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An Introduction to Pavement Overlays

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(In some instances the Figures, Tables and Formulas in this publication may be a little difficult to read, but they are the best available. **DO NOT PURCHASE THIS PUBLICATION IF THIS LIMITATION IS NOT ACCEPTABLE TO YOU.**)

1. GENERAL. Normally, overlays of existing pavements are used to increase the load-carrying capacity of an existing pavement or to correct a defective surface condition on the existing pavement. Of these reasons, the first requires a structural design procedure for determining the thickness of overlay; whereas the second requires only a thickness of overlay sufficient to correct the surface condition, and no increase in load-carrying capacity is considered. The design method for overlays included in this chapter determines the thickness required to increase load-carrying capacity. These methods have been developed from a series of full-scale accelerated traffic tests on various types of overlays and are, therefore, empirical. These methods determine the required thickness of overlay that, when placed on the existing pavement, will be equivalent in performance to the required design thickness of a new pavement placed on subgrade.

2. DEFINITIONS AND SYMBOLS FOR OVERLAY PAVEMENT DESIGN. The following terms and symbols apply to the design of overlay pavements.

2.1 RIGID BASE PAVEMENT. An existing rigid pavement is one on which an overlay is to be placed.

2.2 FLEXIBILE BASE PAVEMENT. Existing pavement to be overlaid is composed of bituminous concrete, base, and subbase courses.

2.3 COMPOSITE PAVEMENT. Existing pavement to be overlaid with rigid pavement is composed of an all bituminous or flexible overlay on a rigid base pavement.

2.4 OVERLAY PAVEMENT. A pavement constructed on an existing base pavement to increase load-carrying capacity or correct a surface defect.

2.5 RIGID OVERLAY. A rigid pavement used to strengthen an existing flexible or rigid pavement.

2.6 FLEXIBLE OVERLAY. A flexible pavement (either all-bituminous or bituminous with base course) used to strengthen an existing rigid or flexible pavement.

3. PREPARATION OF EXISTING PAVEMENT. Exploration and tests of the existing pavement should be made to locate all areas of distress in the existing pavement and to determine the cause of the distress. Areas showing extensive and progressive cracking, rutting, and foundation failures should be repaired prior to the overlay. Such repair is especially needed in areas where excessive pumping, bleeding of water at joints or cracks, excessive settlement in foundation, subgrade rutting, surface rutting, and slides have occurred. If testing of the existing pavement indicates the presence of voids beneath a rigid pavement, they should be filled by grouting prior to the overlay. The properties of the existing pavement and foundation such as the modulus of subgrade reaction, CBR (California Bearing Ratio), thickness, condition index, and flexural strength should be determined. The exact properties to be determined will depend upon the type of overlay to be used. The surface of the existing pavement should be conditioned for the various types of overlays as follows.

3.1 RIGID OVERLAY. Overlay thickness criteria are presented for three conditions of bond between the rigid overlay and existing rigid pavement: fully bonded, partially bonded, and nonbonded. The fully bonded condition is obtained when the concrete is cast directly on concrete and special efforts are made to obtain bond. The partially bonded condition is obtained when the concrete is cast directly on concrete with no special efforts to achieve or destroy bond. The nonbonded condition is obtained when the bond is prevented by an intervening layer of material. When a fully bonded or partially bonded rigid overlay is to be used, the existing rigid pavement will be cleaned of all foreign matter (such as oil and paint), spalled concrete, extruded joint seal, bituminous patches, or anything else that would act as a bond-breaker between the overlay and existing rigid pavement. In addition, for the fully bonded overlay, the surface of the existing pavement must be prepared according to the recommendations in the professional literature. A sand-cement grout or an epoxy grout is applied to the cleaned surface just prior to placement of the concrete overlay. When a nonbonded rigid overlay is being used, the existing rigid pavement will be cleaned of all loose particles and covered with a leveling or bond-breaking course of bituminous concrete, sand asphalt, heavy building paper, polyethylene, or other similar stable material. The bond-breaking medium generally should not exceed a thickness of about 1 inch except in the case of leveling courses where greater thicknesses may be necessary. When a rigid overlay is being applied to an existing flexible pavement, the surface of the existing pavement will be cleaned of loose materials, and any potholing or unevenness exceeding about 1 inch will be repaired by cold planing or localized patching or the application of a leveling course using bituminous concrete, sand-asphalt, or a similar material.

