formula above has been expressed on the nomograph (fig 3-1) for steel yield strengths f_s of 56,000 and 60,000 psi and the maximum W or L can be obtained from the intersection of a straight line drawn between the values of h_{dr} and S that will be used for the JRC pavement. The width of JRC pavement will generally be controlled by the concrete paving equipment and will normally be 25 feet, unless smaller widths are necessary to meet dimensional requirements.

c. Limitations to JRC pavement design procedure. The design procedure for JRC pavements presented herein has been developed from a limited amount of investigational and performance data. Consequently, the following limitations are imposed:

(1) No reduction in the required thickness of JC pavement will be allowed for percentages of steel reinforcement less than 0.05.

(2) No further reduction in the required thickness of JC pavement will be allowed over that indicated for 0.5 percent steel reinforcement in figure 3-1 regardless of the percent steel used.

(3) The maximum width or length of JRC pavement slab will not exceed 100 feet regardless of the percent steel used or slab thickness.

(4) The minimum thickness of JRC pavement or JRC overlay will be 6 inches.

3-3. Reinforcement to control pavement cracking. Reinforcement is mandatory in certain areas of JC pavements to control or minimize the effects of cracking. The reinforcing steel holds cracks tightly closed, thereby preventing spalling at the edges of the cracks and progression of the cracks into adjacent slabs. For each of the following conditions, the slabs or portions of the slabs will be reinforced with 0.05 percent steel in two directions normal to each other unless otherwise specified.

a. Odd-shaped slabs. It is often necessary in the design of pavement facilities to resort to odd-shaped slabs. Unless reinforced, these odd-shaped slabs often crack and eventually spall along the cracks, producing debris that is objectionable from operational and maintenance viewpoints. In addition, the cracks may migrate across joints into adjacent slabs. In general, a slab is considered to be odd-shaped if the longer dimension exceeds the shorter one by more than 25 percent or if the joint pattern does not result in essentially a square or rectangular slab. Figure 3-2 presents typical examples of odd-shaped slabs requiring reinforcement.

b. Mismatched joints. Steel reinforcement in the slabs is mandatory to prevent migration of cracks into adjacent pavements for the following two conditions of mismatched joints:

(1) Where joint patterns of abutting pavement facilities do not match, a partial reinforcement of slabs may be necessary. In such a condition, the mismatch of joints can cause a crack to form in the adjacent pavement unless there is a sufficient width of bond-breaking medium installed in the joint. The determination relative to utilizing reinforcement at mismatched joints in such junctures is based upon the type joint between the two pavement sections. A partial reinforcement of the slab, as described below, is required when the joint between the abutting pavement is one of the following: doweled construction joint, keyed construction joint, thickened-edge butt joint without a bond-breaking medium, doweled expansion joint, and thickened-edge slip joint with less than 1/4-inch bond-breaking medium. Reinforcement is not required if the joint between the abutting pavement facilities is either a thickened-edge expansion joint or a thickened-edge slip joint with 1/4 inch or more of bond-breaking medium, except for a mismatch of joints in the center 75-foot width of runway where reinforcement of the slabs of mismatched joints will be required regardless of the type of joint between the facilities. When reinforcement at mismatched joints is required, the slab in the pavement facility directly opposite the mismatched joint will be reinforced with the minimum 0.05 percent steel. The reinforcing steel will be placed in two rectangular directions for a distance 3 feet back from the juncture and for the full width or length of the slab in a direction normal to the mismatched joint. When a new pavement is being constructed abutting an existing pavement, the new slab opposite mismatched joints will be reinforced in the manner described above. When two abutting facilities

