U.S. Department of Transportation

**Federal Aviation Administration**

# Advisory Circular

**Subject:** Change 2 to Advisory Circular (AC) 150/5320-6D AIRPORT PAVEMENT DESIGN AND EVALUATION

**Date:** DRAFT
**Initiated by:** AAS-200

**AC No:** 150/5320-6D
**Change:** DRAFT

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

**2. PRINCIPAL CHANGES.** The following changes have been made:

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

**b.** Figure 3-42 RIGID PAVEMENT TYPES AND DETAILS has been revised to change the depth, noted as "T/5" in DETAIL 2 to "T/4" and add a new detail, PLAN VIEW – Position of Dowels at Edge of Joint Type A, D, F.

c. Paragraph 337 has been updated to reflect a maximum joint spacing of 20 feet. A definition for the symbol for radius of relative stiffness has been included and Table 3-11 has been updated.

**d.** The formula for steel area in Paragraph 344 has been corrected.

**e.** The modified formula for overlay thickness in Paragraphs 4 11 .a. and 411 .b. have been corrected.

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

g. The Paragraph 505. a. has been updated with an explanation of tension ring design employment.

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

**i.** The formula for split tensile strength in Paragraph 604 (1) (i) has been updated.

**j.** 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.

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 | 9/30/98 |

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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 336 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 which 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 which permits the joint to be sealed. Pavement joint details are shown in Figure 3-42 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 which 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.**

**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-l1 shows the recommended maximum joint spacings. Shorter spacings may be more convenient in some instances. The ratio of slab length to slab width should not exceed 1.25 in unreinforced pavements.