3.2 FLEXIBLE OVERLAY. When a flexible overlay is used, no special treatment of the surface of the existing rigid pavement will be required, other than the removal of loose material. When the flexible overlay is all-bituminous concrete, the surface of the existing rigid pavement will be cleaned of all foreign matter, spalled concrete, fat spots in bituminous patches, and extruded soft or spongy joint seal material. Joints or cracks less than 1 inch wide in the existing rigid pavement will be filled with joint sealant. Joints or cracks that are 1 inch or greater in width will be cleaned and filled with an acceptable bituminous mixture (such as sand asphalt) which is compatible with the overlay. Leveling courses of bituminous concrete will be used to bring the existing rigid pavement to the proper grade when required. Prior to placing the all-bituminous concrete, a tack coat will be applied to the surface of the existing pavement.

4. CONDITION OF EXISTING RIGID PAVEMENT.

4.1 GENERAL. The support that the existing rigid pavement will provide to an overlay is a function of its structural condition just prior to the overlay. In the overlay design equations, the structural condition of the existing rigid pavement is assessed by a condition factor C. The value of C should be selected based upon a condition survey of the existing rigid pavement. Interpolation of C values between those shown below may be used if it is considered necessary to define more accurately the existing structural condition.

4.2 PLAIN CONCRETE OVERLAY. The following values of C are assigned for the following conditions of plain and reinforced concrete pavements.

4.2.1 CONDITION OF EXISTING PLAIN CONCRETE PAVEMENT:

- C = 1.00 — Pavements are in good condition with little or no structural cracking due to load.
- C = 0.75 — Pavements exhibit initial cracking due to load but no progressive cracking or faulting of joints or cracks.
- C = 0.35 — Pavements exhibit progressive cracking due to load accompanied by spalling, raveling, or faulting of cracks and joints.

4.2.2 CONDITION OF EXISTING REINFORCED CONCRETE PAVEMENT:

- C = 1.00 — Pavements are in good condition with little or no short-spaced transverse (1-to 2-foot) cracks, no longitudinal cracking, and little spalling or raveling along cracks.
- C = 0.75 — Pavements exhibit short-spaced transverse cracking but little or no interconnecting longitudinal cracking due to load and only moderate spalling or raveling along cracks.

- C = 0.35—Pavements exhibit severe short-spaced transverse cracking and interconnecting longitudinal cracking due to load, severe spalling along cracks, and initial punchout-type failures.

4.2.3 FLEXIBLE OVERLAY. The following values of C are assigned for the following conditions of plain and reinforced concrete pavement.

4.2.3.1 CONDITION OF EXISTING PLAIN CONCRETE PAVEMENTS:

- C = 1.00 — Pavements are in good condition with some cracking due to load but little or no progressive-type cracking.
- C = 0.75 — Pavement exhibit progressive cracking due to load and spalling, raveling, and minor faulting at joints and cracks.
- C = 0.50—Pavements exhibit multiple cracking along with raveling, spalling, and faulting at joints and cracks

4.2.3.2 CONDITION OF EXISTING REINFORCED CONCRETE PAVEMENT.

- C = 1.00 — Pavements are in good condition but exhibit some closely spaced load-induced transverse cracking, initial interconnecting longitudinal cracks, and moderate spalling or raveling of joints and cracks.
- C = 0.75 — Pavements in trafficked areas exhibit numerous closely spaced load induced transverse and longitudinal cracks, rather severe spalling or raveling, or initial evidence of punchout failures.

5. RIGID OVERLAY OF EXISTING RIGID PAVEMENT.

5.1 GENERAL. There are three basic equations for the design of rigid overlays which depend upon the degree of bond that develops between the overlay degree of bond that develops between the overlay and existing pavement: fully bonded, partially bonded, and nonbonded. The fully bonded overlay equation is used when special care is taken to provide bond between the overlay and the existing pavement. The partially bonded equation will be used when the rigid overlay is to be placed directly on the existing pavement and no special care is taken to provide bond. A bond-breaking medium and the nonbonded equation will be used when a plain concrete overlay is used to overlay an existing reinforced concrete pavement or an existing plain concrete pavement that has a condition factor C < 0.35. They will also be used when matching in a plain concrete overlay with those in the existing plain concrete pavement causes undue construction difficulties or results in odd-shaped slabs.