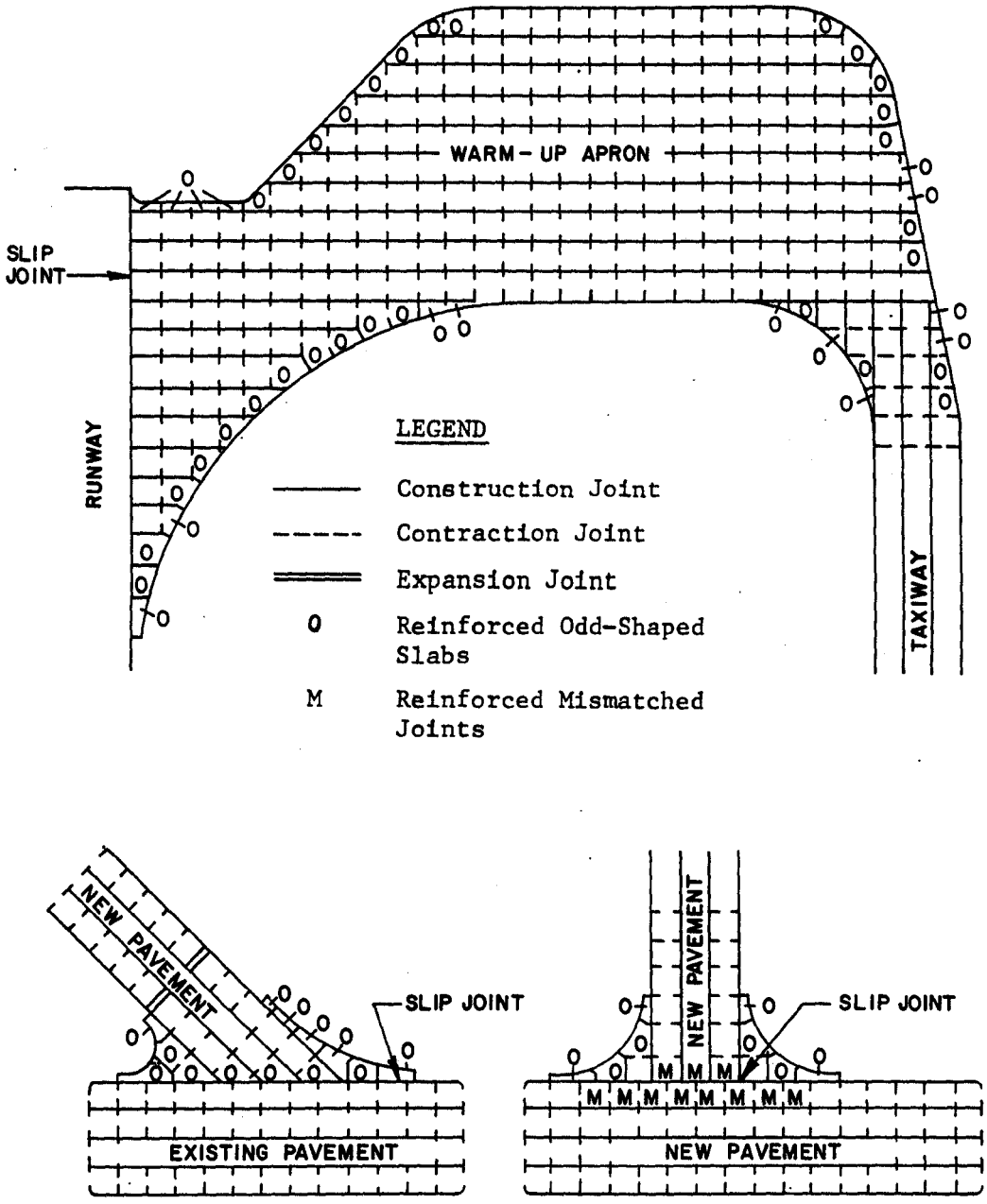

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FIGURE 3-2. TYPICAL LAYOUTS SHOWING REINFORCEMENT OF ODD-SHAPED SLAPS AND MISMATCHED JOINTS

are being constructed concurrently, the slabs on both sides of the juncture opposite mismatched joints will be reinforced in the manner described above. For this condition shown in figure 3-2, the slip joint bond-breaking medium can be specified to be a full 1/4 inch thick, and the reinforcing may be omitted.

