U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: AIRPORT PAVEMENT DESIGN AND EVALUATION

Date: 6/3/02
Initiated by: AAS-100

AC No: 150/5320-6D
Change: 2

1. Purpose of this advisory circular. Advisory Circular (AC) 150/5320-6D, AIRPORT PAVEMENT DESIGN AND EVALUATION, has been revised to incorporate recent changes and corrections.

2. Principal changes. In addition to necessary typographical changes, this AC includes the following revisions:

a. Paragraph 203b(4) has been changed to agree with AC 150/5370-10A, Standards for Specifying Construction of Airports; 60,000 pounds is now the decision point between heavy-load and light-load pavements.

b. Paragraph 337, JOINTING OF CONCRETE PAVEMENTS, has been changed to refer to Table 3-10A, PAVEMENT JOINT TYPES, which has been added as page 86-2.

c. Figures 3-42 and 3-42A, RIGID PAVEMENT TYPES AND DETAILS, have been revised to change the depth, noted as "T/5" in DETAIL 2, to "T/4"; add a chamfer joint detail; and add new detail "PLAN VIEW - Position of Dowels at Edge of Joint Type A, D, F."

d. Paragraph 337b(1) has been updated to reflect a conservative recommendation for maximum joint spacing. A definition for the symbol for radius of relative stiffness has been included.

e. Paragraph 337b(2) has been changed to reflect the maximum recommended ratio of joint spacing in inches to radius of relativity from 6.0 to 5.0.

f. The formula for steel area in paragraph 344a has been corrected.

g. Figure 3-43 has been revised to indicate joint and fillet alternatives.

h. Paragraph 406b(1) has been revised to indicate the correct value for C_r and C_b.

i. Figure 4-3, GRAPH OF "F" FACTORS VS. MODULUS OF SUBGRADE REACTION FOR DIFFERENT TRAFFIC LEVELS, has been updated to include departure levels on the graph.

j. The formulas for overlay thickness in paragraphs 411a and 411b have been corrected.

k. Paragraph 502c has been updated to correct the paragraph reference and update the ASTM title.

l. The example problem in paragraph 503d (1), (2), and (3) has been updated to agree with the referenced figure.

m. The reference in paragraph 503f to paragraph 323 has been corrected to paragraph 322.

n. Paragraph 505a has been updated to include an explanation of tension ring design employment.

o. Paragraph 508 has been added to address thermal resistant pavements for vertiports.

p. The formula for split tensile strength in paragraph 604b(1)(i) has been updated.

The change number and date are shown at the top of each page.

PAGE CONTROL CHART			
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138	7/7/95	138	6/3/02

The following pages are reprinted for convenience iii, 8, 105, 107, 126, and 137.

DAVID L. BENNETT
Director, Office of Airport Safety and Standards

(1) Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants (ASTM D 421) or Wet Preparation of Soil Samples for Grain-Size Analysis and Determination of Soil Constants (ASTM D 2217). The dry method (D 421) should be used only for clean, cohesiveless granular materials. The wet method (D 2217) should be used for all cohesive or borderline materials. In case of doubt, the wet method should be used.

(2) Particle-Size Analysis of Soils (ASTM D 422). This analysis provides a quantative determination of the distribution of particles sizes in soils.

(3) Liquid Limit, Plastic Limit, and Plasticity Index of Soils (ASTM D 4318). The plasticity and liquid limits of soil define in a standard manner the lowest moisture contents at which a soil will change from a semisolid to a plastic state and at which a solid passes from a plastic to a liquid state, respectively. The plasticity index is the numerical difference between the plastic limit and the liquid limit. It indicates the range in moisture content over which a soil remains in a plastic state prior to changing into a liquid. The plastic limit, liquid limit, and plasticity index of soils are used in engineering classification in accordance with the Unified Soil Classification System (ASTM D 2487). In conjunction with particle size analysis, natural moisture content and other soil properties or conditions, the limits may be used to estimate engineering properties or behavior of soils, such as shrink/swell potential, consolidation characteristics, construction/stabilization characteristics, permeability, and strength characteristics.

(4) Moisture-Density Relations of Soils (ASTM D 698, D 1557). For purposes of compaction control during construction, tests to determine the moisture-density relations of the different types of soils should be performed.

(i) Heavy-Load Pavements. For pavements designed to serve aircraft weighing 60,000 pounds (27,000 kg) or more, use ASTM D 1557.

(ii) Light-Load Pavements. For pavements designed to serve aircraft weighing less than 60,000 pounds (27,000 kg), use ASTM D 698.

(5) Bearing Ratio of Laboratory-Compacted Soils (ASTM D 1883). This test is used to assign a California Bearing Ratio (CBR) value to subgrade soils for use in the design of flexible pavements.

(6) Modulus of Soil Reaction (AASHTO T 222). This test is used to determine the modulus of soil reaction, K, for use in the design of rigid pavements.

c. Supplemental Tests. In many cases, additional soil tests will be required over those listed in Paragraph 203b above. It is not possible to cover all the additional tests that may be required; however, a few examples are presented below. This list should not be considered all-inclusive.

(1) Shrinkage Factors of Soils (ASTM D 427). This test may be required in areas where swelling soils might be encountered.

(2) Permeability of Granular Soils (ASTM D 2434). This test may be needed to assist in the design of subsurface drainage.

(3) Determination of Organic Material in Soils by Wet Combustion (AASHTO T 194). This test may be needed in areas where deep pockets of organic material are encountered or suspected.

(4) California Bearing Ratio, Field In-Place Tests (Mil-Std 621, Method 101). Field-bearing tests can be performed when the in-situ conditions satisfy density and moisture conditions that will exist under the pavement being designed. The method is also described in Manual Series No. 10, Soils Manual, The Asphalt Institute, College Park, MD.

204. UNIFIED SOIL CLASSIFICATION SYSTEM.

a. Purpose. The standard method of classifying soils for engineering purposes is ASTM D 2487, commonly called the Unified system. The primary purpose in determining the soil classification is to enable the engineer to predict probable field behavior of soils. The soil constants in themselves also provide some guidance on which to base performance predictions. The Unified system classifies soils first on the basis of grain size, then further subgroups soils on the plasticity constants. Table 2-2 presents the classification of soils by the Unified system.

b. Initial Division. As indicated in Table 2-2, the initial division of soils is based on the separation of coarse- and fine-grained soils and highly organic soils. The distinction between coarse and fine grained is determined by the amount of material retained on the No. 200 sieve. Coarse-grained soils are further subdivided into gravels and sands on the basis of the amount of material retained on the No. 4 sieve. Gravels and sands are then classed according to whether or not the fine material is present. Fine-grained soils are subdivided into two groups on the basis of liquid limit. A separate division of highly organic soils is established for materials which are generally suitable for consideration purposes.

TABLE 2-2. CLASSIFICATION OF SOILS FOR AIRPORT PAVEMENT APPLICATIONS

MAJOR DIVISIONS			GROUP SYMBOLS
Coarse-grained soils more than 50% retained on No. 200 sieve[1]	Gravels 50% or more of coarse fraction retained on No. 4 sieve	Clean Gravels	GW GP
		Gravels with Fines	GM GC
	Sands less than 50% of coarse fraction retained on No. 4 sieve	Clean Sands	SW SP
		Sands with Fines	SM SC
Fine-grained soils 50% or less retained on No. 200 sieve	Silts and clays liquid limit 50% or less		ML CL OL
	Silts and clays liquid limit greater than 50%		MH CH OH
Highly Organic Soils			PT

[1]Based on the material passing the 3-in (75-mm) sieve

c. Soil Groups. Soils are further subdivided into 15 different groupings. The group symbols and a brief description of each is given below:

(1) **GW** Well-graded gravels and gravel-sand mixtures, little or no fines.
(2) **GP** Poorly graded gravels and gravel-sand mixtures, little or no fines.
(3) **GM** Silty gravels, gravel-sand-silt mixtures.
(4) **GC** Clayey gravels, gravel-sand-clay mixtures.
(5) **SW** Well-graded sands and gravelly sands, little or no fines.
(6) **SP** Poorly graded sand and gravelly sands, little or no fines.
(7) **SM** Silty sands, sand-silt mixtures.
(8) **SC** Clayey sands, sand-clay mixtures.
(9) **ML** Inorganic silts, very fine sands, rock flour, silty or clayey fine sands.
(10) **CL** Inorganic clays of low to medium plasticity, gravelly clays, silty clays, lean clays.
(11) **OL** Organic silts and organic silty clays of low plasticity.
(12) **MH** Inorganic silts, micaceous or diatomaceous fine sands or silts, plastic silts.

uniform, stable foundation.

b. Thickness. Pavements subjected to traffic intensities greater than the 25,000 annual departure level shown on the design curves will require more thickness to accommodate the traffic volume. Additional thickness can be provided by increasing the pavement thickness in accordance with Table 3-5.

c. Panel Size. Slab panels should be constructed to minimize joint movement. Panel sizes given in Paragraph 337 should be selected conservatively. Small joint movement tends to provide for better load transfer across joints and reduces the elongation the joint sealant materials must accommodate when the slabs expand and contract. High-quality joint sealants should be specified to provide the best possible performance.

337. JOINTING OF CONCRETE PAVEMENTS. Variations in temperature and moisture content can cause volume changes and slab warping, resulting in significant stresses. In order to reduce the detrimental effects of these stresses and to minimize random cracking, it is necessary to divide the pavement into a series of slabs of predetermined dimensions by means of joints. These slabs should be as nearly square as possible when no reinforcement is used.

a. Joint Categories. Pavement joints are categorized according to the function that the joint is intended to perform. The categories are expansion, contraction, and construction joints. All joints, regardless of type, should be finished in a manner that permits the joint to be sealed. Pavement joint details are shown in Figures 3-42 and 3-42A and are summarized in Table 3-10A. These various joints are described as follows:

(1) Expansion Joints. The function of an expansion joint is to isolate intersecting pavements and to isolate structures from the pavement. There are two types of expansion joints.

(i) Type A. Type A is used when load transfer across the joint is required. This joint contains a 3/4-inch (19 mm) nonextruding compressible material and is provided with dowel bars for load transfer.

(ii) Type B. Type B is used when conditions preclude the use of load transfer devices that span across the joint, such as where the pavement abuts a structure or where horizontal differences in movement of the pavements may occur. These joints are formed by increasing the thickness of the pavement along the edge of slab. No dowel bars are provided.

(2) Contraction Joints. The function of contraction joints is to provide controlled cracking of the pavement when the pavement contracts due to decrease in moisture content or a temperature drop. Contraction joints also decrease stresses caused by slab warping. Details for contraction joints are shown as Types F, G, and H in Figure 3-42.

