

DESIGN RECOMMENDATION FOR  
CONTINUOUS REINFORCED PAVEMENTS IN MICHIGAN

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MICHIGAN DEPARTMENT OF STATE HIGHWAYS

**DESIGN RECOMMENDATION FOR  
CONTINUOUS REINFORCED PAVEMENTS IN MICHIGAN**

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**Research Laboratory Section  
Testing and Research Division  
Research Project 61 F-64(2)  
Research Report No. R-765**

**Michigan State Highway Commission  
Charles H. Hewitt, Chairman; Wallace D. Nunn, Vice-Chairman;  
Louis A. Fisher; Claude J. Tobin; Henrik E. Stafseth, Director  
Lansing, March 1971**

## DESIGN RECOMMENDATION FOR CONTINUOUS REINFORCED PAVEMENTS IN MICHIGAN

At their January 6, 1971 meeting, the Pavement Selection Committee requested the Testing and Research Division to make a study and prepare recommendations concerning continuously reinforced pavement thickness, and percentage of reinforcing steel for general use throughout the state. We have reviewed Research Report No. R-609, "Procedure for Design of Continuously Reinforced Concrete Pavements" (October 1966) and made some comparisons of this procedure with the American Concrete Institute Committee 325, "Recommended Design Procedure for Continuously Reinforced Concrete Pavement for Highways" soon to be published by the ACI. Results from application of the two methods are discussed and recommendations for construction of continuously reinforced pavements in Michigan are presented.

Both methods presented are based on determining the traffic to which the pavement will be subjected, in terms of equivalent 18 kip single-axle loads. This requires estimates of future total traffic flow, percent commercial traffic, and commercial axle load distribution data, so that the traffic flow can be converted to a certain number of equivalent 18 kip single-axle loads. The concept of 18 kip equivalent axle loads was proven by data collected at the AASHO Road Test.

In Table 1, 10 typical locations throughout the state were selected to determine what the resulting pavement thickness should be, using the two design methods. The traffic volume data were obtained from the Research Laboratory's Highway Planning and Research Project, "Statewide Determination of Highway Loadings and Conversion to 18 Kip Single-Axle Load Equivalents." In obtaining the percent commercial in the traffic (right) lane for a four-lane divided highway, Figure 2 of Research Report No. R-609 was used. The number of 18 kip single-axle load equivalents for 1967 was projected to 1985 on the basis of a 5-percent increase each year. The 1985 traffic was used to determine the number of repetitions of 18 kip single-axle load equivalents which might be expected in a 25 year life of the continuously reinforced pavement. Finally, the thickness requirement for the 10 locations is shown on the basis of the ACI Committee 325 Recommended Design Procedure and Research Report No. R-609.

Figure 1 is taken from the ACI Committee 325 report and shows the nomograph used to determine pavement thickness. For Michigan the suggested parameters for use with the chart are as follows:

- k = Subgrade Modulus of Support = 200 psi/inch
- MR = Modulus of Rupture = 650 psi
- $E_c$  = Modulus of Elasticity of Concrete = 3,500,000 psi

The value of the Westergaard Subgrade Modulus 'k' used by the Michigan Department of State Highways is taken from the chart on page 121 of the Field Manual of Soil Engineering. The chart is based on work done by now retired O. L. Stokstad in relation to airport work during World War II. The Department normally uses a 'k' value of 200 for 12-in. subbase. This value is almost identical to that given in Table 1, p. 4 of the current PCA Thickness Design for Concrete Pavements. The PCA chart lists a 'k' value of 190 for a 12-in. subbase. The PCA values are based on extensive plate load tests conducted by them.

The modulus of Rupture of 650 psi is the minimum value for 28-day flexural strength as shown in Table 7.01-1, p. 534, 1970 MDSH Standard Specifications for Highway Construction. The Modulus of Elasticity of 3,500,000 psi is about the most realistic value which can be selected for concrete with a minimum compressive strength of 3,500 psi at 28 days.

To illustrate the method of determining the thickness by Research Report No. R-609, Figure 3 of that report is reproduced here as Figure 2. It is based on the daily equivalent 18 kip single-axle repetitions in one lane and the service life to be expected, while the ACI method is based on the parameters given above plus the total number of equivalent 18 kip single-axle applications expected during the life of the pavement. As shown in Table 1, traffic volumes dictate a thickness of 6.3 to 10.0 in. by ACI Committee 325 method and 6.5 to 9.8 in. by the method of Research Report No. R-609. However, the Department feels that it is more feasible from overall economic considerations rather than initial cost only, to use a minimum thickness of 8 in. for continuously reinforced pavement. The reduced maintenance resulting from this thickness and the added service life would more than offset the slight saving resulting from a pavement thickness decrease of 1 in. to a 7 in. thickness in lower traffic areas.