(2) The second condition of mismatched joints where reinforcement is required occurs in the construction of a JC overlay of an existing rigid pavement. Joints in the overlay should coincide with joints in the base pavement. Sometimes this is impracticable due to an unusual jointing pattern in the existing pavement. When necessary to mismatch the joints in the overlay and the existing pavement, the overlay pavement will be reinforced with the minimum 0.05 percent steel. The steel will be placed in two rectangular directions for a distance of at least 3 feet on each side of the mismatched joint in the existing pavement. The steel will, however, not be carried through any joint in the overlay except as permitted or required by paragraph 3-6. If the joint pattern in the existing pavement is highly irregular, or runs at an angle to the desired pattern in the overlay, the entire overlay slabs will be reinforced in both the longitudinal and transverse directions. When a bond-breaker course is placed between the existing pavement and overlay, reinforcement of the overlay over mismatched joints is not required, except for mismatched expansion joints.

c. Reinforcement of pavements incorporating heating pipes. JC pavements, such as hangar floors that incorporate radiant heating systems within the concrete, are subject to extreme temperature changes. These temperature changes cause thermal gradients in the concrete that result in stresses of sufficient magnitude to cause surface cracking. To control such cracking, these pavement slabs will be reinforced with a minimum of 0.05 percent steel placed in the transverse and longitudinal directions.

d. Reinforcement of slabs containing utility blockouts. The minimum of 0.05 percent steel reinforcement is required in JC pavement slabs containing utility blockouts, such as for hydrant refueling outlets, storm drain inlets, and certain types of flush lighting fixtures. The entire slab or slabs containing the blockouts will be reinforced in two rectangular directions.

3-4. JRC pavements in frost areas. Normally, JC pavements in frost areas will be designed in accordance with EM 1110-3-138 and reinforcement will be unnecessary. There may, however, be special instances when it will be directed that the frost design criteria will not be used. Typical of such instances are: design of new pavements to the strength of existing pavement when the existing pavement does not meet the frost design requirements, and design of an inlay section of adequate strength pavement in the center portion of an existing runway when the existing pavement does not meet the frost design

requirements. In such instances, the new pavements will be reinforced with a minimum of 0.15 percent steel. The minimum 0.15 percent steel will be placed in each of two directions (transverse and longitudinal) in the slab. The reinforcing steel is required primarily to control cracking that may develop because of differential heaving. The pavement thickness may be reduced and the maximum slab length, consistent with the percent steel, may be used as outlined in paragraph 3-3. Longer slabs will help reduce roughness that may result from frost action. Greater percentages of steel reinforcement may be used when it is desired to reduce the pavement thickness more than is allowable for the required minimum percentage of steel. Reinforced rigid pavement may be considered in frost areas to reduce the required depth of nonfrost-susceptible base course material. However, reinforcement will only be considered for this condition when there is an inadequate source of suitable base course materials or when special processing of existing materials would be required.

3-5. Reinforcement steel.

a. Type of reinforcement steel. The reinforcement steel may be either deformed bars or welded wire fabric. Table 3-1 summarizes the cross-sectional areas and weights of wires.

b. Placement of reinforcement steel. The reinforcement steel will be placed at a depth of 1/4 h_{dr} plus 1 inch from the surface of the reinforced slab. This will place the steel above the neutral axis of the slab and will allow clearance for dowel bars. The wire or bar sizes and spacing should be selected to give, as nearly as possible, the required percentage of steel per foot of pavement width or length. In no case should the percent steel used be less than that required by figure 3-1. Two layers of wire fabric or bar mat, one placed directly on top of the other, may be used to obtain the required percent of steel; however, this should only be done when it is impracticable to provide the required steel in one layer. If two layers of steel are used, the layers must be fastened together (either wired or clipped) to prevent excessive separation during concrete placement. When the reinforcement is installed and concrete is to be placed through the mat or fabric, the minimum clear spacing between bars or wires will be 1-1/2 times the maximum size of aggregate. If the strike-off method is used to place the reinforcement (layer of concrete placed and struck off at the desired depth, the reinforcement placed on the plastic concrete, and the remaining concrete placed on top of the reinforcement), the minimum spacing of wires or bars will not be less than the maximum size of aggregate. Maximum bar or wire spacing should not exceed 12 inches or the slab thickness. Figure 3-3 shows the typical details of slab reinforcement with wire fabric or bar mats. The bar mat or wire fabric will be securely anchored to prevent forward creep of the steel mats during concrete placement and finishing operations. The reinforcement shall be fabricated and placed in such a manner that the spacing between the longitudinal wire or bar and the