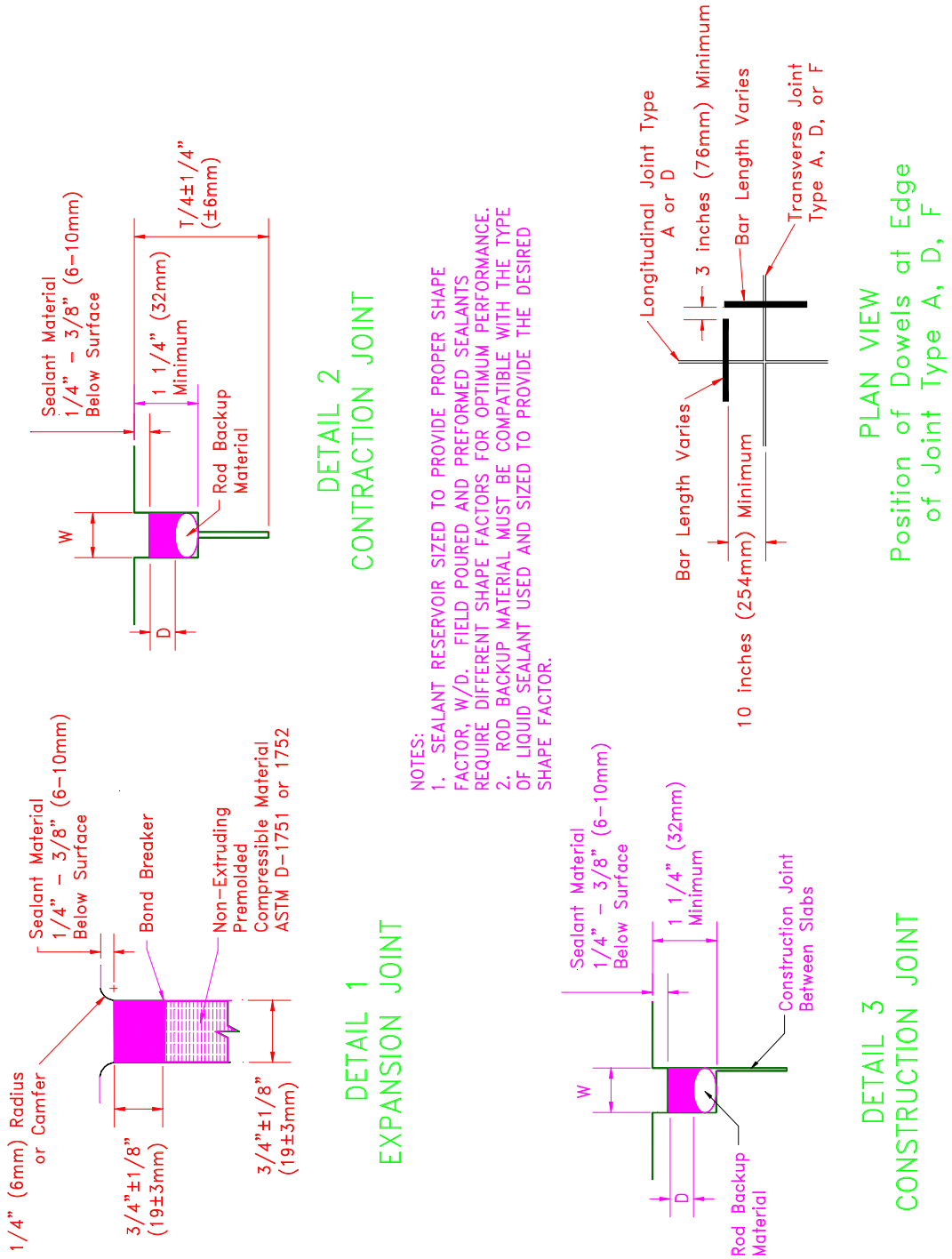


FIGURE 3-42. RIGID PAVEMENT TYPES AND DETAILS

**TABLE 3-10A PAVEMENT JOINT TYPES**

| JOINT TYPES - DESCRIPTION AND USE (Ch. 3 designations) | | | |
|---|---|---|---|
| TYPE | DESCRIPTION | LONGITUDINAL | TRANSVERSE |
| A | Doweled Expansion Joint | | 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 structure. (Should be considered at locations along a pavement edge where future expansion is possible.) | Provide thickened edge (or keyway) where pavement extension is likely. (On thinner pavement sections the thickened edge will provide additional section for placement of future dowel bars) |
| C | Keyed Construction Joint. | Acceptable for all construction joint except where type E is used. | |
| D | Doweled Contraction Joint | Acceptable for all construction joints except where type E is used. | 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. | |
| F | Doweled Contraction Joint | May be considered for general use. | Use on all contraction joints for a distance of at least 3 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 | Use 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. | |
| H | Dummy Contraction Joint | Use for all other contraction joints in pavement. | Use for all remaining contraction joints in non-reinforced pavements. |

**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 to the radius of relative stiffness is between 4 and 6. 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:

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

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

**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 > | 230 > | 20 | 6.1 | 20 | 6.1 |

Note: The joint spacings shown in this table are recommended maximum values. 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.

**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 which 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

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. It is impossible to illustrate all of the variations which 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 normally good practice to maintain sections which are nearly square or rectangular in shape. Pavement intersection which 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% steel in both directions in slabs where the length-to-width ratio exceeds 1.25 or in slabs which are not rectangular in shape. The steel reinforcement should be placed in accordance with the recommendations given in Paragraph 341, 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 spacings, 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, = area of steel per foot of width or length, square inches
L= length or width of slab, feet
t = thickness of slab, inches
f, = allowable tensile stress in steel, psi

**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, or may be 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 (NDT) 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-l1, 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 overlap

where:

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

$h_b$ = 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 of 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 actors between these values can normally be computed to sufficient accuracy by interpolation.

**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 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 insure bond.

**413. JOINTING OF CONCRETE OVERLAYS.** Where a rigid pavement is to receive the overlay, some modification to jointing criteria may bc 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.

**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 = 20,000 Ibs. (9100 kg)
Subgrade CBR = 7

**(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 20,000 lbs. (9100 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 11.8 inches (300 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 5 inches (127 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, 3 inches (75 mm) of base, and 7 inches (178 mm) of subbase. Should difficulties be anticipated in compacting the 3-inch (75 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 - 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. See Appendix 4. 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 lbs (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 (5700 kg) and 30,000 pounds (13000 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% 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. Such as 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% steel in both directions. Odd-shaped slabs are defined as slabs which are not rectangular in shape or rectangular slabs which length-to-width ratios 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 in a manner which limits the use of the tension ring concept to pavements less than 60 feet in width. Also, the use of the half-round keyway is limited to only those pavements utilizing the tension ring concept. Use of the half-round keyway as a standard construction joint is not acceptable in pavements not using the tension ring concept.