5.2 PLAIN CONCRETE OVERLAY.

5.2.1 THICKNESS DETERMINATION. The required thickness h_o of plain concrete overlay will be determined from the following applicable equations:

Fully bonded

$$h_o = h_d - h_E$$

Partially bonded

$$h_o = \sqrt[1.4]{h_d^{1.4} - C\left(\frac{h_d}{h_e} \times h_E\right)^{1.4}}$$

Nonbonded

$$h_o = \sqrt{h_d^{2} - C\left(\frac{h_d}{h_e} \times h_E\right)^{2}}$$

where h_d is the design thicknesses of plain concrete pavement determined from figures 3 and 4 using the design flexural strength of the overlay and h_c is the design thickness of plain concrete pavement using the measured flexural strength of the existing rigid pavement; the modulus of soil reaction k of the existing rigid pavement foundation; and the design index needed for overlay design. The use of fully bonded overlay is limited to existing pavements having a condition index of 1.0 and to overlay thickness of 2.0 to 5.0 inches. The fully bonded overlay is used primarily to correct a surface problem such as scaling rather than as a structural upgrade. The factor h_E represents the thickness of the existing plain concrete pavement or the equivalent thickness of plain concrete pavement having the same load-carrying capacity as the existing pavement. If the existing pavement is reinforced concrete, h_E is determined and the percent steel can be selected using the percent reinforcing steel S and design thickness h_c **.** The minimum thickness of plain concrete overlay will be 2 inches for a fully bonded overlay and 6 inches for a partially bonded or nonbonded overlay. The required thickness of overlay must be rounded to the nearest full or ½**-** inch increment. When the indicated thickness falls midway between 1 and ½-inch, the thickness will be rounded up.

5.2.2 JOINTING. For all partially bonded and fully bonded plain concrete overlays, joints will be provided in the overlay to coincide with all joints in the existing rigid pavement. It is not necessary for joints in the overlay to be of the same type as joints in the existing pavement. When it is impractical to match the joints in the overlay to joints in the existing rigid pavement, either a bond-breaking medium will be used and the overlay designed as a nonbonded overlay or the overlay will be reinforced over the mismatched joints. Should the mismatch of joints become severe, a reinforced concrete overlay design should be considered as an economic alternative to the use of a nonbonded plain concrete overlay. For nonbonded plain concrete overlays, the design and spacing of transverse contraction joints will be in accordance with requirements for plain concrete pavements. For both partially bonded and nonbonded plain concrete, the longitudinal construction joints will be doweled using the dowel size and space recommended in the professional literature. Dowels and load-transfer devices will not be used in fully bonded overlays. Joint sealing for plain concrete overlays will conform to the requirements for plain concrete pavements.

5.2.3 REINFORCED CONCRETE OVERLAY. A reinforced concrete overlay may be used to strengthen either an existing plain concrete or reinforced concrete pavement. Generally, the overlay will be designed as a partially bonded overlay. The nonbonded overlay design will be used only when a leveling course is required over the existing pavement. The reinforcement steel for reinforced concrete overlays will be design and place in accordance with reinforced concrete pavements.

5.2.3.1 THICKNESS DETERMINATION. The required thickness of reinforced concrete overlay will be determined using figure 2 after the thickness of plain concrete overlay has been determined from the appropriate overlay equation. Then, using the value for the thickness of plain concrete overlay, either the thickness of reinforced concrete overlay can be selected and the required percent steel determined or the percent steel can be selected and the thickness of reinforced concrete overlay determined from figure 2. The minimum thickness of reinforced concrete overlay will be 4 inches.

5.2.3.2 JOINTING. Whenever possible, the longitudinal construction joints in the overlay should match the longitudinal joints in the existing pavement. All longitudinal joints will be doweled with dowel size and spacing designated in chapter 15 using the thickness of reinforced concrete overlay. It is not necessary for transverse joints in the overlay to match joints in the existing pavement; however, when practical, the joints should be matched. The maximum spacing of transverse contraction joints will be determined in accordance with the formula below, but it will not exceed 75 feet regardless of the thickness of the pavement or the percent steel used. Joint sealing for reinforced concrete pavements will conform to the requirements for plain concrete pavements.