Table 3-1. Welded Wire Fabrics

Size No.	Nominal Diameter, inches	Nominal Area, square inches
W 31	0.628	0.310
W 30	0.618	0.300
W 28	0.597	0.280
W 26	0.575	0.260
W 24	0.553	0.240
W 22	0.529	0.220
W 20	0.505	0.200
W 18	0.479	0.180
W 16	0.451	0.160
W 14	0.422	0.140
W 12	0.391	0.120
W 10	0.357	0.100
W 8	0.319	0.080
W 7	0.299	0.070
W 6	0.276	0.060
W 5.5	0.265	0.055
W 5	0.252	0.050
W 4.5	0.239	0.045
W 4	0.226	0.040
W 3.5	0.211	0.035
W 3	0.195	0.030
W 2.5	0.178	0.025
W 2	0.160	0.020
W 1.5	0.138	0.015
W 1.2	0.124	0.012
W 1	0.113	0.010
W 0.5	0.080	0.005

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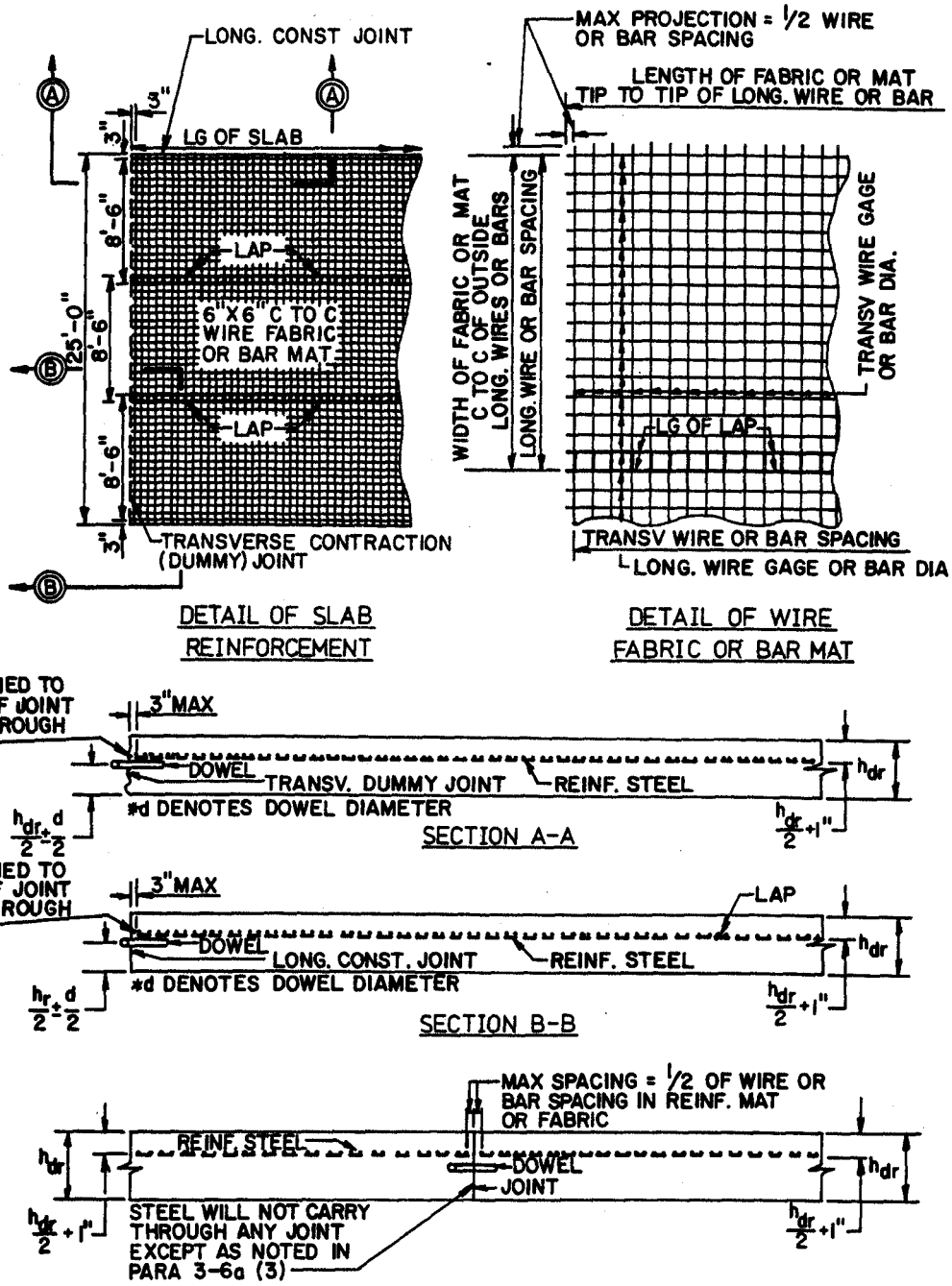

NOTES: 1. h_{dr} denotes JRC pavement design thickness.