(3) Construction Joints. Construction joints are required when two abutting slabs are placed at different times, such as at the end of a day's placement, or between paving lanes. Details for construction joints are shown as Types C, D, and E in Figure 3-42.

b. Joint Spacing.

(1) Without Stabilized Subbase. A rule-of-thumb for joint spacing given by the Portland Cement Association is applicable for rigid pavements without stabilized subbase: "As a rough guide, the joint spacing (in feet) should not greatly exceed twice the slab thickness (in inches)." Table 3-11 shows the recommended maximum joint spacings. Shorter spacings may be more convenient in some instances and may be required to provide minimum clearance between pavement joints and in-pavement obstructions such as light cans. The recommended maximum spacing for slabs thicker than 12 inches (305 mm) should only be used when historical records can verify satisfactory performance. In lieu of historical performance records, a maximum spacing of 20 feet (6.1 m) is recommended. The ratio of slab length to slab width should not exceed 1.25 in unreinforced pavements.

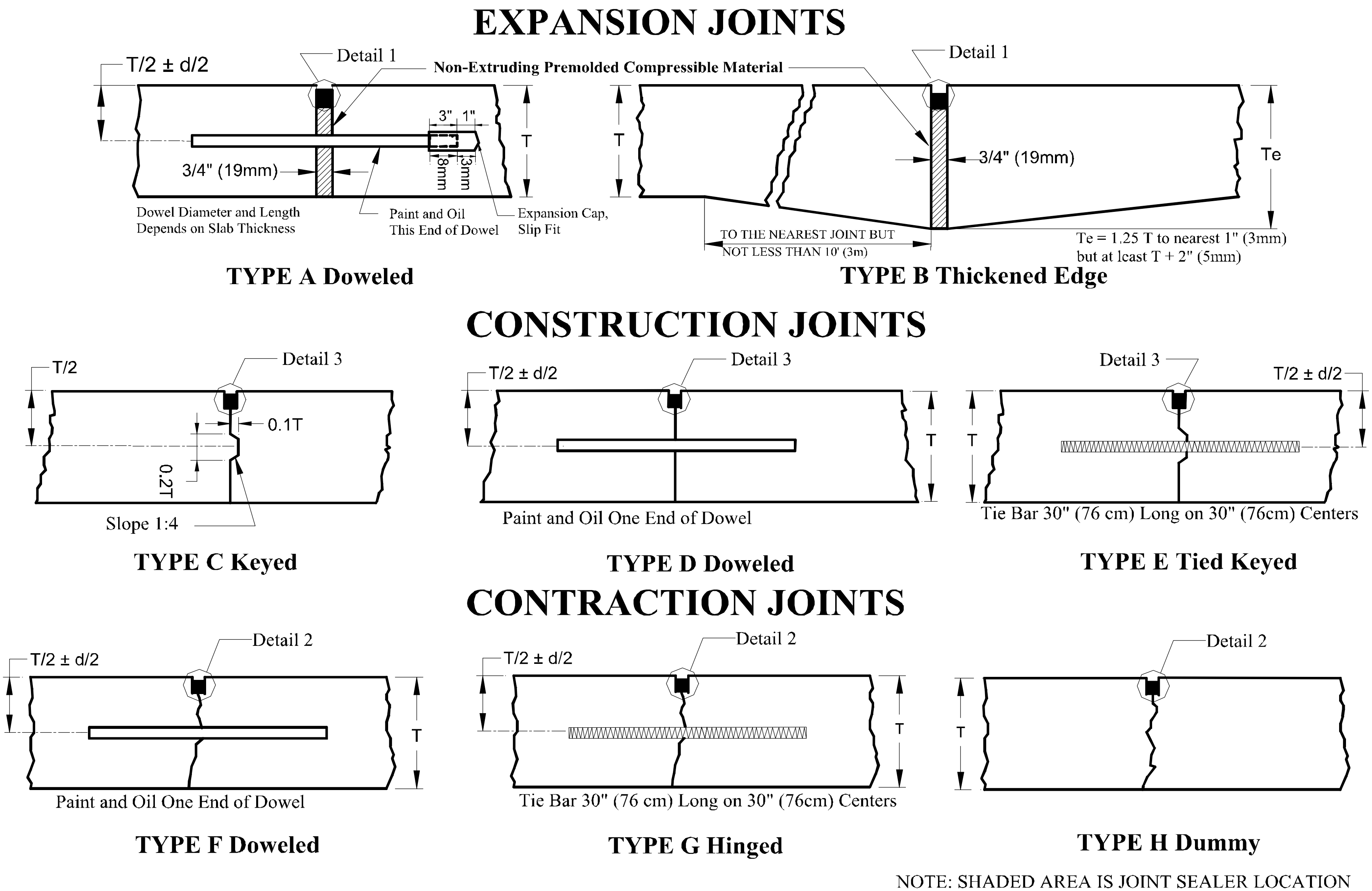
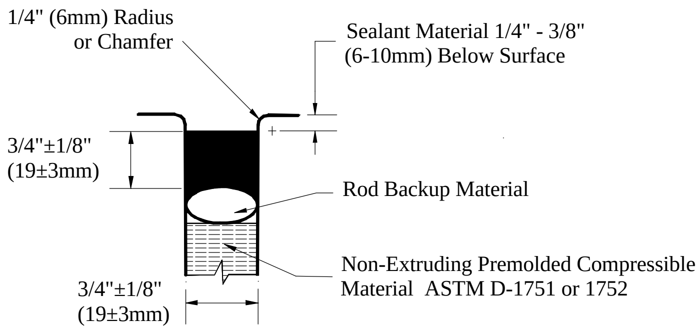
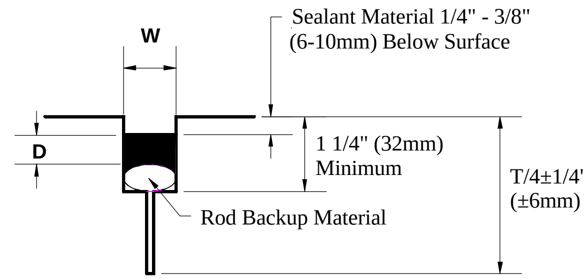


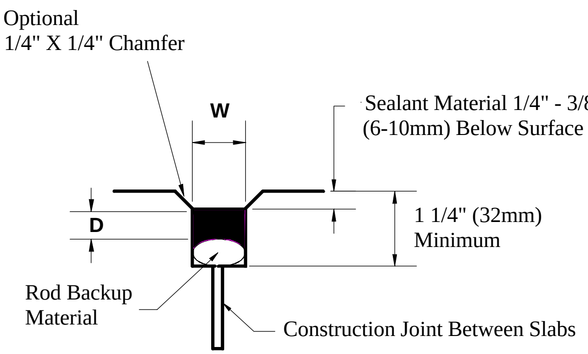
FIGURE 3-42. RIGID PAVEMENT JOINT TYPES AND DETAILS



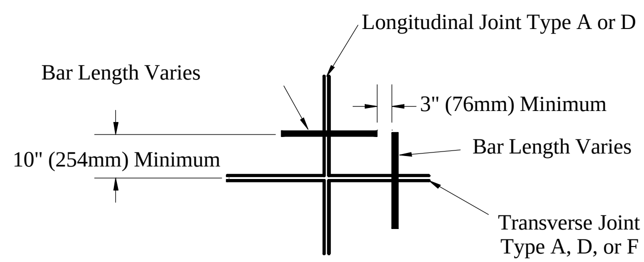
DETAIL 1
EXPANSION JOINT



DETAIL 2
CONTRACTION JOINT



DETAIL 3
CONSTRUCTION JOINT



PLAN VIEW
Position of Dowels at Edge of Joint
Type A, D, F

NOTES:
1. SEALANT RESERVOIR SIZED TO PROVIDE PROPER SHAPE FACTOR, W/D. FIELD POURED AND PREFORMED SEALANTS REQUIRE DIFFERENT SHAPE FACTORS FOR OPTIMUM PERFORMANCE.
2. ROD BACKUP MATERIAL MUST BE COMPATIBLE WITH THE TYPE OF SEALANT USED AND SIZED TO PROVIDE THE DESIRED SHAPE FACTOR.
3. RECESS SEALER 3/8" - 1/2" FOR JOINTS PERPENDICULAR TO RUNWAY GROOVES
4. CHAMFERED EDGES ARE RECOMMENDED FOR DETAILS 2 AND 3 WHEN PAVEMENTS ARE SUBJECT TO SNOW REMOVAL EQUIPMENT OR HIGH TRAFFIC VOLUMES.

FIGURE 3-42A. RIGID PAVEMENT JOINT TYPES AND DETAILS

TABLE 3-10A PAVEMENT JOINT TYPES

JOINT TYPES - DESCRIPTION AND USE (Chapter 3 designations)			
TYPE	DESCRIPTION	LONGITUDINAL	TRANSVERSE
A	Doweled Expansion Joint	Not used.	Use near intersections to isolate different pavement areas. Not recommended to isolate different joint patterns.
B	Thickened Edge Expansion Joint	Use at intersections where dowels are not suitable and where pavements abut structures. Consider at locations along a pavement edge where future expansion is possible.	Provide thickened edge where pavement extension is likely. On thinner pavement sections the thickened edge will provide additional section for placement of future dowel bars. Recommended to isolate different joint patterns.
C	Keyed Construction Joint	Acceptable for all construction joints except where type E is required.	Not used.
D	Doweled Construction Joint	Acceptable for all construction joints.	Use at locations where paving operations are delayed or stopped.
E	Hinged Construction Joint	Acceptable for use on all construction joints of taxiways and for all other construction joints placed 25' or less from the pavement edge unless wide body aircraft are expected. See paragraph 338b for wide body aircraft requirements.	Not used.
F	Doweled Contraction Joint	May be considered for general use.	Use on all contraction joints for a distance of at least three joints from a free edge, for the first two joints on each side of expansion joints, and for all contraction joints in reinforced pavements. May be considered for general use.
G	Hinged Contraction Joint	For all contraction joints of the taxiway and for all other contraction joints placed 25' or less from the pavement edge unless wide body aircraft are expected. See paragraph 338b for wide body aircraft requirements.	Not used.
H	Dummy Contraction Joint	For all other contraction joints in pavement.	For all remaining contraction joints in non-reinforced pavements.

TABLE 3-11. RECOMMENDED MAXIMUM JOINT SPACINGS - RIGID PAVEMENT WITHOUT STABILIZED SUBBASE

Slab Thickness		Transverse		Longitudinal	
Inches	Millimeters	Feet	Meters	Feet	Meters
6	150	12.5	3.8	12.5	3.8
7-9	175-230	15	4.6	15	4.6
9-12	230-305	20	6.1	20	6.1
> 12	>305	25	7.6	25	7.6

Note: Joint spacings shown in this table are maximum values that may be acceptable under ideal conditions. Smaller joint spacings should be used if indicated by past experience. Pavements subject to extreme seasonal temperature differentials or extreme temperature differentials during placement may require smaller joint spacings. See also Chapter 5 for light-load rigid pavement jointing.