6. RIGID OVERLAY OF EXISTING FLEXIBLE OR COMPOSITE PAVEMENTS.

6.1 FLEXIBLE PAVEMENTS. A rigid overlay of an existing flexible pavement should be designed in the same manner as a rigid pavement on grade. A modulus of subgrade reaction k should be determined by a plate-bearing test made on the surface of the existing flexible pavement. If not practicable to determine k from a plate-bearing test, an approximate value may be determined using methods described in the professional literature. These will yield an effective k value at the surface of the flexible pavement as a function of the subgrade k and thickness of base and sub- base above the subgrade. When using these methods, the bituminous concrete is considered to be unbound base course material. Using this k value and the concrete flexural strength, the required thickness of plain concrete overlay must be determined. However, the following limitations should apply:

- In no case should a k value greater than 500 pci be used.
- The plate-bearing test to determine the k value should be performed on the flexible pavement at a time when the temperature of the bituminous concrete is of the same order as the ambient temperature of the hottest period of the year in the locality of the proposed construction.

6.2 COMPOSITE BASE PAVEMENTS. Two conditions of composite pavement can be encountered when considering a rigid overlay. When the composite pavement is composed of a rigid base pavement with less than 4 inches of all-bituminous overlay, the required thickness of rigid overlay should be determined using the nonbonded overlay equation. If the composite pavement is composed of a rigid base pavement with 4 inches or more of either all bituminous or bituminous with base course overlay, the required thickness of overlay should be determined using the method discussed below. The same limitations for maximum k value and temperature of pavement at the time of test should apply.

7. FLEXIBLE OVERLAY OF FLEXIBLE PAVEMENT. Overlays are used for strengthening or rehabilitation of an existing pavement. Strengthening is required when heavier loads are introduced or when a pavement is no longer capable of supporting the loads for which it was designed. Rehabilitation may include sealing or resealing of cracks, patching, limited reconstruction prior to an overlay, restoration of the surface profile, improvement of skid resistance by a friction course, or improvement of the surface quality. When it has been determined that strengthening is required, the design of an overlay will be accomplished by initially designing a new pavement and comparing its thickness with the thickness of the existing pavement. The difference between these two pavements is the thickness of overlay required to satisfy design requirements. Overlays may be all-bituminous concrete or AC and base course. The flexible pavement after being overlaid shall meet all compaction requirements of a new pavement. Where the existing construction is complex, consisting of several layers, and especially where there are semirigid layers, such as soil cement, cement stabilized soils, or badly cracked portland cement concrete, careful exercise of judgment will be necessary to evaluate the existing materials. Guidance for evaluating existing construction is given in the professional literature.

8. FLEXIBLE OVERLAY OF RIGID BASE PAVEMENT.

8.1 DESIGN PROCEDURE. The design procedure presented determines the thickness of flexible overlay necessary to increase the load-carrying capacity of existing rigid pavement. This method is limited to the design of the two types of flexible overlay, the all-bituminous and the bituminous with base course. The selection of the type of flexible overlay to be used for a given condition is dependent only on the required thickness of the overlay. Normally, the bituminous with base course overlay should be used when the required thickness of overlay is sufficient to incorporate a minimum 4-inch compacted layer of high-quality base-course material plus the required thickness of bituminous concrete surface courses. For lesser thicknesses of flexible overlay, the all-bituminous overlay should be used. The method of design is referenced to the deficiency in thickness of the existing rigid base pavement and assumes that a controlled degree of cracking will take place in the rigid base pavement during the design life of the pavement.

8.2 THICKNESS DETERMINATION. Regardless of the type of nonrigid overlay, the required thickness t_0 will be determined by

$$t_0 = 3.0\ (Fh_d - Ch_E)$$

where h_d is the design thickness of plain concrete pavement using the flexural strength R of the concrete in the existing rigid pavement, the modulus of soil reaction k of the existing pavement, and the appropriate design index. The factor h represents the thickness of plain concrete pavement equivalent in load-carrying ability to the thickness of existing rigid pavement. If the existing rigid pavement is plain concrete, then the equivalent thickness equals the existing thickness; however, if the existing reinforced concrete, the equivalent be determined from the professional literature. F is a factor, determined from figure 1, that projects the cracking expected to occur in the base pavement during the design life of the overlay. C is a coefficient based upon the structural condition of the existing rigid pavement. The computed thickness of overlay will be rounded to the nearest whole or ½ inch. To reduce reflective cracking, the minimum thickness of all-bituminous overlay used for strengthening purposes will be 4 inches. No limitation is placed on the minimum thickness of an all-bituminous overlay when used for maintenance or to improve pavement surface smoothness. In certain instances, the flexible overlay design equation will indicate thickness requirements less (sometimes negative values) than the minimum values. In such cases the minimum

