CHAPTER 8

EXAMPLES OF PAVEMENT DESIGN

8-1. Example 1. Heavily trafficked road. Design flexible and rigid pavements for the following conditions:

- Class B (rolling terrain within the "built-up area").

- Category III.

- Design index: 4 (for flexible pavements).

  3 (for rigid pavements).

- Design air freezing index: 700 degree-days.

- Subgrade material: uniform sandy clay, CL; plasticity index, 18; frost group, F3; water content, 20 percent (average); normal-period CBR, 10; normal-period modulus of subgrade reaction k = 200 psi/inch on subgrade and 400 psi/inch on 24 inches of base course.

- Base course material: crushed gravel (GW), normal-period CBR=80, 30 percent passing no. 10 sieve, 1 percent passing No. 200 sieve.

- Subbase course material: course to fine silty sand (SP-SM), normal-period CBR=20, 11 percent passing No. 200 sieve, 6 percent finer than 0.02 millimeters, frost classification S2, meets filter criteria for material in contact with subgrade.

- Average dry unit weight (good quality base and subbase): 135 pcf.

- Average water content after drainage (good quality base and subbase): 5 percent.

- Highest ground water: about 4 feet below surface of subgrade.

- Concrete flexural strength: 650 psi.

Since this pavement has a design index of 4 or less, criteria in local highway department requirements may be used in lieu of criteria in EM 1110-3-131 and EM 1110-3-132. Local experience with existing pavements indicates that frost heave has been relatively uniform.

a. Flexible pavement design by limited subgrade frost penetration method. From figure 3-4, the combined thickness a of pavement and base to prevent freezing of the subgrade in the design freezing index year is 45 inches. According to criteria in EM 1110-3-131, the minimum pavement thickness is 2 inches over a CBR=80 base course that must be at least 4 inches thick. The ratio of subgrade to base water content is r = 20/5 = 4. Since this is a highway pavement, the maximum allowable r of 3 is used in figure 4-1 to obtain the required thickness of base b of 24 inches, which would allow about 6 inches of frost penetration into the subgrade in the design year. Subgrade preparation would not be required since the combined thickness of pavement and base is more than one-half the thickness required for complete protection.

b. Flexible pavement design by reduced subgrade strength method. From table 4-1 the frost-area soil support index is 3.5, which from the design curve in EM 1110-3-131, yields a required combined thickness of pavement and base of 19 inches. Since this is less than the (2 + 24) 26-inch thickness required by the limited subgrade frost penetration method, the 19-inch thickness would be used. The pavement structure could be composed of the following: 2 inches of asphalt concrete, 9 inches of crushed gravel, (since the crushed gravel contains only 1 percent passing the No. 200 sieve, it also serves as the free-draining layer directly beneath the pavement) and 9 inches of the silty sand subbase material. Subgrade preparation would be required to a depth of 1/2 x 45 - 19 = 3-1/2 inches.

c. Rigid pavement design by limited subgrade frost penetration method. From EM 1110-3-132 the required pavement thickness p, based on the normal-period k = 400 psi per inch, the concrete flextural strength of 650 psi and the design index of 3, is 5.0 inches. From figure 3-4, the combined thickness of pavement and base is 45 inches, equivalent to that for the flexible pavement. By use of r = 3 in figure 4-1, the required thickness of base b is 23 inches, which would allow about 6 inches of frost penetration into the subgrade in the design year. No subgrade preparation would be required.

d. Rigid pavement design by the reduced subgrade strength method. Since frost heave has not been a major problem, a minimum of 4 inches of the free-draining base course material could be used, plus 4 inches of the subbase that will serve as a filter material on the subgrade. For this case, the frost-area index of reaction would be 50 psi per inch (fig 4-2), requiring a pavement slab 8 inches thick. Subgrade preparation to a depth of 1/2 x 45 - 16 = 6-1/2 inches would be required.

e. Alternative designs. Other designs using stabilized layers, including all bituminous concrete pavements, should be investigated to determine whether they are more economical than the designs presented above.

