ORIGINATOR Director, Office of Construction		PROCEDURE 14-1-20
CHAPTER 14	Pavements	
SECTION 1	Pavement Design	
SUBJECT 20	Rigid Pavement Thickness Design	

Basis of Design

This procedure describes the thickness design process for rigid pavement structures. It is based on data developed by the AASHTO Road Test, supplemented and modified by theoretical analysis.[1]

Roughness Index

The value of the roughness index for rigid pavement design is 3.0 IRI (P_t = 2.5).

Traffic Loading

Separate ESAL factors have been established for rigid pavement design as follows:

Rigid Pavement ESAL Factors	
Truck Type	Factor
2D	0.3
3SU	1.2
2-S1, 2-S2	0.6
3-S2 & Above	1.6
Double Bottoms	2.1

Multiplying the rigid pavement ESAL Factors by the percent of the ADT of each truck type and by the DLT (Procedure 14-1-1) and then summing the results for all truck types gives the Design Lane Daily ESALs for rigid pavement design purposes. The Design Lane Total Life ESAL value is then computed by multiplying the Design Lane Daily ESAL value by 365 and then by the analysis period in years (typically 20 years).

Modulus of Subgrade Reaction

Westergaard's Modulus of Subgrade Reaction (k) is used in this procedure to express the supporting capability of the subgrade soil. It represents the load in pounds per square inch **(kPa)** on a loaded area, divided by the deflection in inches **(millimeters)** of that loaded area, psi/inch **(kPa/mm)**. Measurements can be obtained in the field by placing a 30-inch **(750 mm)** diameter plate on a representative portion of a subgrade soil, applying a definite load (commonly 10 psi or **70 kPa**), and then measuring the amount of deflection.

The "k" value is best estimated on the basis of previous experience or by correlation with other tests. The "k" value to be used for design purposes is to be determined and reported in the soils report.

Design Equations

Two types of portland cement concrete pavement are used on highways in Wisconsin. These consist of jointed concrete pavement (non-reinforced) and continuously reinforced concrete pavement (CRCP).

The AASHTO ’72 Portland Cement Concrete design equation is used to determine the design thickness (D) of both jointed concrete pavement and CRCP.

This equation is based on protected corner conditions which, for jointed pavements, assumes that adequate load transfer is obtained through mechanical devices.

The recommended working stress of concrete (f_t) is calculated using the following equation:

$$f_t = \frac{S_c}{C}$$

Where S_c = modulus of rupture (28-day flexural strength of third point loading in psi (MPa)).

C = constant (for most conditions a value of 1.33 is recommended. See Section 3.4.2, AASHTO Interim Guide for Design of Pavement Structures, 1972, Chapter III Revised, 1981 for other recommendations).

Design Chart

Figure 1 shows the design nomograph which can be used to determine the design thickness (D) for concrete pavements with P_t=2.5 (3.0 IRI). The nomograph assumes a fixed 20 year design life, so the Design Lane Daily ESAL value should be used.

Wisconsin uses a value of 650 psi (4.48 MPa) for the modulus of rupture. Therefore, using the above formula, the working stress is found to be 490 psi (3.38 MPa). By knowing the total Life ESALs, and the modulus of subgrade reaction (k), the design thickness (D) can readily be determined.

The following equation is the AASHTO ’72 Portland Cement Concrete Design Equation. It is the theoretical basis for both the design nomograph (see Figure 1) and the PCC thickness design portion of the computer program described in Procedure 14-1-35. This equation is based on the English system so the computer program calculates D in English units and then automatically converts the results to metric values. The nomograph also provides thickness results only in English units.