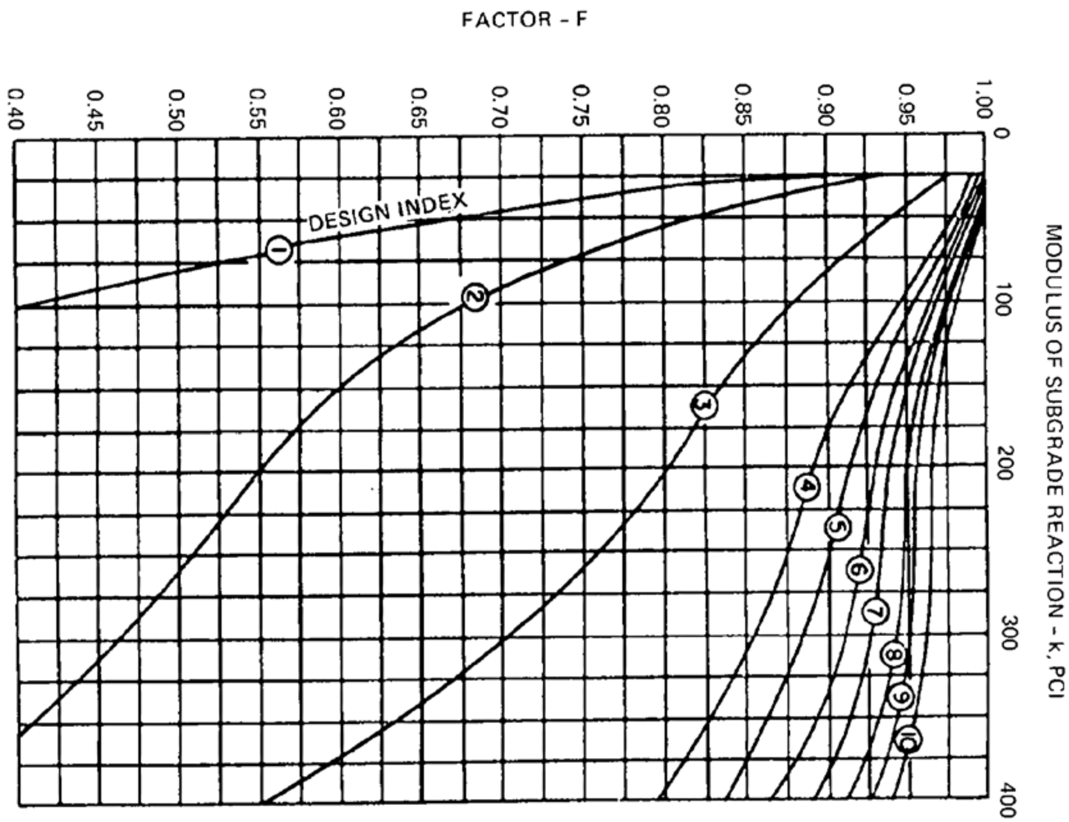

Figure 1

Factor for projecting cracking in a flexible pavement

thickness requirement will be used. When strengthening existing rigid pavements that exhibit low flexural strength (less than 500 psi) or that are constructed on high-strength foundation (k exceeding 200 pci), it may be found that the flexible pavement design procedure in this manual indicates a lesser required overlay thickness than the overlay design formula. For these conditions, the overlay thickness will be determined by both methods, and the lesser thickness will be used for design. For the flexible pavement design procedure, the existing rigid pavement is rigid pavement will be considered an equivalent thickness must thickness of high-quality crushed aggregate base(CBR=100), and the total pavement thickness determined based upon the subgrade CBR. Any existing base or subbase layers will be considered as corresponding layers in the flexible pavement. The thickness of required overlay will then be the difference between the required flexible pavement thickness and the combined thicknesses of existing rigid pavement and any base or subbase layers above the subgrade.