(2) With Stabilized Subbase. Rigid pavements supported on stabilized subbase are subject to higher warping and curling stresses than those supported on unstabilized foundations. When designing a rigid pavement supported on a stabilized subbase a different procedure is recommended to determine joint spacing. Joint spacing should be a function of the radius of relative stiffness of the slab. The joint spacing should be selected such that the ratio of the joint spacing, in inches, to the radius of relative stiffness is 5.0 or less to control transverse cracking. In the absence of conclusive local experience, a maximum joint spacing of 20 feet (6.1 m) is recommended. The radius of relative stiffness is defined by Westergaard as the stiffness of the slab relative to the stiffness of the foundation. It is determined by the following formula:

$$l = \left(\frac{\mathrm{E}h^3}{12\left(1-u^2\right)\mathrm{k}} \right)^{\frac{1}{4}}$$

Where:
l = radius of relative stiffness, inches.
E = modulus of elasticity of the concrete, usually 4 million psi.
h = slab thickness, inches.
u = Poisson's ratio for concrete, usually 0.15.
k = modulus of subgrade reaction, pci.

338. SPECIAL JOINTING CONSIDERATIONS. A number of special considerations are required when designing the jointing system for a Portland cement concrete pavement. Several considerations are discussed below.

a. Keyed Joints. Keyed construction joints should not be used for slabs less than 9 inches (230 mm) in thickness. Keyed joints in slabs of lesser thickness result in very small keys and key-ways with limited strength.

b. Jointing Systems for Wide Body Jet Aircraft. Experience indicates poor performance may result from keyed longitudinal construction joints supported on low-strength foundations when wide body aircraft loadings are encountered. Special jointing recommendations are discussed below.

(1) Low Strength Foundations. For foundation moduli of 200 pci (54 MN/m^3) or less, a doweled or thickened edge construction joint, Type D or B, is recommended. Keyed joints should not be used as poor performance will likely result. In areas of low traffic usage, such as extreme outer lanes of runways and aprons, keyed joints, Type C, may be used.

(2) Medium Strength Foundations. For foundation moduli between 200 pci (54 MN/m^3) and 400 pci (109 MN/m^3), hinged construction joints, Type E, may be used as well as doweled or thickened edge. The maximum width of pavement that can be tied together depends on several factors such as subgrade frictional restraints, pavement thickness, and climatic conditions. Normally, the maximum width of tied pavement should not exceed 75 feet (23 m). Type C joints may be used in low traffic areas.

(3) High Strength Foundations. For foundation moduli of 400 pci (109 MN/m^3) or greater conventional keyed joints, Type C, may be used regardless of traffic usage. Note, however, that the prohibition against keyed joints in pavements less than 9 inches (230 mm) thick shall still remain in effect.

c. Future Expansion. When a runway or taxiway is likely to be extended at some future date, it is recommended that a thickened edge joint be provided at that end of the runway or taxiway. Likewise, if any pavement is to be widened in the future, a key-way or thickened edge should be provided at the appropriate edge.

339. JOINTING STEEL.

a. Tie Bars. Tie bars are used across certain longitudinal contraction joints and keyed construction joints to hold the slab faces in close contact. The tie bars themselves do not act as load transfer devices. By preventing wide opening of the joint, load transfer is provided by the keyed joint or by aggregate interlock in the crack below the groove-type joint. Tie bars should be deformed bars conforming to the specifications given in Item P-501. The bars should be 5/8 inches (16 mm) in diameter and 30 inches (760 mm) on center.

b. Dowels. Dowels are used at joints to provide for transfer of load across the joint and to prevent relative vertical displacement of adjacent slab ends. Dowels permit longitudinal movement of adjacent slabs.

(1) Where used. Provision for load transfer by dowels is provided at all transverse expansion joints and all butt-type construction joints. Dowels for contraction joints should be provided at least three joints from a free edge. Contraction joints in the interior of the pavement may be the dummy groove type.

(2) Size Length and Spacing. Dowels should be sized such that they will resist the shearing and bending stresses produced by the loads on the pavement. They should be of such length and spacing that the bearing stresses exerted on the concrete will not cause failure of the concrete slab. Table 3-12 indicates the dowel dimensions and spacing for various pavement thicknesses.

Table 3-12. DIMENSIONS AND SPACING OF STEEL DOWELS

Thickness of Slab	Diameter	Length	Spacing
6-7 in (150-180 mm)	3/4 in (20 mm)	18 in (460 mm)	12 in (305 mm)
8-12 in (210-305 mm)	1 in (25 mm)	19 in (480 mm)	12 in (305 mm)
13-16 in (330-405 mm)	1 1/4 in[1] (30 mm)	20 in (510 mm)	15 in (380 mm)
17-20 in (430-510 mm)	1 1/2 in[1] (40 mm)	20 in (510 mm)	18 in (460 m)
21-24 in (535-610 mm)	2 in[1] (50 mm)	24 in (610 mm)	18 in (460 mm)

[1]Dowels noted may be solid bar or high-strength pipe. High-strength pipe dowels must be plugged on each end with a tight-fitting plastic cap or with bituminous or mortar mix.

(3) Dowel Positioning. The alignment and elevation of dowels is extremely important in obtaining a satisfactory joint. Transverse dowels will require the use of a fixture, usually a wire cage or basket firmly anchored to the subbase, to hold the dowels in position. During the concrete placement operations, it is advisable to place plastic concrete directly on the dowel assembly immediately prior to passage of the paver to prevent displacement of the assembly by the paving equipment. Some paving machines have a dowel placer, which can be used to accurately position dowels.

340. JOINT SEALANTS AND FILLERS. Sealants are used in all joints to prevent the ingress of water and foreign material in the joint. Premolded compressible filler are used in expansion joints to permit expansion of the slabs. Joint sealants are applied above the filler in expansion joints to prevent infiltration of water and foreign material. In areas subject to fuel spillage, fuel-resistant sealants should be used. Specifications for joint sealants are given in Item P-605.

341. JOINT LAYOUT. Pavement joint layout is a matter of selecting the proper joint types and dimensions so that the joints can perform their intended function. Construction considerations are also vitally important in determining the joint layout pattern. Paving lane widths will often dictate how the pavement should be jointed. Generally speaking, it is more economical to keep the number of passes of the paving train to a minimum while maintaining proper joint function. Figure 3-43 shows a typical jointing plan for a runway end, parallel taxiway, and connector. In-pavement light fixtures may also affect joint spacing. Joint patterns should be such that the nearest edge of a light fixture is approximately 2 feet (610 mm) from any joint. It is impossible to illustrate all of the variations that can occur at pavement intersections. Reference 8 in Appendix 4 contains further information on jointing patterns. Two important considerations in designing joint layouts for intersections are isolation joints and odd-shaped shapes. More discussion on these follows:

a. Isolation Joints. Two intersecting pavements, such as a taxiway and runway, should be isolated to allow the pavements to move independently. Isolation can best be accomplished by using a Type B expansion joint between the two pavements. The expansion joint should be positioned such that the two pavements can expand and contract independently; normally this can be accomplished by using a Type B expansion joint where the two pavements abut. One isolation joint is normally sufficient to allow independent movement.

b. Odd-Shaped Slabs. Cracks tend to form in odd-shaped slabs; therefore, it is good practice to maintain sections that are nearly square or rectangular in shape. Pavement intersections that involve fillets are difficult to design without a few odd-shaped slabs. In instances where odd-shaped slabs cannot be avoided, steel reinforcement is recommended. Steel reinforcement should consist of 0.050 percent steel in both directions in slabs where the length-to-width ratio exceeds 1.25 or in slabs that are not rectangular in shape. The steel reinforcement should be placed in accordance with the recommendations given in paragraph 342, Reinforced Concrete Pavement. Fillets may also be defined by constructing slabs to the normal, full dimensions and painting out the unused portion of the slab with bitumen.

342. REINFORCED CONCRETE PAVEMENT. The main benefit of steel reinforcing is that, although it does not prevent cracking, it keeps the cracks that form tightly closed so that the interlock of the irregular faces provides structural integrity and usually maintains pavement performance. By holding the cracks tightly closed, the steel minimizes the infiltration of debris into the cracks. The thickness requirements for reinforced concrete pavements are the same as plain concrete and are determined from the appropriate design curves, Figures 3-17 through 3-41. Steel reinforcement allows longer joint spacing; thus the cost benefits associated with fewer joints must be considered in the decision to use plain or reinforced concrete pavement.

343. TYPE AND SPACING OF REINFORCEMENT. Reinforcement may be either welded wire fabric or bar mats installed with end and side laps to provide complete reinforcement throughout the slab panel. End laps should be a minimum of 12 inches (305 mm) but not less than 30 times the diameter of the longitudinal wire or bar. Side laps should be a minimum of 6 inches (150 mm) but not less than 20 times the diameter of the transverse wire or bar. End and side clearances should be a maximum of 6 inches (150 mm) and a minimum of 2 inches (50 mm) to allow for nearly complete reinforcement and yet achieve adequate concrete cover. Longitudinal members should be spaced not less than 4 inches (100 mm) nor more than 12 inches (305 mm) apart; transverse members should be spaced not less than 4 inches (100 mm) nor more than 24 inches (610 mm) apart.