Michigan's oldest continuously reinforced pavement is now 12-1/2 years old. It was constructed 8 in. thick with 0.6 percent steel. On the basis of 1967 traffic data we would expect this pavement to last approximately 25 years in accordance with Research Report No. R-609. By ACI

Committee 325 recommendations we would expect it would take 6 million 18-kip single-axle load equivalents, or a life of approximately 30 years. However, assuming a 5-percent traffic volume increase each year and based on projected 1972 traffic volumes this would reduce to 20 and 24 years by the two design methods.

Pavement Thickness Recommendation:

Nine inch thickness for pavements where the traffic lane is subjected to 9 million or more 18 kip single-axle load equivalents in a 25 year service period.

Eight inch thickness for pavements where the traffic lane is subjected to less than 9 million 18-kip single-axle load equivalents in a 25 year period.

Percentage of Steel:

ACI Committee 325, "Recommended Design Procedure for Continuously Reinforced Concrete Pavements," gives five formulas to calculate the proper percentage of reinforcing steel with the specification that the largest amount resulting from these five formulas should be used. The following formula based on the minimum amount of steel to control restrained volume changes due to temperature results in the greatest steel requirement.

$$p_s = \left[ \frac{f'_t}{f_y - nf'_t} \right] 100 = \left[ \frac{365}{60,000 - 8.5 (365)} \right] \times 100$$

$$p_s = 0.642\%$$

where,

$p_s$  = specified percentage of longitudinal steel

$f'_t$  = tensile strength of concrete in psi = 365 psi based on minimum Modulus of Rupture of 650 psi and average value of  $f'_t/MR = 0.564$  from Table 6, p. 77 of "Relations Between Various Strengths of Concrete" by Sandor Popovics, Highway Research Board Record No. 210.

$$f_y = \text{yield strength of steel in psi} = 60,000 \text{ min.}$$

$$n = \frac{E_s}{E_c} \frac{\text{Elastic modulus of steel}}{\text{Elastic modulus of concrete}} = \frac{30 \times 10^6}{3.5 \times 10^6} = 8.6 \text{ say } 8.5$$

Research Report No. R-609, p. 7, bases the steel percentage determination on an approximation of the above formula, using an allowable steel stress of about 45,000 psi which limits the crack opening to about 0.025 in. for No. 5 bars, and a minimum concrete tensile strength of .08  $f'_t$  or 320 psi. This results in a steel rate of  $\frac{320}{45,000} \times 100 \cong 0.7\%$ .

Currently we have CRCP with both 0.6 and 0.7 percent steel in Michigan. However, the smaller steel percentage allows wider crack openings, resulting in greater possibility of steel corrosion due to salt infiltration. Therefore we believe that the use of the higher steel percentage is warranted in areas of heavy salt usage.