8.3 JOINTING. Normally, joints, other than those required for construction of a bituminous concrete pavement, will not be required in flexible overlays of existing rigid pavements. It is good practice to attempt to lay out paving lanes in the bituminous concrete to prevent joints in the overlay from coinciding with joints in the rigid base pavement. Movements of the existing rigid pavement, both from contraction and expansion and deflections due to applied loads, cause high concentrated stresses in the flexible overlay directly over joints and cracks in the existing rigid pavements. These stresses may result in cracking, often referred to as reflection cracks, in the overlay. The severity of this type cracking will, in part, depend upon the type of rigid pavement. For example, a plain concrete pavement normally will have closely spaced joints and may result in reflection cracks over the joints, but the cracks will be fairly tight and less likely to ravel. Nevertheless, reinforced concrete pavements will normally have joints spaced farther apart, which will, in turn, experience larger movements. The reflection cracks over these joints are more likely to ravel and spall. Likewise, either existing plain concrete or reinforced concrete pavements may have expansion joints that experience rather large movements, and consideration may be given to provide an expansion joint in the flexible overlay to coincide with the expansion joint in the existing pavement. No practical method has been developed to absolutely prevent reflective cracking in flexible overlays; however, experience has shown that the degree of cracking is related to the thickness of the overlay, with the thinner overlays exhibiting the greater tendency to crack.

9. USE OF GEOTEXTILES TO RETARD REFLECTIVE CRACKING. Geotextiles have been effective in retarding reflective cracking in some areas of the United States, as shown in figure 2. When geotextiles are used under an AC pavement, the existing pavement should be relatively smooth with all cracks larger than ¼ inch sealed. A leveling course is also recommended before application of the fabric to ensure a suitable surface. A tack coat is also required prior overlay thickness is as shown in figure 2. When using geotextiles under a flexible pavement overlay, the geotextiles can be used as a membrane strip or a full-width application. The existing pavement should be stable with negligible movement under loads and all joints and cracks larger than ¼ inch sealed. With the strip method, the geotextile is applied directly on the concrete joints and cracks and then overlaid. With the full-width method, the geotextile can be applied directly to the existing pavement or placed on a leveling course. It has also been observed that in flexible overlays, the lower viscosity (or higher penetration grade) asphalts are less likely to experience reflective cracking. Therefore, the lowest viscosity grade asphalt that will provide sufficient stability during high temperatures should be used.

10. OVERLAYS IN FROST REGIONS. Whenever the subgrade is susceptible to differential heaving or weakening during the frost-melt period, the overlay design should meet the requirements for frost action. When it is determined that distress in an existing pavement has been caused by differential heaving due to frost action, an overlay may not correct the condition unless the combined thickness of the pavement is sufficient to prevent substantial frost penetration into the underlying frost-susceptible material.