8-2. Example 2. Lightly trafficked road. Design flexible pavements for the following conditions:

- Class E (flat terrain within the "open" area)

- Category III

- Design index: 2 (from EM 1110-3-131).

- Design air freezing index: 1,500 degree-days.

- Subgrade material: fine silty sand, SM, nonplastic; frost group, F4; water content, 15 percent (average); normal-period CBR, 15.

- Base course material: gravel (GW), normal-period CBR=80, 30 percent passing No. 10 sieve and 3 percent passing the No. 200 sieve.

- Subbase course material: Coarse to fine silty sand (SP-SM), normal-period CBR=20, 10 percent passing No. 200 sieve, 5 percent finer than 0.02 millimeters, frost classification S2, meets filter criteria for material in contact with subgrade.

- Average dry unit weight of the base and subbase: 125 pcf.

- Average water content of the base and subbase after drainage: 7 percent.

- Select borrow material: Silty sand (SM), normal period CBR=15, 25 percent passing No. 200 sieve, 15 percent finer than 0.02 millimeters; frost classification F2, meets filter criteria for materials in contact with subgrade.

- Highest ground water: approximately 3 feet below surface of subgrade.

a. Limited subgrade frost penetration method. By use of the procedure outlined in example 1, paragraph 8-1, the combined thickness of pavement and base a to prevent freezing of the subgrade in the design year is 70 inches, which was determined by interpolation between the soils having densities of 115 and 135 pcf. From EM 1110-3-131, the minimum pavement thickness over an 80 CBR base course is 1-1/2 inches. From figure 4-1, the design base thickness is 48 inches for r = 15/7 = 2.1. This would allow about 12 inches of frost penetration into the subgrade in the design year. No subgrade preparation would be required since the thickness is greater than 1/2 x 70 = 35 inches.

b. Reduced subgrade strength design method. From table 4-1, the frost area soil support index is 3.5, which from the design curve in EM 1110-3-131, yields a required thickness of pavement and base of 15 inches. This is substantially less than the thickness required by the limited subgrade frost penetration method. Subgrade penetration would be required to a depth of 1/2 x 70 - 15 = 20 inches. The pavement structure could be composed of 1-1/2 inches of pavement, 8 inches of base course, and 5.5 inches of subbase course plus the 20 inches of prepared subgrade. Since the base course material contains more than 2 percent passing the No. 200 sieve, material in at least the upper 4 inches must be washed to reduce the amount passing the No. 200 sieve to 2 percent or less.

c. All-bituminous concrete (ABC) pavement. The pavement structure from paragraph 8-2.b. can be used to obtain the thickness required through the use of equivalency factors listed in EM 1110-3-131. For the base course, the equivalency factor is 1.15, and 8 inches/1.15 = 7.0 inches of bituminous concrete that could be substituted for the base course. The equivalency factor for the subbase is 2.30, and 5.5 inches/2.30 = 2.4 inches of bituminous concrete that could be substituted for the subbase. The all-bituminous concrete pavement would be 1.5 + 7.0 + 2.4 = 10.9 inches or 11 inches thick. A filter course a minimum of 4 inches thick is required beneath the pavement. Subgrade preparation would be required to a depth of 1/2 x 70 - 15 = 20 inches. The required thickness of the pavement may also be determined from elastic modulus values for the pavement and subgrade. The procedure for obtaining the modulus values can be found in U.S. Army Engineer Waterways Experiment Station Technical Report No. 5-75-10. Figure 8-1 is used to obtain the pavement thickness when the modulus values have been obtained. For this example, a subgrade modulus, E_2, of 4,000 psi and a pavement modulus, E_1, of 200,000 psi will be used. The minimum pavement thickness is 7.5 inches. This thickness is substantially less than that determined using the equivalency values. A 4-inch thick filter course is required beneath this pavement, and the depth of subgrade preparation would be 24 inches.