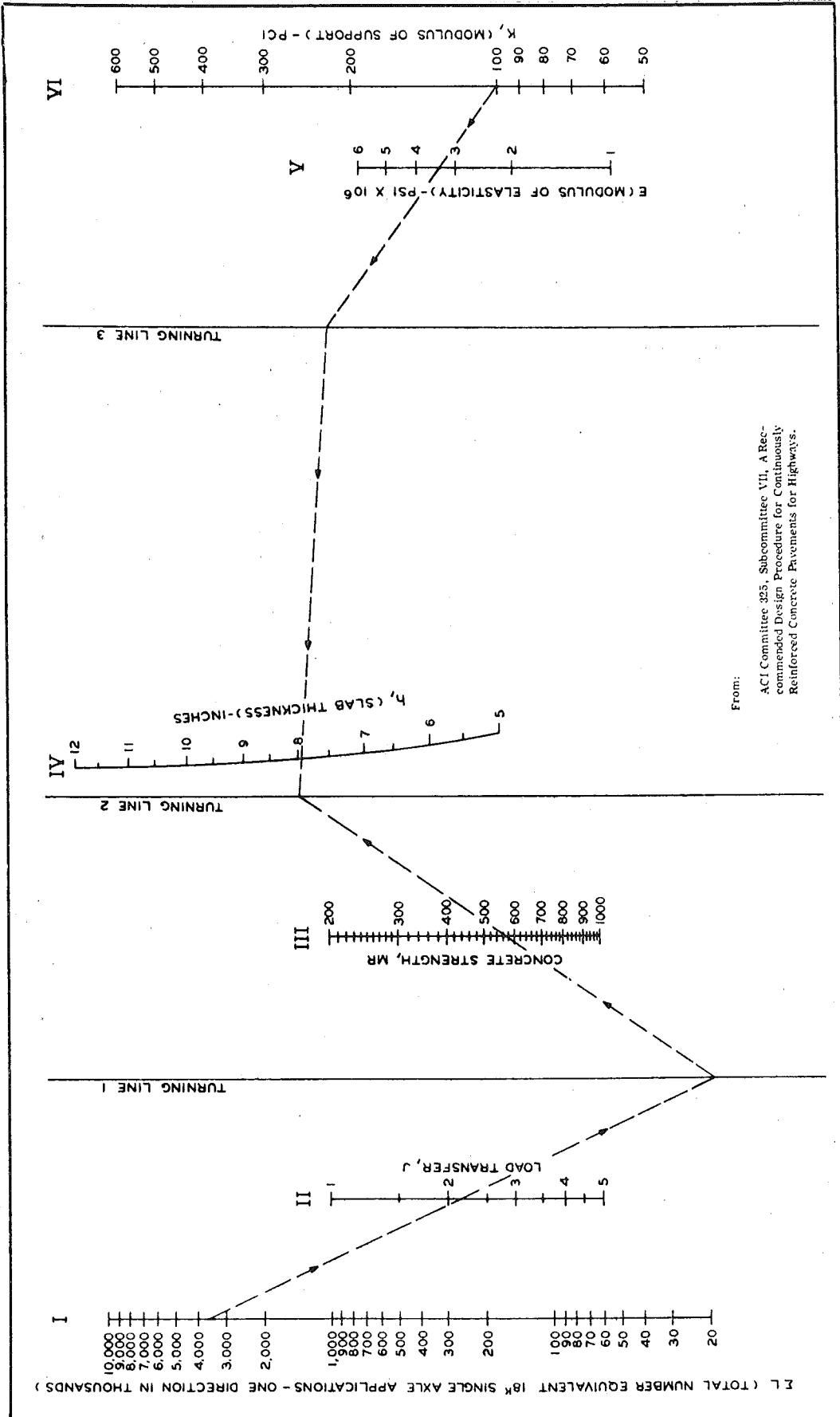
#### Recommendation for Steel Reinforcement

In areas of the state where heavy applications of maintenance chemicals are used we recommend 0.7 percent steel for both 8 in. and 9 in. continuously reinforced pavements.

In areas of the state where lesser applications of maintenance chemicals are used we recommend 0.6 percent steel for both 8 in. and 9 in. continuously reinforced pavements.

TABLE 1  
CONTINUOUSLY REINFORCED CONCRETE PAVEMENT THICKNESS FOR TEN TYPICAL LOCATIONS IN MICHIGAN

Location	Average Daily Traffic 1967	Hundreds of Vehicles Per Hour in One Direction	Percent Commercial in Right Lane	Average Daily Commercial Traffic in Right Lane 1967	No. of 18 Kip Single Axles Per 100 Commercial Vehicles	18 Kip Equivalent Right Lane 1967 Per Day	18 Kip Equivalent Right Lane 1985 5% Annual Increase	18 Kip Equivalent Right Lane for 25 yr service 25 x 365 = 9,120	Thickness Requirement	
									ACI Committee 325	MDSH Report R-609
I 96 Fowlerville	14,400	3.0	93	12.0	62.5	750	1,840	16.8 x 10 <sup>6</sup>	9.5"	9.3"
I 96 Portland	9,300	1.94	96	8.9	59.9	530	1,295	11.8 x 10 <sup>6</sup>	8.9"	8.8"
I 94 Grass Lake	18,500	3.85	91	17.3	63.7	1,010	2,490	22.7 x 10 <sup>6</sup>	10.0"	9.8"
I 75 Erie	19,500	4.07	91	20.2	47.1	950	2,320	21.2 x 10 <sup>6</sup>	10.0"	9.6"
I 75 Saginaw	19,600	4.09	90	11.5	53.8	620	1,520	13.9 x 10 <sup>6</sup>	9.2"	9.1"
US 41 & M 35 Menominee	10,300	-----	-----	5.75	20.5	118	288	2.64 x 10 <sup>6</sup>	6.6"	6.9"
US 131 & M 46 Howard City	6,900	-----	-----	3.6	26.7	96	234	2.14 x 10 <sup>6</sup>	6.3"	6.5"
US 27 & M 78 Lansing	8,600	1.8	96	9.3	37.1	345	840	7.70 x 10 <sup>6</sup>	8.0"	8.2"
M 78 & M 47 Perry	9,600	2.0	96	9.8	36.0	354	860	7.88 x 10 <sup>6</sup>	8.0"	8.2"
US 10 Pontiac	22,000	4.58	90	24.6	29.4	722	1,760	16.2 x 10 <sup>6</sup>	9.5"	9.2"



Concrete Pavement  
1970

Example:

Note: In using this nomograph one must use compatible values for concrete properties on lines III and V.