344. AMOUNT OF REINFORCEMENT.

a. The steel area required for a reinforced concrete pavement is determined from the subgrade drag formula and the coefficient of friction formula combined. The resultant formula is expressed as follows:

$$A_S = \frac{(3.7)L\sqrt{Lt}}{f_s}$$

Where:

A_s = area of steel per foot of width or length, square inches
L = length or width of slab, feet
T = thickness of slab, inches
f_s = allowable tensile stress in steel, psi

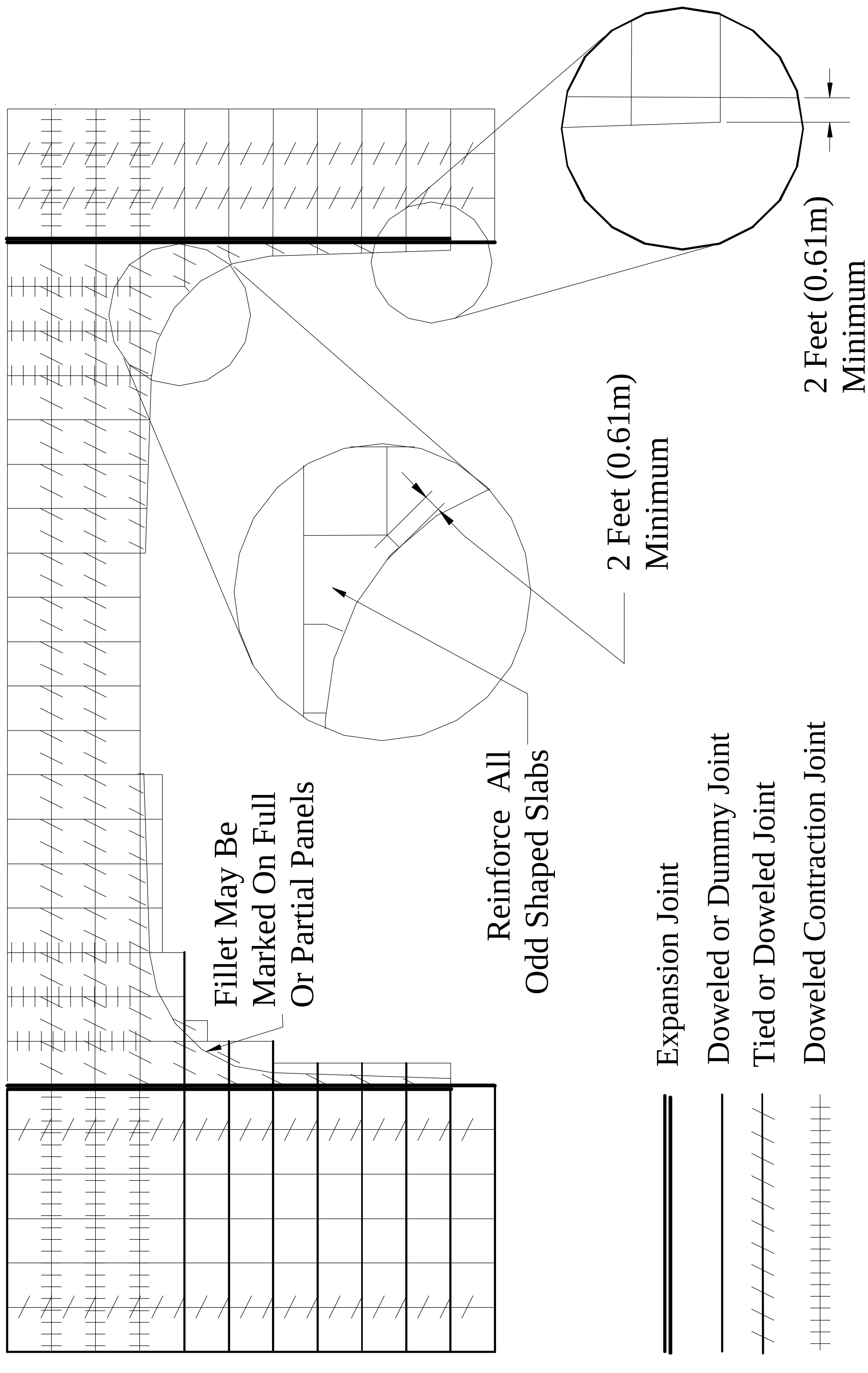


FIGURE 3-43. TYPICAL JOINT LAYOUT PATTERN FOR RUNWAY, PARALLEL TAXIWAY, AND CONNECTOR

404. DESIGN OF STRUCTURAL HOT MIX ASPHALT OVERLAYS. Structural hot mix asphalt overlays can be applied to either flexible or rigid pavements. Certain criteria and design assumptions are different for hot mix asphalt overlays of flexible or rigid pavements. The design procedures are presented separately.

405. HOT MIX ASPHALT OVERLAYS ON EXISTING FLEXIBLE PAVEMENT. The design of structural hot mix asphalt overlays on existing flexible pavements is based on a thickness deficiency approach. That is, the existing pavement is compared to what is needed for a new pavement, and any deficiency is made up in the overlay.

a. Calculate New Pavement Requirements. Using the appropriate flexible pavement design curves (Figures 3-2 through 3-15), calculate the thickness requirements for a flexible pavement for the desired load and number of equivalent design departures. A CBR value is required for the subgrade material and subbase. Thicknesses of all pavement layers must be determined.

b. Compare New Pavement Requirements With Existing Pavement. The thickness requirements for a new pavement are compared with the existing pavement to determine the overlay requirements. Adjustments to the various layers of the existing pavement may be necessary to complete the design. This is particularly difficult when overlaying old pavement. Hot mix asphalt surfacing may have to be converted to base, and/or base converted to subbase. Note that a high-quality material may be converted to a lower quality material, such as surfacing to base or base to subbase. A lesser-quality material may not be converted to a higher-quality material. For example, excess subbase cannot be converted to base. The equivalency factors shown in Tables 3-6 through 3-8 may be used as guidance in the conversion of layers. It must be recognized that the values shown in Tables 3-6 through 3-8 are for new materials, and the assignment of factors for existing pavement must be based on judgment and experience. Surface cracking, high degree or oxidation, evidence of low stability, etc. are a few of the considerations that would tend to reduce the equivalency factor. Any hot mix asphalt layer located between granular courses in the existing pavement should be evaluated inch for inch as granular base or subbase course.

c. Example. To illustrate the procedure of designing a hot mix asphalt overlay, assume an existing taxiway pavement composed of the following section: the subgrade CBR is 7, the hot mix asphalt surface course is 4 inches (10 mm) thick, the base course is 6 inches (150 mm) thick, the subbase is 10 inches (250 mm) thick, and the subbase CBR is 15. Frost action is negligible. Assume the existing pavement is to be strengthened to accommodate a dual wheel aircraft weighing 100,000 pounds (45,000 kg) and an annual departure level of 3,000. The flexible pavement required (referring to Figure 3-3) for these conditions is:

Hot mix asphalt surface	4 inches (100 mm)
Base	9 inches (230 mm)
Subbase	10 inches (250 mm)
Total pavement thickness	23 inches (585 mm)

The total pavement thickness must be 23 inches (585 mm) in order to protect the CBR 7 subgrade. The combined thicknesses of surfacing and base must be 13 inches (330 mm) to protect the CBR 15 subbase. The existing pavement is 3 inches (75 mm) deficient in total pavement thickness. All of the thickness deficiency is in the base course. For the sake of illustration, assume the existing hot mix asphalt surface is in such condition that surfacing can be substituted for base at an equivalency ratio of 1.3 to 1. Converting 2.5 inches (64 mm) of surfacing to base yields a base course thickness of 9.2 inches (234 mm) leaving 1.5 inches (40 mm) of unconverted surfacing. A 2.5-inch (54-mm) overlay would be required to achieve a 4-inch (100-mm) thick surface.

d. Summary. Structurally, a 2.5-inch-thick overlay should satisfy the design conditions. The overlay thickness calculated from structural considerations should be compared with that required to satisfy geometric requirements. Geometric requirements include, for example, provision of drainage, correcting crown and grade, meeting grade of other adjacent pavements and structures, etc. The most difficult part of designing hot mix asphalt overlays for flexible pavements is the determination of the properties of the existing pavement. Subgrade and subbase CBR values can be determined by conducting field in place CBR tests. Field CBR tests should be performed in accordance with the procedures given in Manual Series No. 10 (MS-10 by the Asphalt Institute. See Appendix 4.). The subgrade and subbase must be at the equilibrium moisture content when field CBR tests are conducted. Normally, a pavement that has been in place for at least 3 years will be in equilibrium. Procedures for calculating CBR values from NDT tests are also available. Layer conversions (i.e., converting base to subbase, etc.) are largely a matter of engineering judgment. When performing the conversions, it is recommended that any converted thicknesses not be rounded off.

406. HOT MIX ASPHALT OVERLAY ON EXISTING RIGID PAVEMENT. The design of a hot mix asphalt overlay on an existing rigid pavement is also based on a thickness deficiency approach. However, new pavement thickness requirements for rigid pavements are used to compare with the existing rigid pavement. The formula for computing overlay thickness is as follows:

$$t = 2.5\left(Fh_d - C_b h_e\right)$$

Where:

- t = thickness of hot mix asphalt overlay, inches (mm).
- F = a factor which controls the degree of cracking in the base rigid pavement.
- h_d = thickness of new rigid pavement required for design conditions, inches (mm). Use the exact value for h_d; do not round off. In calculating h_d use the k value of the existing foundation and the flexural strength of the existing concrete as design parameters.
- C_b = a condition factor that indicates the structural integrity of the existing rigid pavement. Values range from 1.0 to 0.75.
- h_e = thickness of existing rigid pavement, inches (mm).

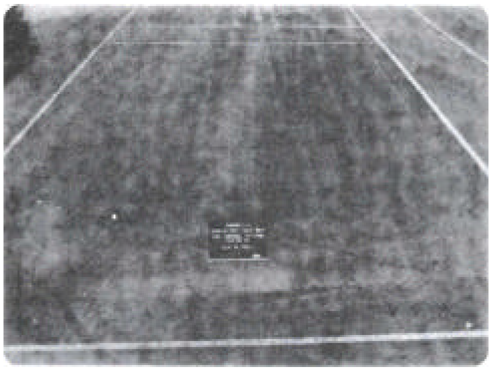
a. F Factor. The "F" factor is an empirical method of controlling the amount of cracking that will occur in the rigid pavement beneath the hot mix asphalt overlay. It is a function of the amount of traffic and the foundation strength. The assumed failure mode for a hot mix asphalt overlay on a existing rigid pavement is that the underlying rigid pavement cracks progressively under traffic until the average size of the slab pieces reaches a critical value. Further traffic beyond this point results in shear failures within the foundation, producing a drastic increase in deflections. Since high strength foundations can better resist deflection and shear failure, the F factor is a function of subgrade strength as well as traffic volume. Photographs of various overlay and base pavements shown in Figure 4-2 illustrate the meaning of the F factor. Figures 4-2a, b, and c show how the overlay and base pavements fail as more traffic is applied to a hot mix asphalt overlay on an existing rigid pavement. Normally an F factor of 1.0 is recommended unless the existing pavement is in quite good condition, see paragraph 406b(1) below. Figure 4-3 should be used to determine the appropriate F factor for pavements in good condition.

b. C_b Factor. The condition factor "C_b" applies to the existing rigid pavement. The C_b factor is an assessment of the structural integrity of the existing pavement.