Pavement 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 keyway is not permitted in pavements less than nine inches thick (tension ring being the only exclusion). 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 designation and steel size and spacing of Chapter 5 is different than that of 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 note concerning 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.

**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 Table 3-4 or from 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, as 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:

$$\mathbf{R = 1.02 \times T + 117}$$

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:

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

where:
R = flexural strength
$f_c'$ = compressive strength

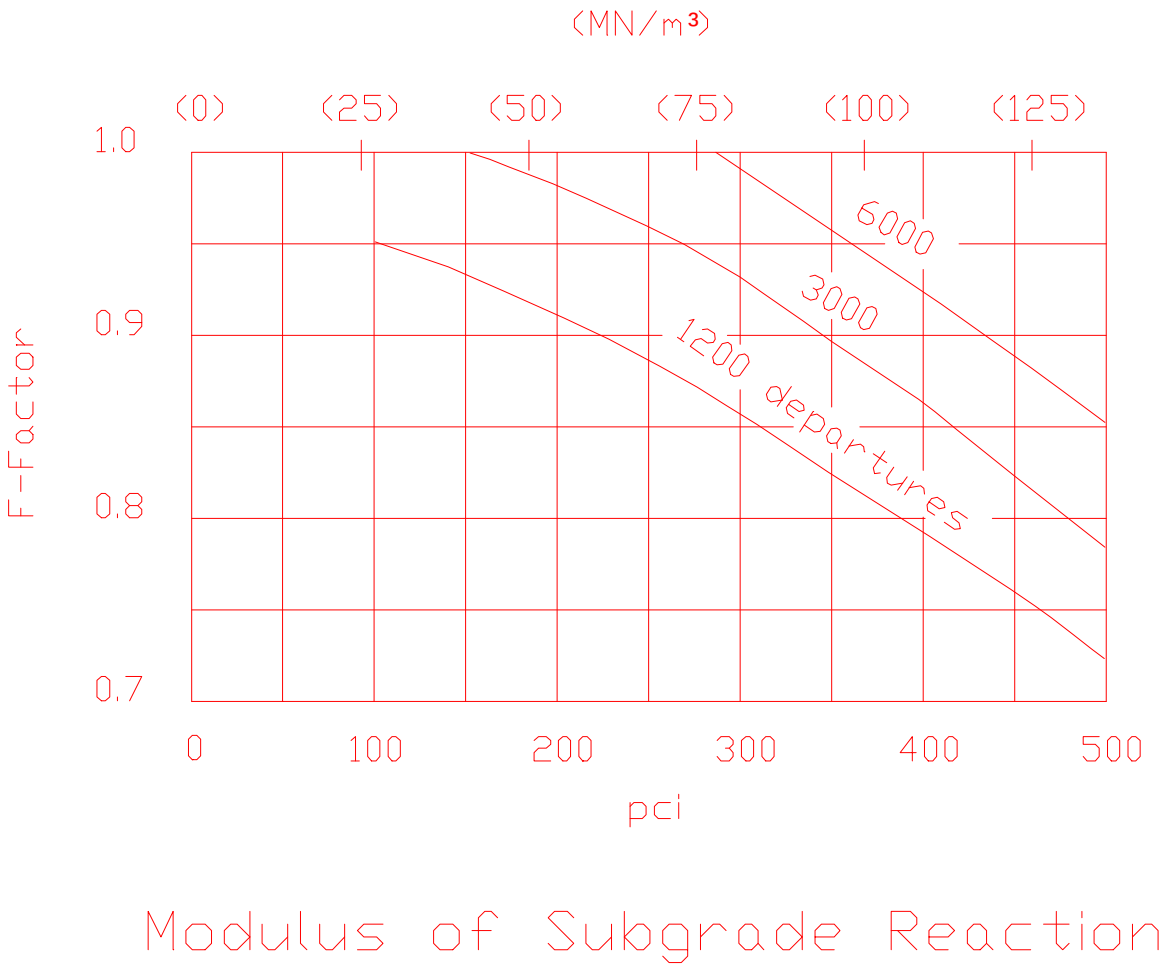


FIGURE 4.3 GRAPH OF "F" FACTOR VS. MODULUS OF SUBGRADE REACTION FOR DIFFERENT TRAFFIC LEVELS