2. Reinforced steel will not be carried through any joint except as noted in para 3-6a.

3. All joints in JRC pavements doweled except as noted in para 3-6a.

4. Dowel size, spacing and length determined from para 2-3a(5) using JRC pavement thickness, h_{dr}.

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FIGURE 3-3. REINFORCEMENT STEEL DETAILS

longitudinal joint, or between the transverse wire or bar and the transverse joint, will not exceed 3 inches or one half of the wire or bar spacing in the fabric or mat (fig 3-3). The wires or bars will be lapped as follows:

(1) Deformed steel bars will be overlapped for a distance of at least 24-bar diameters, measured from the tip of one bar to the tip of the other bar. The lapped bars will be wired or otherwise securely fastened to prevent separation during concrete placement.

(2) Wire fabric will be overlapped for a distance equal to at least one spacing of the wire in the fabric or 32-wire diameters, whichever is the greater. The length of lap is measured from the tip of one wire to the tip of the other wire normal to the lap. The wires in the lap will be wired or otherwise securely fastened to prevent separation during concrete placement.

3-6. Jointing.

a. Requirements. Figures 3-4 through 3-6 present details of joints in JRC pavements. Joint requirements and types in JRC pavement will be the same as for the JC pavements except for the following:

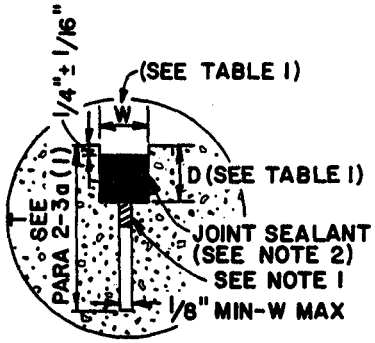
(1) All joints, with the exception of thickened-edge-type joints and transverse construction joints, falling at a point other than at a regularly scheduled transverse contraction joint, will be doweled. One end of the dowel will be painted and oiled or greased to permit movement at the joint.

(2) Thickened-edge-type joints (expansion, butt, or slip) will not be doweled. The edge will be thickened to 1-1/4 h_{dr}.

(3) When a transverse construction joint is required within a reinforced slab unit, the reinforcing steel will be carried through the joint. In addition, dowels meeting the size and spacing requirements of table 3-1 for the design thickness h_{dr} will be used in the joint.

(4) Maximum spacing of transverse contraction joints or longitudinal construction joints will be determined in accordance with paragraphs 2-3a and 2-3b.

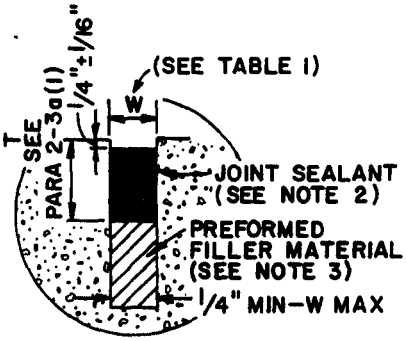
b. Joint sealing. Joint sealing for JRC pavements will be the same as for the JC pavements (para 2-3f). The use of preformed compression sealants will be required when the joint spacing exceeds 50 feet.



SAWED

TABLE I

CONTRACTION JOINT SPACING, ft.	DIMENSIONS, in.	
	W	D
<20	3/8 ± 1/16	3/4 ± 1/16
20-25	1/2 ± 1/16	1 ± 1/16
>25-50	3/4 ± 1/16	1-1/4 ± 1/16
>50-100	1 ± 1/16	1-1/2 ± 1/16



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NOTE: 1. Nonabsorptive material required to prevent joint sealant from flowing into sawcut and to separate noncompatible materials.