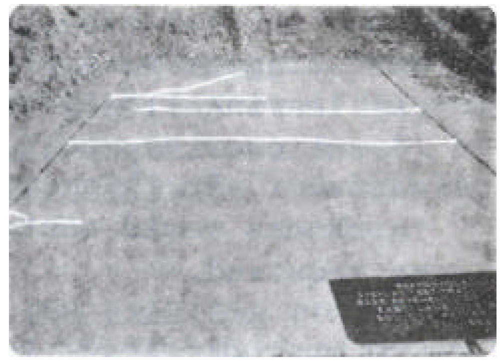
(1) Selection of C_b Factor. The overlay formula is rather sensitive to the C_b value. A great deal of care and judgement are necessary to establish the appropriate C_b. NDT can be a valuable tool in determining a proper value. A C_b value of 1.0 should be used when the existing slabs contain nominal structural cracking and 0.75 when the slabs contain structural cracking. The designer is cautioned that the range of C_b values used in hot mix asphalt overlay designs is different from the "C_r" values used in rigid overlay pavement design. A comparison of C_b and C_r and the recommended F factor to be used for design is shown below:

C_r	C_b	Recommended F factor
0.35 to 0.50	0.75 to 0.80	1.00
0.51 to 0.75	0.81 to 0.90	1.00
0.76 to 0.85	0.91 to 0.95	1.00
0.86 to 1.00	0.96 to 1.00	Use Figure 4.3

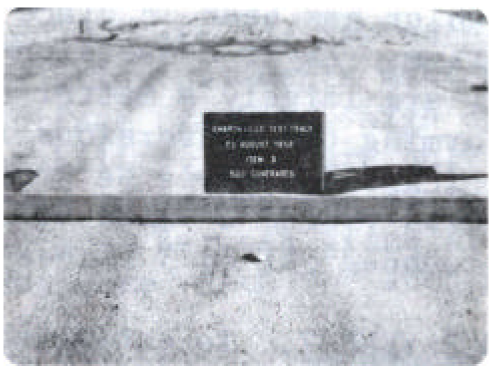
The minimum C_b value is 0.75. A single C_b should be established for an entire area. The C_b value should not be varied along a pavement feature. Figures 4-4 and 4-5 illustrate C_b values of 1.0 and 0.75, respectively.



SURFACE OF OVERLAY



BASE PAVEMENT



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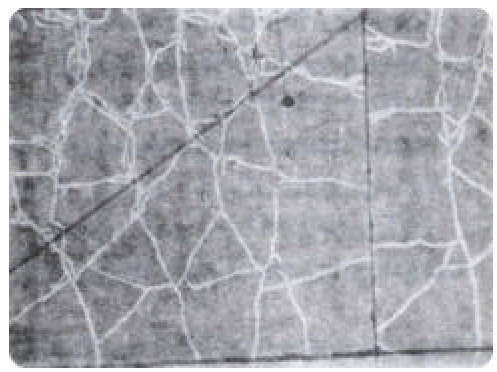
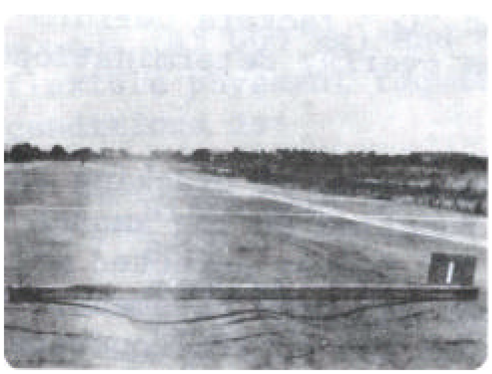
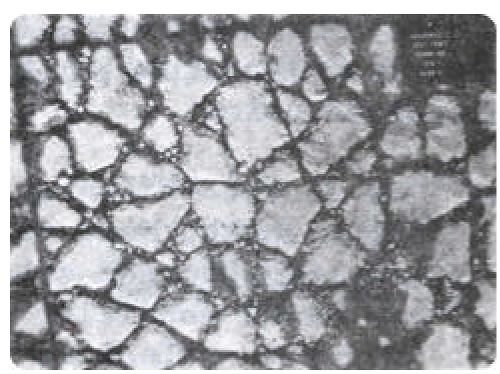


BASE PAVEMENT



SURFACE OF OVERLAY



BASE PAVEMENT

FIGURE 4-2. ILLUSTRATION OF VARIOUS "F" FACTORS FOR HOT MIX ASPHALT OVERLAY

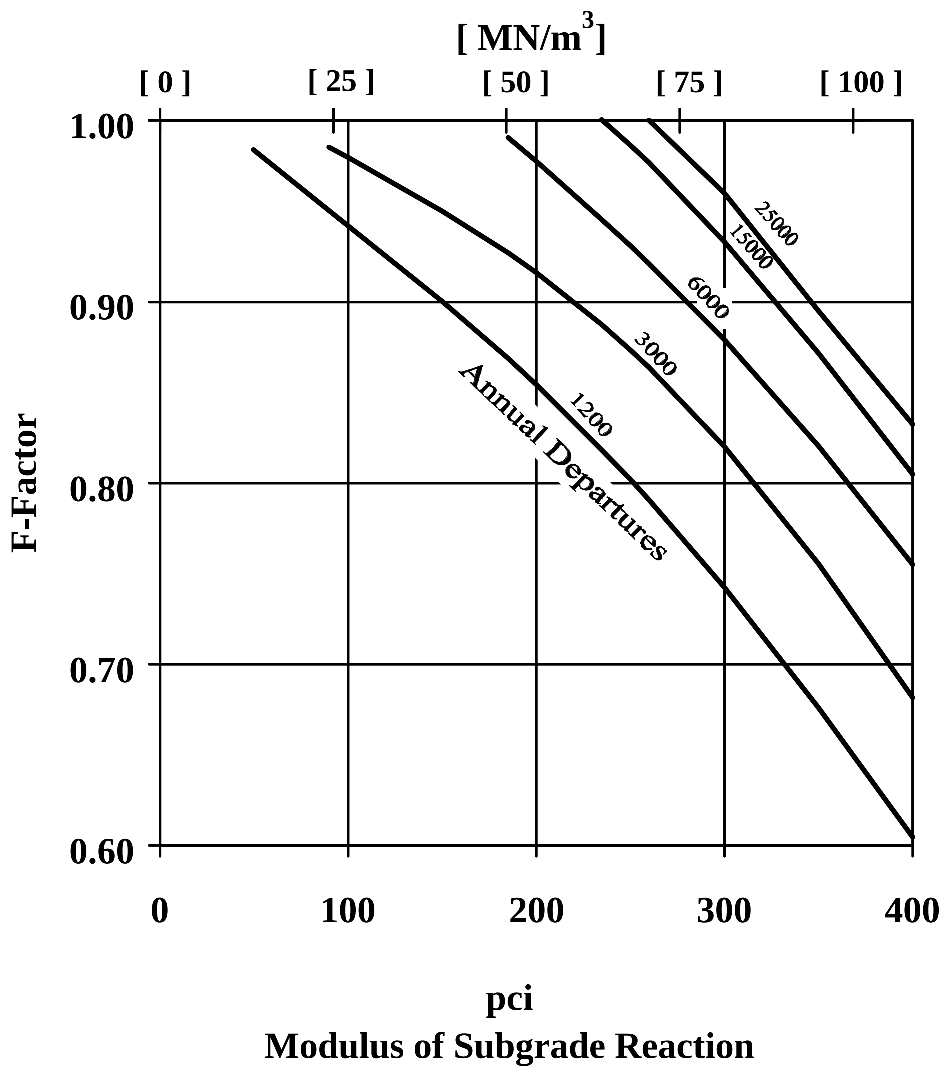


FIGURE 4.3 GRAPH OF "F" FACTOR VS. MODULUS OF SUBGRADE REACTION FOR DIFFERENT TRAFFIC LEVELS

410. CONCRETE OVERLAY ON FLEXIBLE PAVEMENT. The design of concrete overlays on existing flexible pavements assumes the existing flexible pavement is a foundation for the overlay slab. Overlay slab thickness is based on the design curves in Figures 3-17 through 3-40. The existing flexible pavement should be assigned a k value using Figure 2-4 or 3-16 or by conducting a plate-bearing test on the existing flexible pavement or by NDT testing. In any case, the k value assigned should not exceed 500. When frost conditions require additional thickness, the use of nonstabilized material below the rigid pavement overlay is not allowed, as this would result in a sandwich pavement. Frost protection must be provided by stabilized material.

411. CONCRETE OVERLAY ON RIGID PAVEMENT. The design of concrete overlays on existing rigid pavements is also predicated on the rigid pavement design curves, Figures 3-17 through 3-40. The rigid pavement design curves indicate the thickness of concrete required to satisfy the design conditions for a single thickness of concrete pavement. Use of this method requires the designer to assign a k value to the existing foundation. The k value may be determined by field NDT tests or by bearing tests conducted in test pits cut through the existing rigid pavement, they may also estimated from construction records for the existing pavement. The design of a concrete overlay on a rigid pavement requires an assessment of the structural integrity of the existing rigid pavement. The condition factor, C_r, should be selected after an extensive pavement condition survey. The selection of a condition factor is a matter of engineering judgment. The use of nondestructive testing can be of considerable value in assessing the condition of an existing pavement. NDT can also be used to determine sites for test pits. NDT procedures are given in Advisory Circular 150/5370-11, *Use of Nondestructive Testing Devices in the Evaluation of Airport Pavements*. See Appendix 4. In order to provide a more uniform assessment of condition factors, the following values are defined:

C_r =	1.0 for existing pavement in good condition - some minor cracking evident, but no structural defects
C_r =	0.75 for existing pavement containing initial corner cracks due to loading but no progressive cracking or joint faulting
C_r =	0.35 for existing pavement in poor structural condition, badly cracked or crushed and faulted joints

The three conditions discussed above are used to illustrate the condition factor rather than establish the only values available to the designer. Conditions at a particular location may require the use of an intermediate value of C_r within the recommended range. Sketches of three different values of C_r are shown in Figures 4-6, 4-7, and 4-8.

a. Concrete Overlay Without Leveling Course. The thickness of the concrete overlay slab applied directly over the existing rigid pavement is computed by the following formula.

$$h_c = \sqrt[1.4]{h^{1.4} - C_r h_e^{1.4}}$$

Where:

h_c =	required thickness of concrete overlay
h =	required single slab thickness determined from design curves
h_e =	thickness of existing rigid pavement
C_r =	condition factor

Due to the inconvenient exponents in the above formula, graphic solutions are given in Figures 4-9 and 4-10. These graphs were prepared for only two different condition factors, C_r = 1.0 and 0.75. The use of a concrete overlay pavement directly on an existing rigid pavement with a condition factor of less than 0.75 is not recommended because of the likelihood of reflection cracking. The above equation assumes the flexural strength of the concrete used for the overlay will be approximately equal to that of the base pavement. If the flexural strengths differ by more than 100 psi (0.7 MN/m^2), the following modified equation should be used to determine the required thickness of the overlay

$$h_c = \sqrt[1.4]{h^{1.4} - C_r \left(\frac{h}{h_b} \times h_e \right)^{1.4}}$$

Where:

h_b = required single slab thickness determined from design curves based on the flexural strength of the base pavement

Other factors are the same as previous formula.

b. Concrete Overlay With Leveling Course. In some instances it may be necessary to apply a leveling course of hot mix asphalt concrete to an existing rigid pavement prior to the application of the concrete overlay. Under these conditions a different formula for the computation of the overlay thickness is required. When the existing pavement and overlay pavement are separated, the slabs act more independently than when the slabs are in contact with each other. The formula for the thickness of an overlay slab when a leveling course is used is as follows:

$$h_c = \sqrt{h^2 - C_r h_e^2}$$

Where:

h_c = required thickness of concrete overlay
h = required single slab thickness determined from design curves
h_e = thickness of existing rigid pavement
C_r = condition factor

When the flexural strength of the overlay and the existing pavements differ by more than 100 psi (0.7 MN/m^2), the equation is modified as follows:

$$h_c = \sqrt{h^2 - C_r \left(\frac{h}{h_b} \times h_e \right)^2}$$

Where:

h_b = required single slab thickness determined from design curves based on the flexural strength of the base pavement

The leveling course must be constructed of highly stable hot mix asphalt concrete. A granular separation course is not allowed as this would constitute sandwich construction. Graphic solutions of the above equation are shown in Figures 4-11 and 4-12. These graphs were prepared for condition factors of 0.75 and 0.35. Other condition factors between these values can should be computed as part of the design.