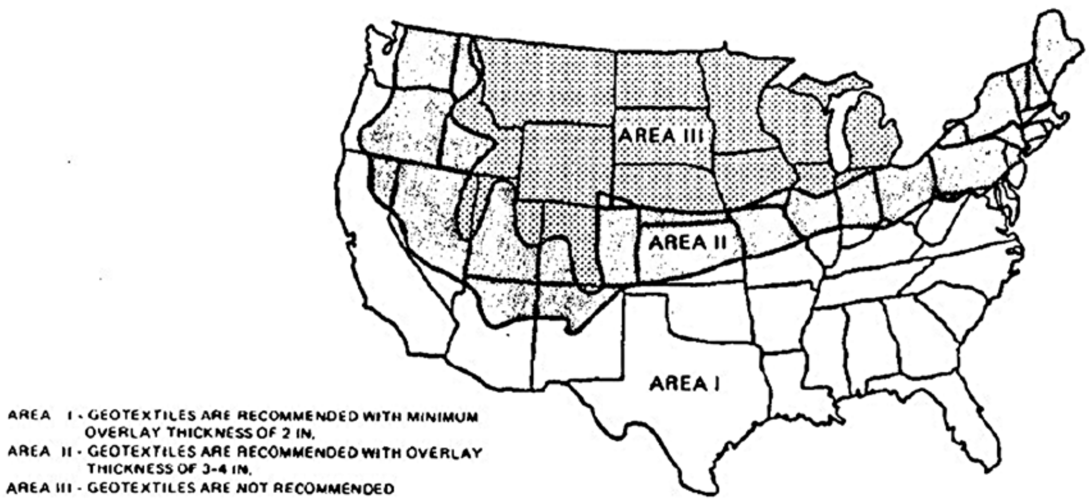

Figure 2

Location guide for the use of geotextiles in retarding reflective cracking

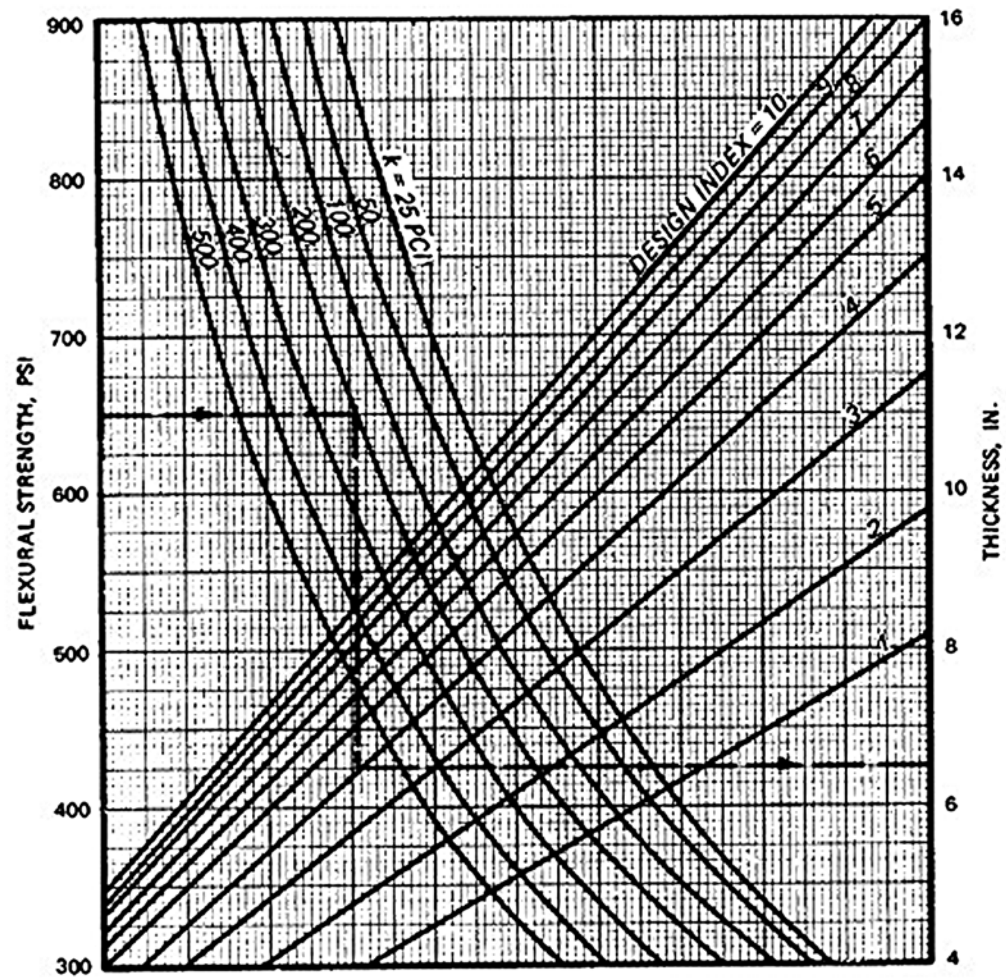

Figure 3

Design curves for concrete roads and streets, and RCCP

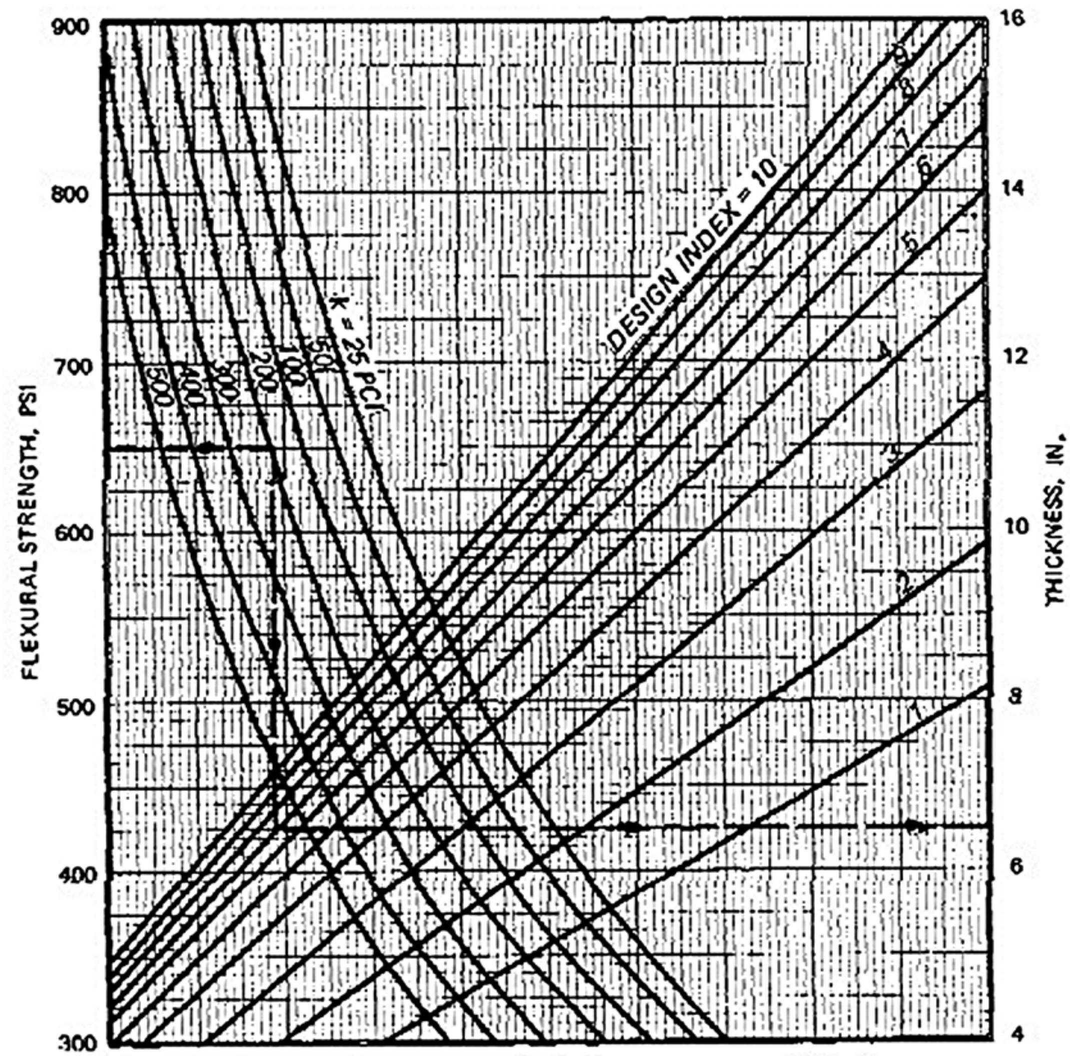

Figure 4

Design curves for plain concrete parking and open storage areas

11. OVERLAY DESIGN EXAMPLE. Design an overlay for an existing road having a plain concrete thickness of 6 inches, a flexural strength of 650 psi, a subgrade k value of 100 pci, and a design index of 8. The concrete overlay will also have a flexural strength of 650 psi. The factor for projecting cracking in a flexible overlay is 0.975 from figure 1. The existing pavement is in good condition with little or no structural cracking. The condition factor C is therefore equal to 1.0 