Design Process

Jointed Concrete Pavement (Non-Reinforced) (JPCP)

Non-reinforced concrete pavement utilizes short contraction joint spacings (20 feet **(6.0 m)** or less) to control transverse cracking. See Procedure 14-15-5 for specific transverse contraction joint spacing. This eliminates the need for distributed steel reinforcement. Experience in Wisconsin shows that non-reinforced concrete pavement has a wide application;

$$\log(ESAL) = 7.35\log(D+1) - 0.06 + \frac{\log\left(\frac{4.5 - P_t}{4.5 - 1.5}\right)}{1 + \frac{1.62x10^7}{(D+1)^{8.46}}} + (4.22 - 0.32\,P_t)\log\left[\left(\frac{f_t}{690}\right)\frac{D^{0.75} - 1.132}{D^{0.75} - \frac{18.42}{\left(\frac{E}{k}\right)^{0.25}}}\right]$$

where:
ESAL = Total Life Rigid ESAL's
D = Concrete Slab Thickness (inches)
P_t = Terminal Serviceability Index (2.5 for Rigid Pavements)
f_t = Working Stress of Concrete (490 psi)
E = Modulus of Elasticity of Concrete (4,200,000 psi)
k = Modulus of Subgrade Reaction (psi)

therefore, thicknesses used can vary from six inches **(150 mm)** on up.

Non-reinforced concrete pavement can be constructed with doweled contraction joints (positive load transfer method) or without doweled contraction joints (aggregate interlock load transfer method). Non-reinforced concrete pavements constructed without doweled contraction joints and carrying moderate to heavy truck loading are susceptible to excessive joint faulting resulting in unacceptable pavement roughness. Therefore, doweled contraction joints should be used in all non-reinforced concrete pavements regardless of thickness.

Continuously Reinforced Concrete Pavement (CRCP)

This type of concrete pavement utilizes continuous longitudinal reinforcement achieved by lapping the steel. Such construction permits long stretches of pavement to be built without installing the traditional transverse joints. The only transverse joints occurring in CRCP are construction joints placed at the end of a day's run and terminal joints placed where the pavement ends at a structure or abuts an existing pavement.

In CRCP, the cracks occur randomly at close intervals, normally 2-10 feet (**0.6-3.0 m**). They are kept small and tightly closed by the longitudinal reinforcement.[2] The best performance can be expected when the average crack spacing is four to six feet **(1.2 to 1.8 meters)**.

CRCP is best utilized on rural highways of the higher design classes where truck loading generates pavement design thicknesses of 9-inches **(225 mm)** or more and where the use of terminal devices can be kept to a minimum by building long, uninterrupted stretches of pavement.

The design process for determining the concrete slab thickness is the same for both JPCP and CRCP. The use of the "Pavement Structural Design and Life Cycle Cost Analysis" computer program (Procedure 14-1-35) is recommended. Within the computer program is the "Rigid Pavement Design Worksheet" which calculates the minimum slab thickness based on traffic and soils data that is entered in the "General Project Data Worksheet".

If the computer program is not accessible, the following hand calculation procedure should be followed.

1.) Determine the Design Lane Traffic (DLT) (see Procedure 14-1-1).

2.) Determine the Design Lane Daily ESALs as stated earlier.

3.) Using the Design Lane Daily ESAL, P_t=2.5 (3.0 IRI), f_t=490 psi, and the k value from the soil's report; use Figure 1 by drawing straight lines between the known values as shown on the figure.