412. BONDED CONCRETE OVERLAYS. Concrete overlays bonded to existing rigid pavements are sometimes used under certain conditions. By bonding the concrete overlay to the existing rigid pavement, the new section behaves as a monolithic slab. The thickness of bonded overlay required is computed by subtracting the thickness of the existing pavement from the thickness of the required slab thickness determined from design curves.

$$h_c = h - h_e$$

Where:

h_c = required thickness of concrete overlay
h = required single slab thickness determined from design curves using the flexural strength of the existing concrete
h_e = thickness of existing rigid pavement

Bonded overlays should be used only when the existing rigid pavement is in good condition. Defects in the existing pavement are more likely to reflect through a bonded overlay than other types of concrete overlays. The major problem likely to be encountered with bonded concrete overlays is achieving adequate bond. Elaborate surface preparation and exacting construction techniques are required to ensure the bond.

413. JOINTING OF CONCRETE OVERLAYS. Where a rigid pavement is to receive the overlay, some modification to jointing criteria may be necessary because of the design and joint arrangement of the existing pavement. The following points may be used as guides in connection with the design and layout of joints in concrete overlays.

500. GENERAL. Pavements for light aircraft are defined as those intended to serve aircraft weights of less than 30,000 pounds (13,000 kg). Aircraft of this size are usually engaged in nonscheduled activities, such as agricultural, instructional, or recreational flying. Pavements designed to serve these aircraft may be flexible or rigid-type pavements. The design of pavements serving aircraft of 30,000 pounds (13,000 kg) gross weight or more should be based on the criteria contained in Chapter 3 of this publication. Some areas of airports serving light aircraft may not require paving. In these areas, the development of an aggregate-turf or turf surface may be adequate for limited operations of these light aircraft. Aggregate-turf surfaces are constructed by improving the stability of a soil with the addition of aggregate prior to development of the turf. Aggregate-turf construction is covered in some detail in the latter part of this chapter. Information on stabilization of soils can be found in Chapter 2 of this circular and in AC 150/5370-10, *Standards for Airport Construction*.

501. TYPICAL SECTIONS. Typical cross-sections for light aircraft pavements are shown in Figure 5-1. No distinction is made between critical and noncritical pavement sections for pavements serving light aircraft.

502. FLEXIBLE PAVEMENT MATERIALS. Flexible pavements for light aircraft are composed of hot mix asphalt surfacing, base course, subbase, and prepared subgrade. The function of these layers and applicable specifications are discussed below.

a. Hot Mix Asphalt Surfacing. The function of the hot mix asphalt surface or wearing course is the same as discussed earlier in Chapter 3. Specifications covering the composition and quality of hot mix asphalt mixtures are given in Item P-401, Plant Mix Bituminous Mixtures. Note that under certain conditions, state highway hot mix asphalt mixtures may be used for pavements intended to serve aircraft weighing 12,500 pounds (5,700 kg) or less.

b. Base Course. As in heavy loaded pavements, the base course is the primary load-carrying component of a flexible pavement. Specifications covering materials suitable for use as base courses for light-load pavements are as follows:

(1) Item P-208 - Aggregate Base Course
(2) Item P-209 - Crushed Aggregate Base Course
(3) Item P-220 - Caliche Base Course
(4) Item P-211 - Lime Rock Base Course
(5) Item P-212 - Shell Base Course
(6) Item P-213 - Sand-Clay Base Course
(7) Item P-301 - Soil-Cement Base Course
(8) Item P-304 - Cement-Treated Base Course
(9) Item P-306 - Econocrete Subbase Course
(10) Item P-401 - Plant Mix Bituminous Pavement

Note: Use of some of the above materials in areas where frost penetrates into the base course may result in some degree of frost heave and/or may require restricted loading during spring thaw.

c. Subbase Coarse. A subbase course is usually required in flexible pavement except those on subgrades with CBR value of 20 or greater (usually GW or GP type soils). Materials conforming to specification Item P-154, Subbase Course, may be used as subbase course. Also any items listed above in paragraph 502b may be used as subbase course if economy and practicality dictate. Since the loads imposed on these pavements are much less than those on pavements designed for heavier aircraft, compaction control for base and subbase layers should be based upon ASTM D 698, Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 [600 kN-m/m^3]).

d. Stabilized Base and Subbase. Stabilized base and subbase courses may be used in light-load pavements. Reduced thicknesses of base and subbase may result. Thickness equivalencies for stabilized materials are given in Chapter 3.

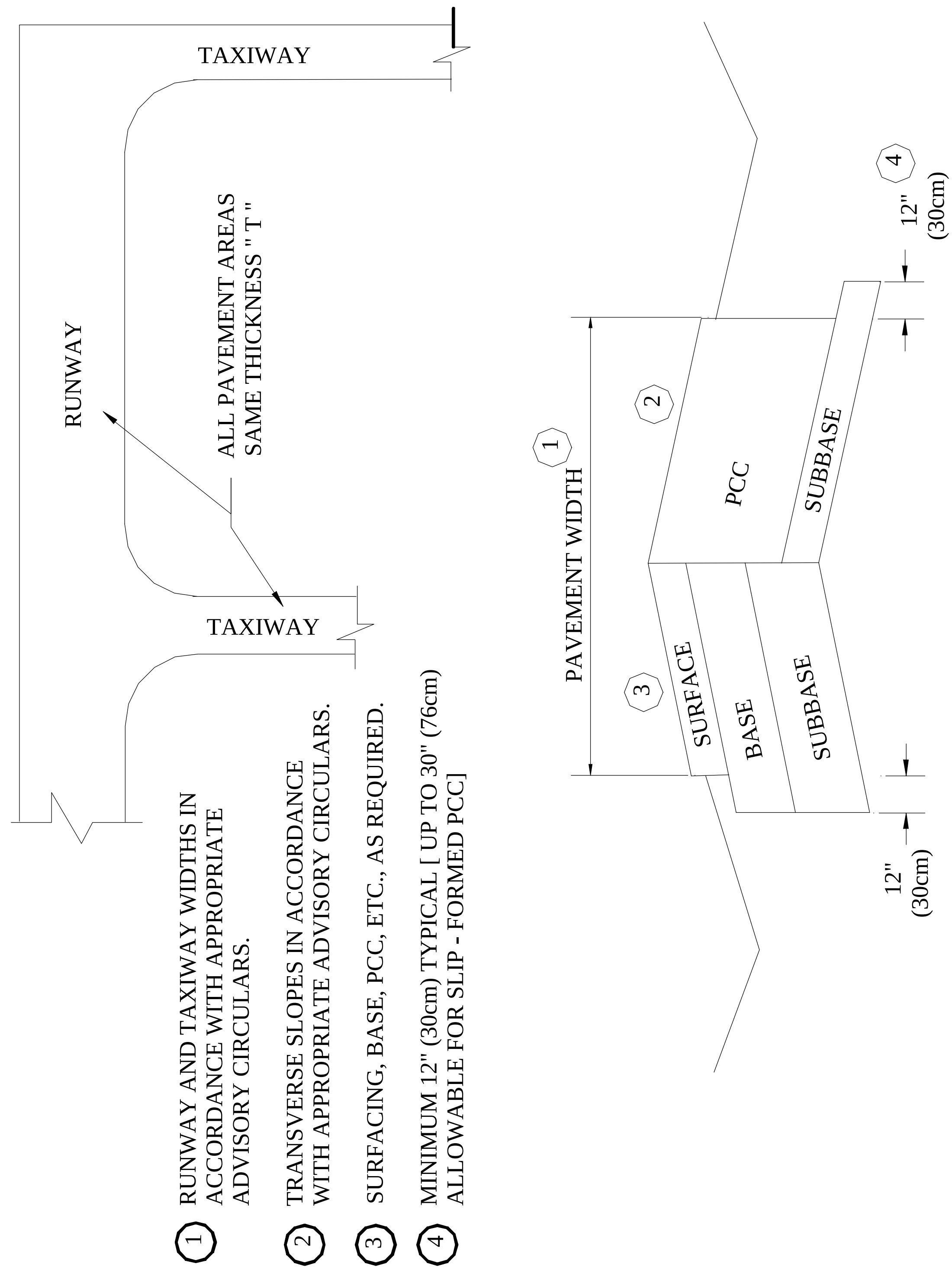


FIGURE 5-1. TYPICAL SECTIONS FOR LIGHT AIRCRAFT PAVEMENTS

d. Example. As an example of the use of Figure 5-2, assume a pavement is to be designed for the following conditions:

Aircraft gross weight = 24,000 pounds (10,900 kg)
Subgrade CBR = 7.5

(1) Total Pavement Thickness. Enter the upper abscissa of Figure 5-2 with the subgrade CBR value of 7. Make a vertical projection downward to the aircraft gross weight line of 24,000 pounds (10,900 kg). At the point of intersection of the vertical projection and the aircraft gross weight line, make a horizontal projection to the pivot line. At the point of intersection of the horizontal projection and the pivot line, make a vertical projection down to the lower abscissa and read the total pavement thickness required, in this example 12.3 inches (312 mm).

(2) Thickness of Surfacing and Base. To determine the thickness of surfacing and base, proceed as in the steps above using a CBR value of 20. In this example, a thickness of 6.7 inches (170 mm) is read on the lower abscissa. This represents the combined thickness of surfacing and base.