Values in brackets for Michigan practice.

Given

- L = 3,650,000 applications
- J = 2.2
- k = 100 psi/inch (200 psi/in.)
- MR = 580 psi (650 psi)
- $E_c$  = 3,400,000 pis (3,500,000 psi)

Answer: h = 8.0 inches

Figure 1. Thickness Design Method.



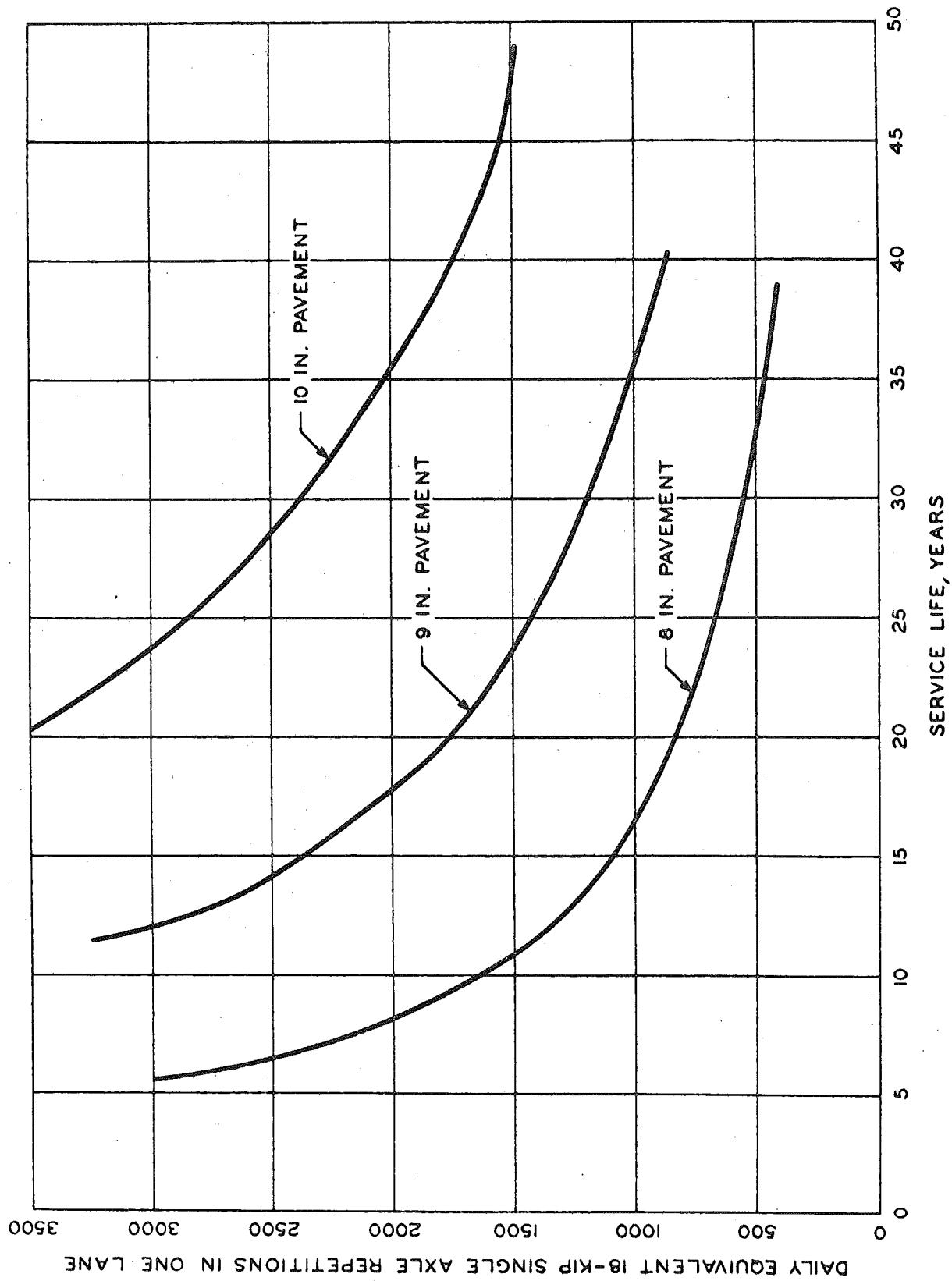


Figure 2. From Research Report No. R-609. Traffic loading related to years of service, based on AASHO Road Test pavement performance equations, with Terminal Serviceability Index of 2.5.