2. Joint sealant may be pourable or preformed type (see para 2-3e).

3. Preformed filler may be fiberboard or other approved material which can be sawed or which can have a section removed to form a sealant reservoir.

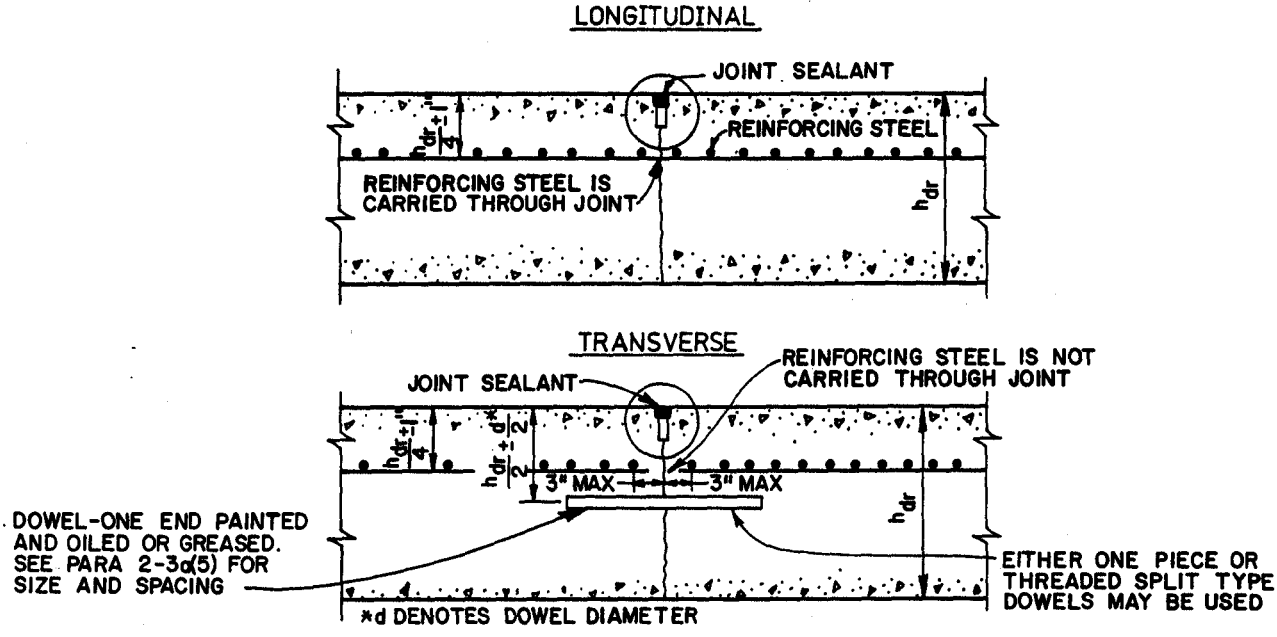

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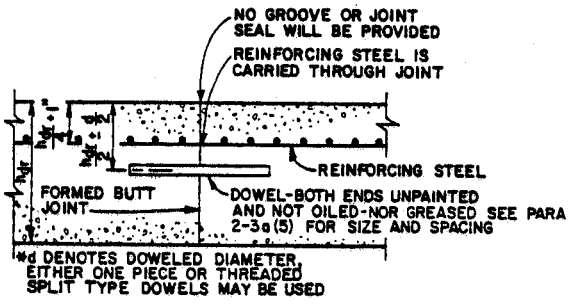
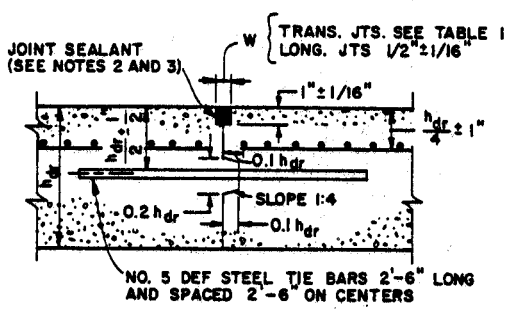
FIGURE 3-4. CONTRACTION JOINTS FOR JRC PAVEMENTS

DOWELED TRANSVERSE (1)