(3) Final Design Section. The design section would thus consist of 2 inches (50 mm) of hot mix asphalt surfacing, 5 inches (102 mm) of base, and 6 inches (152 mm) of subbase. Should difficulties be anticipated in compacting the 5-inch (102-mm) base course, the base course thickness should be increased. The thickness increase can be accomplished by substituting some of the subbase material with base course. If base material is substituted for subbase material, a thickness credit can be taken. The thickness credit should be determined using the equivalency factors given in Table 3-7.

e. Omission of Hot Mix Asphalt Surfacing. Under certain conditions, it may be desirable to utilize a bituminous surface treatment on a prepared base course in lieu of hot mix asphalt. In such instances, the strength of the pavement is furnished by the base, subbase, and subgrade. Additional base course thickness will be necessary to make up for the missing surface course. Additional base should be provided at a ratio of 1.2 to 1.6 inches (30 to 41 mm) of base for each 1 inch (25 mm) of surfacing.

f. Full-Depth Asphalt Pavements. Pavements to serve light aircraft may be constructed of full-depth asphalt using the criteria specified in paragraph 322. The Asphalt Institute has published guidance on the design of full depth asphalt pavements for light aircraft in Information Series No. 154, *Full Depth Asphalt Pavements for General Aviation*. Use of the Asphalt Institute method of design for full-depth asphalt pavements requires approval on a case-by-case basis.

g. Local Materials. Since the base and subbase course materials discussed in Chapter 3 are more than adequate for light aircraft, full consideration should be given to the use of locally available, less-expensive materials. These locally available materials may be entirely satisfactory for light-load pavements. These materials may include locally available granular materials, soil aggregate mixtures, or soils stabilized with portland cement, bituminous materials, or lime. The designer is cautioned, however, if the ultimate design of the pavement is greater than 30,000 pounds (13,000 kg), higher quality materials should be specified at the outset.

504. RIGID PAVEMENT MATERIALS. Rigid pavements for light aircraft are composed of Portland cement concrete surfacing, subbase, and prepared subgrade. The functions of these layers and applicable specifications are discussed below:

a. Portland Cement Concrete. Specifications concerning the quality and placement of Portland cement concrete should be in accordance with Item P-501, Portland Cement Concrete Pavement. Local state highway specifications for paving quality concrete may be substituted for Item P-501 if desired.

b. Subbase. Rigid pavements designed to serve aircraft weighing between 12,500 pounds (5,700 kg) and 30,000 pounds (13,000 kg) will require a minimum subbase thickness of 4 inches (100 mm) except as shown in Table 3-4 of Chapter 3. No subbase is required for designs intended to serve aircraft weighing 12,500 pounds (5,700 kg) or less, except when soil types OL, MH, CH, or OH are encountered. When the above soil types are present, a minimum 4-inch (100-mm) subbase should be provided. The materials suitable for subbase courses are covered in Item P-154, Subbase Course.

c. Subgrade. Subgrade materials should be compacted in accordance with Item P-152 to the following depths. For cohesive soils used in fill sections, the entire fill shall be compacted to 90-percent maximum density. For cohesive soils in cut sections, the top 6 inches (150 mm) of the subgrade shall be compacted to 90-percent maximum density. For noncohesive soils used in fill sections, the top 6 inches (150 mm) of fill shall be compacted to 100-percent maximum density, and the remainder of the fill shall be compacted to 95-percent maximum density. For cut sections in noncohesive soils, the top 6 inches (150 mm) of subgrade shall be compacted to 100-percent maximum density and the next 18 inches (460 mm) of subgrade shall be compacted to 95-percent maximum density. For treatment of swelling soils refer to paragraph 3-14.

505. RIGID PAVEMENT THICKNESS. No design curves for light-duty rigid pavements are presented since there are only two thickness requirements. Rigid pavements designed to serve aircraft weighing 12,500 pounds (5,700 kg) or less should be 5 inches (127 mm) thick. Those designed to serve aircraft weighing between 12,501 pounds (5,700 kg) and 30,000 pounds (13,000 kg) should be 6 inches (150 mm) thick.

a. Jointing of Light Load Rigid Pavements. The maximum spacing of joints for light-load rigid pavements should be 12.5 feet (3.8 m) for longitudinal joints and 15 feet (4.6 m) for transverse joints. Jointing details are shown in Figure 5-3. Note that several differences exist between light-load and heavy-load rigid pavement joints. For instance, butt-type construction and expansion joints are permitted when an asphalt or cement stabilized subbase is provided. Also, half-round keyed joints are permitted even though the slab thicknesses are less than 9 inches (230 mm). Odd-shaped slabs should be reinforced with 0.05 percent steel in both directions. Odd-shaped slabs are defined as slabs that are not rectangular in shape or rectangular slabs with length-to-width ratios that exceed 1.25. Two recommended joint layout patterns are shown in Figure 5-4 for 60-foot (18-m) and Figure 5-5 for 50-foot (15-m) wide pavements. The concept behind the jointing patterns shown is the creation of a “tension ring” around the perimeter of the pavement to hold joints within the interior of the paved area tightly closed. A tightly closed joint will function better than an open joint. The last three contraction joints and longitudinal joints nearest the free edge of the pavement are tied with #4 deformed bars, 20 inches (510 mm) long, spaced at 36 inches (1 m) center to center. At the ends of the pavement and in locations where aircraft or vehicular traffic would move onto or off the pavement, a thickened edge should be constructed. The thickened edge should be 1.25 times the thickness of the slab and should taper to the slab thickness over a distance of 3 feet (1 m).

The intent of this paragraph is to allow the use of the tension ring design but limit it to pavements less than 60 feet in width. Also, the use of the half-round keyway is limited to those pavements utilizing the tension ring concept. Use of the half-round keyway as a standard construction joint is not acceptable in pavements that do not use the tension ring concept.

Pavements that do not use the tension ring design should be designed in a manner similar to Chapter 3. The designer is reminded that the use of any type of keyway is not permitted in pavements less than 9 inches thick (except with the tension ring concept). The general recommendations of Table 3-10A may be employed for Chapter 5 pavements not using the tension ring concept; however, the designer should note that the joint designations and steel sizes and spacing discussed in Chapter 5 are different those in Chapter 3.

506. AGGREGATE TURF. Aggregate-turf differs from normal turf in that the stability of the underlying soil is increased by the addition of granular materials prior to establishment of the turf. The objective of this type of construction is to provide a landing areas that will not soften appreciably during wet weather and yet has sufficient soil to promote the growth of grass. Aggregate-turf should be considered only for areas designed to serve aircraft having gross weights of 12,500 pounds (5,700 kg) or less.

a. Materials. Construction details and material requirements are covered in Item P-217, Aggregate-Turf Pavement. A minimum CBR of 20 is recommended for aggregate-soil layers.

b. Thickness. The thickness to be stabilized with the granular materials varies with the type of soil and the drainage and climatic conditions. The total thickness of aggregate stabilized soil should be read directly from the thickness scale of Figure 5-2 using the CBR of the subgrade, (disregard the note concerning the surfacing course).

507. OVERLAYS. Overlays of pavements intended to serve light aircraft are designed in the same manner as overlays for heavy aircraft.

508. HELIPORT/VERTIPORT DESIGN. The guidance contained in paragraph 500 of this section is appropriate for pavements designed to serve rotary-wing aircraft. Where direct thermal effects of jet blast is a concern (e. g., at vertiports serving tiltrotor traffic), incorporation of unique pavement formulations specific to thermal resistance may be required. Any pavement that is subjected to the direct thermal effects of high temperature exhaust gases can become progressively damaged with repeated thermal cycles, resulting in surface spalling, a potential for foreign object damage (FOD), as well as subsequent deterioration of the affected slab. An example formulation for thermal resistant pavement can be found in TR-2079-SHR, Development of Mix Designs for F/A-18 Resistant Pavement Systems, Naval Facilities Engineering Service Center, July 1997.

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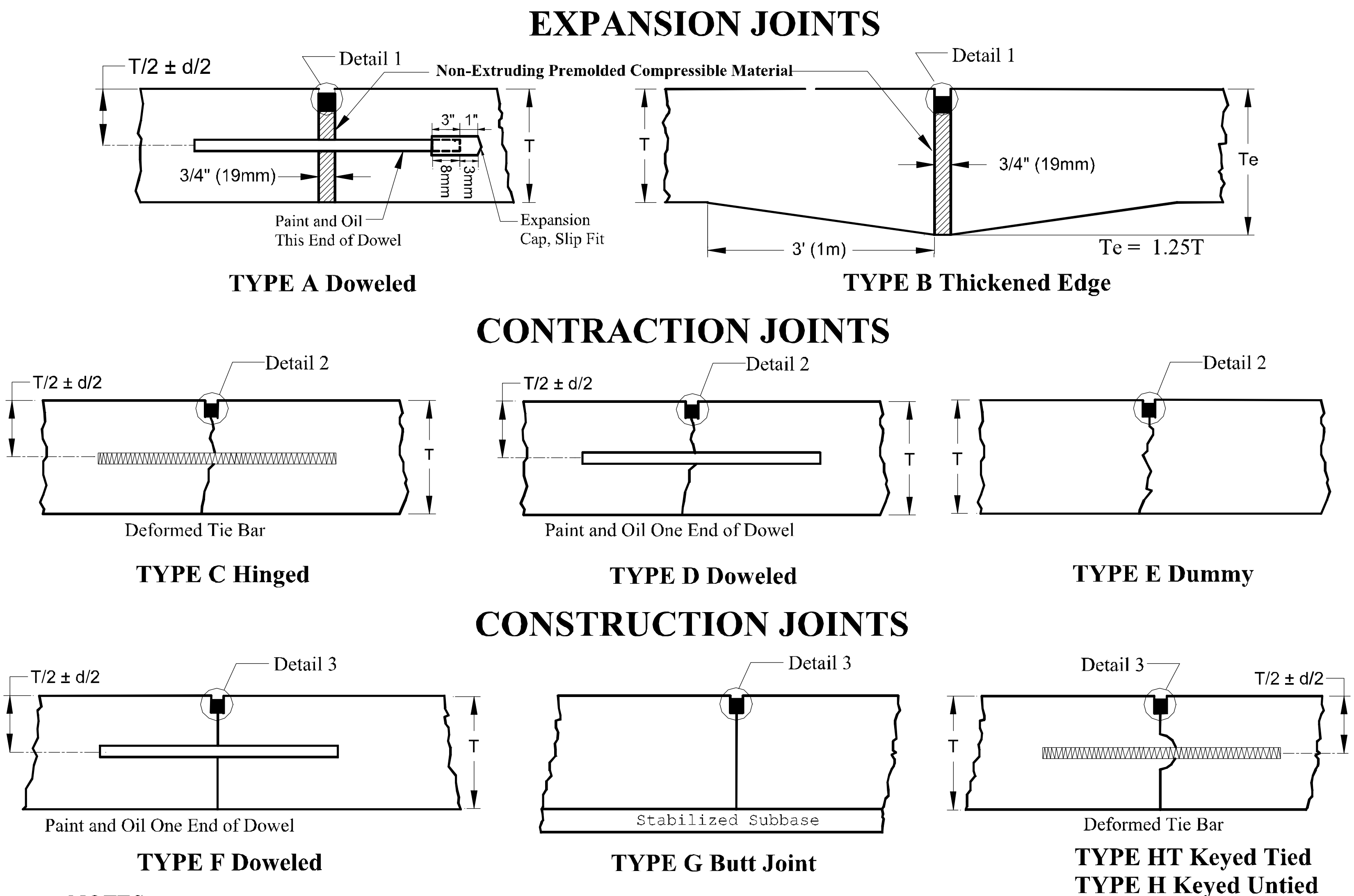
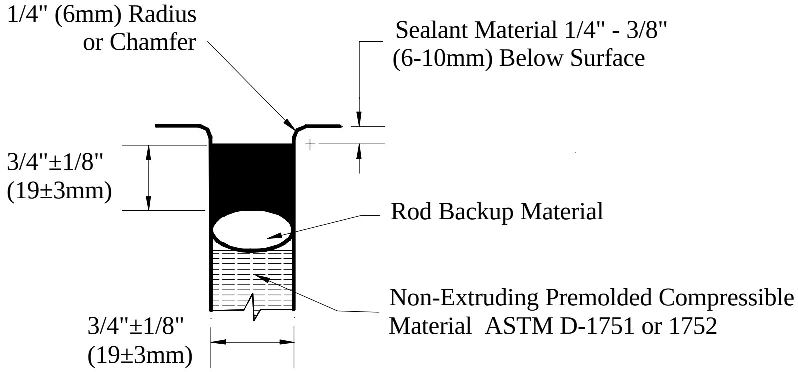