for concrete and flexible overlay, and h_d and h_e are 8.6 inches. Overlay thickness requirements for the various types of overlays are as follows:

Bonded Overlay

$h_o = h_d - h_g$

$h_o = 8.6 - 6.0$

$h_o = 2.6$ inches (round to 3.0 inches)

Partially Bonded Overlay

$$h_o = \sqrt[1.4]{h_d^{1.4} - C\left(\frac{h_d}{h_e} \times h_E\right)^{1.4}}$$

$$h_o = \sqrt[1.4]{(8.6)^{1.4} - 1.0\left(\frac{8.6}{8.6} \times 6.0\right)^{1.4}}$$

$h_o = 4.4$ inches (use minimum thickness of 6 inches)

Unbonded Overlay

$$h_o = \sqrt[2]{h_d^{2} - C\left(\frac{h_d}{h_e} \times h_E\right)^{2}}$$

$$h_o = \sqrt[2]{8.6^{2} - 1.0\left(\frac{8.6}{8.6} \times 6\right)^{2}}$$

$h_o = 6.16$ inches (round to 6.5 inches)

Flexible Overlay

$t_o = 3.0((Fh_d - Ch_g)$

$t_o = 3.0(0.975 \times 8.6 - 1.0 \times 6)$

$t_o = 7.2$ inches (round to 7.5 inches)