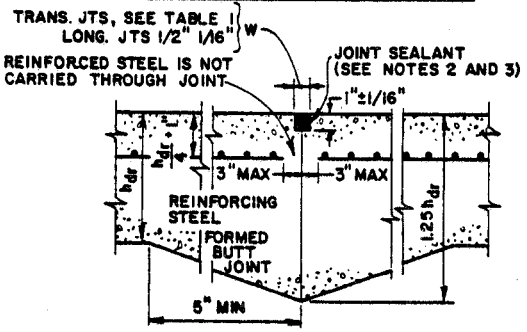
NOTE: 1. **This detail will be used only when a transverse construction joint is required at a location other than a regularly scheduled transverse contraction joint.**

KEYED AND TIED LONGITUDINAL

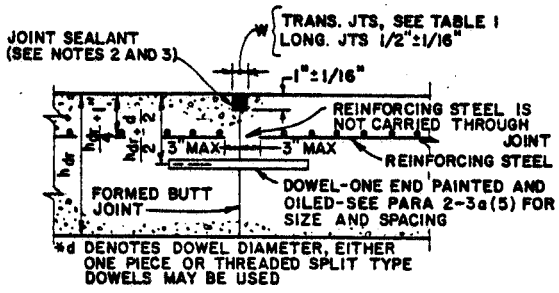


NOTE: A tolerance of plus or minus 1/16 inch may be allowed for key dimensions and location.

THICKENED EDGE LONGITUDINAL

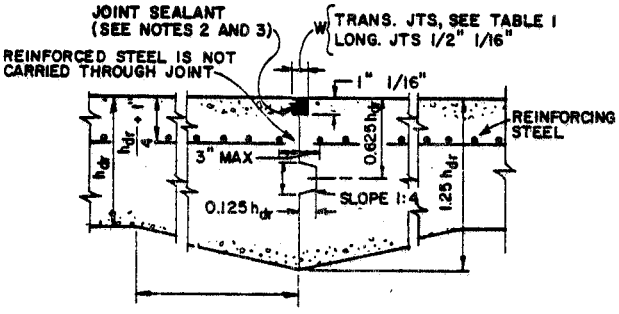


DOWELED TRANSVERSE (4) OR LONGITUDINAL



NOTE: 4. **This detail will be used when a transverse construction joint is required at a regularly scheduled transverse contraction joint.**

KEYED THICKENED EDGE LONGITUDINAL

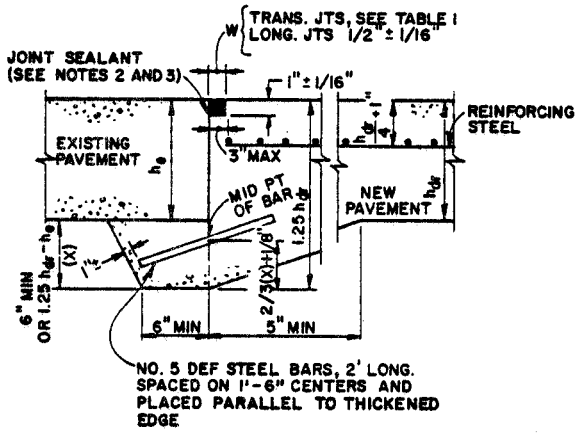


NOTE: A tolerance of plus or minus 1/16 inch may be allowed for key dimensions and location.

TABLE I

DISTANCE BETWEEN JOINTS (SLAB LENGTH) OR WIDTH) FT	W INCHES	D INCHES
UP TO 50	1/2 1/8	1/2 1/8
51 TO 100	3/4 1/8	3/4 1/8

SPECIAL JOINT BETWEEN NEW AND EXISTING PAVEMENTS



NOTE: 2. Top of joint sealant will be 1/4 inch plus or minus 1/16 inch below top of pavement.

NOTE: 3. Joint sealant may be pourable or preformed type (See para 2-3e).