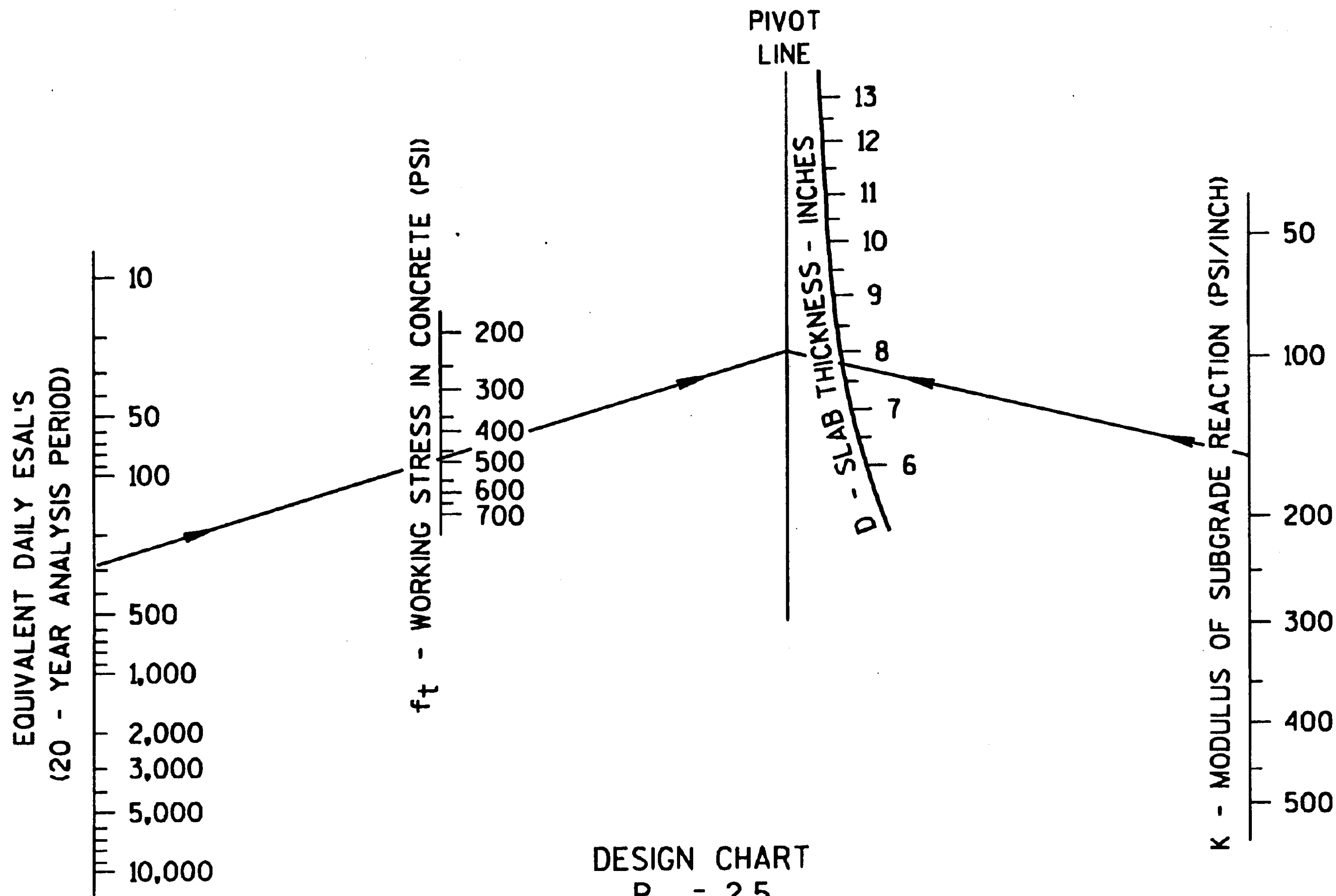
Selection of Rigid Pavment Type

Based on performance experience and economics, it is present policy to construct most rigid pavements with jointed, non-reinforced (plain) concrete with doweled contraction joints. Continuously reinforced concrete pavement should be used on the more heavily traveled highways in the higher design classes. The decision to use CRCP must be based on an economic analysis and consideration of other factors as described in Procedure 14-1-30. When it becomes impractical to build CRCP because of interruptions such as many closely spaced structures, jointed, non-reinforced concrete pavement with doweled contraction joints should be used in the short sections.

References

[1] AASHTO Interim Guide for Design of Pavement Structures, 1972, Chapter III Revised, 1981.

[2] Design and Construction, Continuously Reinforced Concrete Pavement, Continuously Reinforced Pavement Group. ★



DESIGN CHART
$P_t = 2.5$
IRI = 3.0