d. Use of F2 soil. Use of the available F2 borrow material will allow reduced thicknesses of base and subbase and, if desired, could also be used to reduce the depth of preparation of the F4 subgrade. The reduced subgrade strength design method is used to determine the minimum thickness of pavement and base above the F2 soil which has a frost area soil support index of 6.5 (table 4-1). The design curve in EM 1110-3-131 yields a required thickness of pavement and base of 10 inches above the F2 soil. Therefore, the pavement structure could be composed of 1-1/2 inches of pavement, 5 inches of washed base course, 4.5 inches of subbase, and at least 7 inches of F2 soil above the subgrade to comply with the minimum of 17 inches of cover which was required over the F4 subgrade. The pavement structure outlined above would still require processing and preparation of the upper 18 inches of the F4 subgrade. This depth could be reduced by increasing the thickness of F2 soil. For example, if 12 inches of F2 soil was used, preparation to a depth of only 13 inches would be necessary in the F4 soil.

e. Use of local highway design criteria. Local state highway design criteria and standards may be used. If the state criteria are used, however, they must be completely adapted. Portions of the state criteria and portions of the Corps of Engineers criteria should not be mixed.

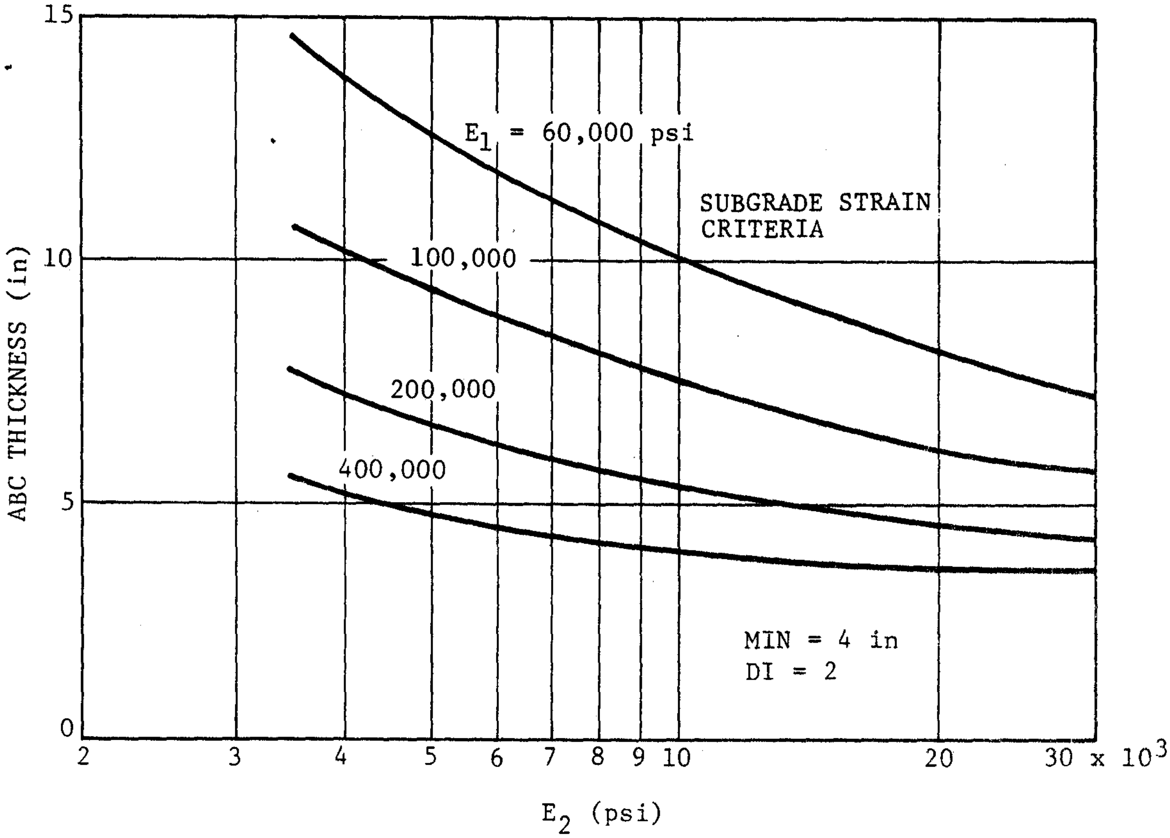

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FIGURE 8-1. DESIGN CURVES FOR ABC ROAD PAVEMENT