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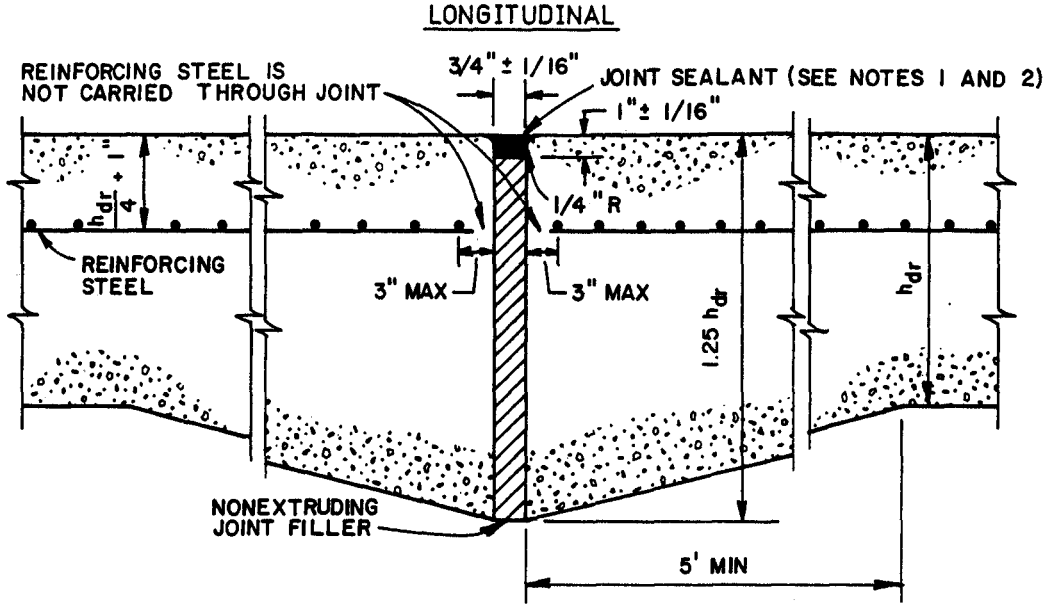
FIGURE 3-5. CONSTRUCTION JOINTS FOR JRC PAVEMENTS



NOTE: 1. Top of joint sealant will be 1/4 inch plus or minus 1/16 inch below top of pavement.

2. Joint sealant may be pourable or preformed type (see para 2-3e).

3. Either one piece or threaded split type dowels may be used.

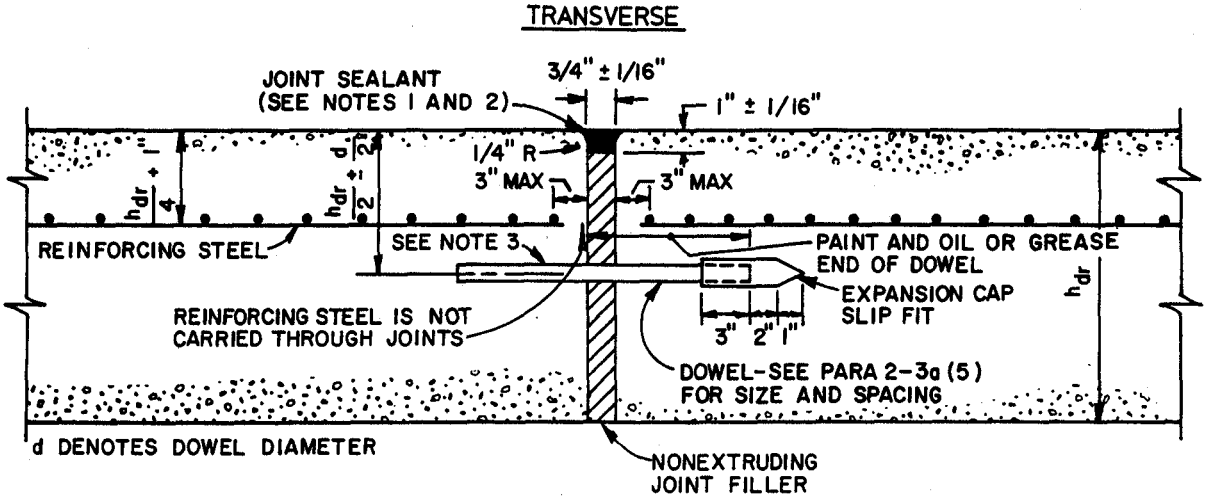


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FIGURE 3-6. EXPANSION JOINTS FOR JRC PAVEMENTS