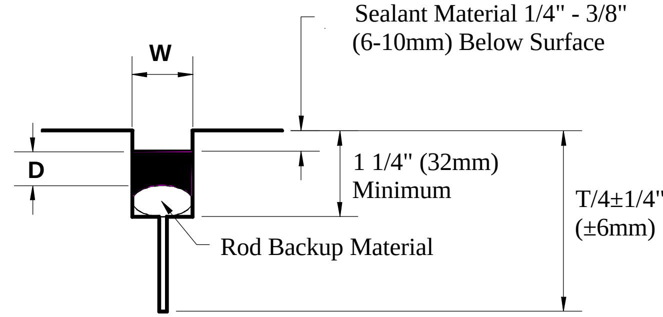
NOTES:

1. For details 1, 2, and 3, see Figure 5-4.
2. All Dowels 3/4" (19mm) Diameter, 18" (460mm) Long, Spaced 12" (300mm) on Centers
3. All Tie Bars No. 4 Deformed Bars, 20" (510mm) Long, Spaced 36" (0.9m) on Centers.

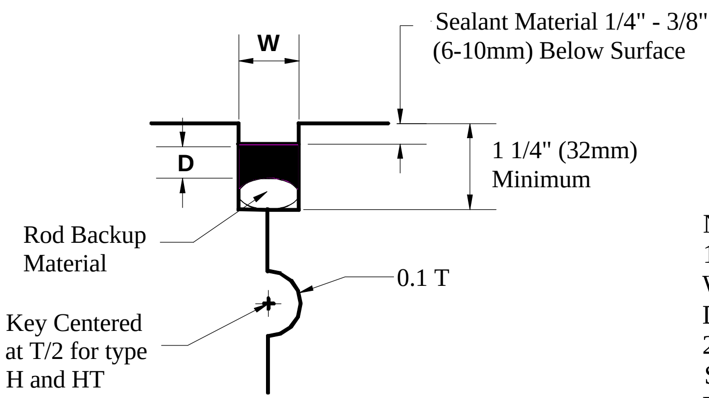
FIGURE 5-3. JOINTING DETAILS FOR LIGHT-LOAD RIGID PAVEMENT



DETAIL 1
EXPANSION JOINT



DETAIL 2
CONTRACTION JOINT



DETAIL 3
CONSTRUCTION JOINT

NOTES:
1. SEALANT RESERVOIR SIZED TO PROVIDE PROPER SHAPE FACTOR, W/D. FIELD POURED AND PREFORMED SEALANTS REQUIRE DIFFERENT SHAPE FACTORS FOR OPTIMUM PERFORMANCE.
2. ROD BACKUP MATERIAL MUST BE COMPATIBLE WITH THE TYPE OF SEALANT USED AND SIZED TO PROVIDE THE DESIRED SHAPE FACTOR.

Figure 5-4. JOINTING DETAILS FOR LIGHT-LOAD RIGID PAVEMENT (CONT.)

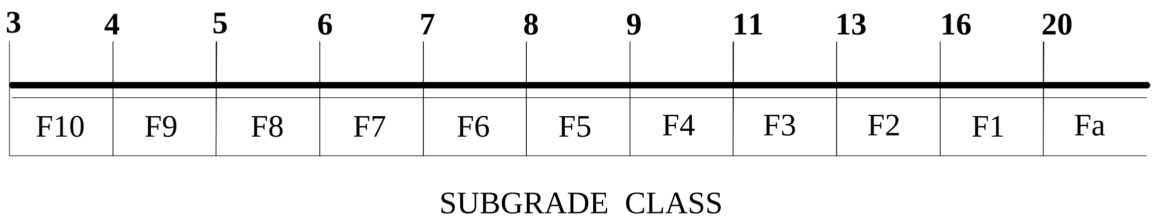


FIGURE 6-1. CBR -- FAA SUBGRADE CLASS COMPARISONS

(1) Subbase and Base Equivalencies. Equivalency factor ranges shown in Tables 3-6 through 3-9 for subbase and base are recommended for evaluation purposes. The actual value selected will depend on the composition, quality, and condition of the layer. In instances where experience or physical test results show that other values are valid, they may be used in lieu of the values recommended here. Subbase or base courses should not be assigned a higher equivalency factor than a layer above it in the pavement structure. Conversion of material to a higher classification, such as subbase to base, will not be permitted, except where excess stabilized base course (P-401or P-304) exists immediately under a flexible surface; in this instance, the stabilized material may be counted as an equal thickness of surface.

(2) Surfacing. Broken hot mix asphalt surface course (shrinkage cracks due to age and weathering, without evidence of base failure) shall be evaluated as an equal thickness of nonstabilized base. A hot mix asphalt surface, with limited cracking and well maintained, may justify use of an equivalency between the limits noted.

603. APPLICATION OF FLEXIBLE PAVEMENT EVALUATION PROCEDURES. After all of the evaluation parameters of the flexible pavement have been established using the guidance given in the above paragraphs, the evaluation process is essentially the reverse of the design procedure. The design curves presented in Chapter 3 or 5 are used to determine the load-carrying capacity of the existing pavement. Required inputs are subgrade and subbase CBR values, thicknesses of surfacing, base, and subbase courses; and an annual departure level. Several checks must be performed to determine the load-carrying capacity of a flexible pavement. The calculation that yields the lowest allowable load will control the evaluation.

a. Total Pavement Thickness. Enter the lower abscissa of the appropriate design curve in Chapter 3 or 5 with the total pavement thickness of the existing pavement. Make a vertical projection to the annual departure level line. For light-load pavements, Chapter 5, a single pivot line is used. At the point of intersection between the vertical projection and the departure level line, or a single pivot line in the case of light-load pavements, make a horizontal projection across the design curve. Enter the upper abscissa with the CBR value of the subgrade. Make a vertical projection downward until it intersects with horizontal projection made previously. The point of intersection of these two projections will be in the vicinity of the load lines on the design curves. An allowable load is read by noting where the intersection point falls in relation to the load lines.

b. Thickness of Surfacing and Base. The combined thickness of surfacing and base must also be checked to establish the load-carrying capacity of an existing flexible pavement. This calculation requires the CBR of the subbase, the combined thickness of surfacing and base, and the annual departure level as inputs. The procedure is the same as that described in subparagraph **a** above, except that the subbase CBR and combined thickness of surfacing and base are used to enter the design curves.

c. Minimum Base Course Thickness. The thickness of the existing base course should be compared with the minimum base course thicknesses in Table 3-4 or Figure 5-2. Notice that the minimum base course thickness is 4 inches (100 mm) for heavy-load pavements and 3 inches (75 mm) for light-load pavements. If there is a deficiency in the thickness of the existing base course, the pavement should be closely monitored for signs of distress. The formulation of plans for overlaying the pavement to correct the deficiency should be considered.

d. Minimum Surface Thickness. The thickness of the existing surface course should be compared with that shown on the appropriate design curve. If the existing surface course is thinner than that given on the design curve, the pavement should be closely observed for surface failures. It is recommended that correction of the deficiency in surfacing thickness be considered.

604. RIGID PAVEMENTS. Evaluation of rigid pavements requires, at a minimum, the determination of the thickness of the component layers, the flexural strength of the concrete, and the modulus of subgrade reaction.

a. Layer Thicknesses. The thickness of the component layers is sometimes available from construction records. Where information is not available or of questionable accuracy, thicknesses may be determined by borings or test pits in the pavement.

b. Concrete Flexural Strength. The flexural strength of the concrete is most accurately determined from test beams sawed from the existing pavement and tested in accordance with ASTM C 78. Quite often this method is impractical as sawed beams are expensive to obtain and costs incurred in obtaining sufficient numbers of beams to establish a representative sample is prohibitive. Construction records, if available, may be used as a source of concrete flexural strength data. The construction data will probably have to be adjusted for age as concrete strength increases with time. Strength-age relationships can be found in Portland Cement Association, Engineering Bulletin, Design of Concrete Airport Pavement.

(1) Correlations With Other Strength Tests. Correlations between concrete flexural strength and other concrete strength tests are available. It should be noted that correlations between flexural strength and other strength tests are approximate and considerable variations are likely.

(i) Tensile Split Strength. An approximate relationship between concrete flexural strength and tensile splitting strength (ASTM C 496) exists and can be computed by the following formula:

$$R = 1.02(T) + 117$$

Where:
R = flexural strength, psi.
T = tensile split strength, psi.
Note: For conversions in metric units, the above formula remains the same, except the +117 psi constant should be changed to +0.81 Mpa.

(ii) Compressive Strength. Flexural strength can be estimated from compressive strength (ASTM C 39) using the formula below:

$$R = 9\sqrt{f_c'}$$

Where:
R = flexural strength
f_c' = compressive strength