# Procedure for the Selection of Asphalt Concrete Resurfacing Thickness

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•THE INTENT of this paper is to discuss the work being conducted by the Illinois Division of Highways in cooperation with the U. S. Bureau of Public Roads to develop an empirical design procedure for composite pavement. The procedure will have its greatest application in determining the thickness of asphalt concrete resurfacing necessary to effectively rehabilitate existing portland cement concrete (PCC) pavements. This is a continuation of the work to evaluate the findings of the AASHO Road Test so that they can be applied to the structural design of regular highway pavements in Illinois.

Already completed and put into practice are two interim procedures for the structural design of rigid and flexible pavements that are based on the AASHO Road Test performance equations. They are now being used in the structural design of all rigid pavements and all flexible pavements with bituminous mats in Illinois. The development of the interim procedures are discussed elsewhere (1, 2).

The development of a third interim procedure for determining the thickness of resurfacing needed in rehabilitating existing PCC pavements has not been completed but has progressed to a point where it now appears that the study will be successful. This third procedure will permit the determination of the thickness of resurfacing needed to rehabilitate an existing rigid pavement and is based on a consideration of the thickness and condition of the existing pavement, the type of resurfacing to be used, the volume and composition of traffic to be served by the rehabilitated pavement, and the length of time the rehabilitated pavement is expected to adequately serve this traffic.

This study has progressed on the assumption that the two presently developed design procedures for rigid and flexible pavements can be further modified for application to composite pavement design, and that the general procedures followed in their development also can be used in developing the necessary modifications. Several factors led to this assumption. In the first place, while it was determined that neither procedure could be applied directly, it was believed that the ultimate procedure should lie somewhere between the two, because a resurfaced pavement includes a rigid base combined with a flexible surface.

Observations of the behavior of resurfaced pavements in Illinois had a significant effect on the assumption. In the early 1950's Illinois launched a major resurfacing program following the policy that, in addition to widening the existing pavement and making geometric corrections in alignment and grade when necessary, a nominal 3-in. thick bituminous concrete resurfacing, constructed in two lifts, would be placed over the existing pavement. Although the results generally are very satisfactory, considerable differences in service lives of the rehabilitated pavements have developed. Those rehabilitated pavements carrying high volumes of heavy commercial traffic generally showed signs of deterioration and distress rather early, while other pavements of the same design, but carrying lower volumes of commerical traffic, have performed quite satisfactorily for extended periods of time. In some cases where adjacent sections of pavement having the same slab thickness and carrying the same traffic were resurfaced with different thicknesses of resurfacing, the thicker sections generally have given better performances than the thinner sections.

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TABLE 1

EQUIVALENT 18-KIP SINGLE AXLE-LOAD APPLICATIONS PER VEHICLE CLASSIFICATION—FLEXIBLE PAVEMENT

| Road or Street Class | Highway System | 18-kip Equivalent Single Axle Load per Vehicle | | |
|---|---|---|---|---|
| | | Passenger | Single-Unit Commercial | Multiple-Unit Commercial |
| I | Primary | 0.0004 | 0.117 | 0.947 |
| II | Primary | 0.0004 | 0.109 | 0.924 |
| III | Secondary | 0.0004 | 0.098 | 0.794 |
| IV | Local | 0.0004 | 0.027 | 0.216 |

Before proceeding further with the discussion of this study, it might be well to briefly outline the procedures that were developed for rigid and flexible pavement design because these same procedures are being followed in this study.

The first step was to establish some method for converting mixed-traffic axle loadings to a common denominator, or equivalent numbers of applications of a given axle loading, to permit comparisons to be made with the AASHO Road Test performance equations. This was accomplished by developing factors for converting passenger cars and average single- and multiple-unit commercial vehicles into equivalent numbers of applications of an 18-kip single axle load for each of four classifications of highways. Classes I and II include the primary system of highways, Class III the secondary system, and Class IV the local roads. The factors were developed by analyzing loadometer and traffic-classification count data, obtained for Illinois pavements since 1945, in combination with the 18-kip single axle equivalency factors derived from the AASHO Road Test data. The loadometer data and axle-load equivalency factors were used to determine average equivalency factors for each individual classification of commercial vehicle within each of the single-unit and multiple-unit groupings for each year that loadometer data were available. These values were then weighted in accordance with the classification count data to develop weighted average factors for single-unit and multiple-unit commercial vehicles. Equivalency factors for passenger cars, single-unit commercial vehicles, and multiple-unit commercial vehicles for each of the four highway classifications used in the flexible pavement design procedure are given in Table 1. Similar values are included in the rigid pavement procedure. The actual values differ somewhat in the two procedures because of the differences in axle-load equivalency factors developed from rigid and flexible pavement performance equations of the AASHO Road Test.

The next step in the development of the rigid and flexible pavement design procedures was to test the AASHO Road Test performance equations for applicability to Illinois pavements in regular service. This was done by comparing actual performance of selected pavements to performance as predicted by the equations. The results showed that both the rigid and flexible pavement equations predicted higher levels of performance than those actually obtained, but that a modification of the design term would suitably modify the equation.

In the flexible pavement equation, the design term is presented as an index related to the types and thicknesses of materials used in the various layers of the pavement structure. The design term in the rigid equation is expressed as the thickness, in inches, of the concrete slab. The design term in the Illinois flexible pavement procedure is expressed by the equation $D_t = a_1 D_1 + a_2 D_2 + a_3 D_3$. $D_t$ is the Illinois structural number, the a values are strength coefficients associated with the various materials used in the surfacing, base, and subbase, and the D values are the thicknesses in inches of the various layers of the pavement structure. The design term in the performance equations was modified by a factor representing the ratio of the average of the ratios of the pavement sections in the Illinois study to the AASHO Road Test that can be expected to give the same performance. This factor has been termed the time-traffic exposure factor.

A plot of pavement age vs the ratios of the Illinois structural number to the AASHO Road Test thickness index that would give the same performance is shown in Figure 1. The average of all these values, shown as a dashed line, is 1.11. A factor of 1.1 was used in the design procedure. This means that, to give the same performance as that predicted by the AASHO Road Test performance equation, an Illinois flexible pavement in regular service would have to have a design term 1.1 times greater than that of the AASHO Road Test pavement.

A similar plot of the thickness ratios vs pavement age for rigid pavements is shown in Figure 2. The average value, or time-traffic exposure factor, for these sections is 1.34, which was later rounded to 1.3 in the design procedure. This indicates that on the average an Illinois rigid pavement in regular service would have to be 1.3 times thicker than one at the AASHO Road Test to provide approximately the same performance. It is believed that these differences in performance are brought about by the variations in the behavior of pavements subjected to long-term traffic while undergoing gradual deterioration from climatic exposure as compared with the behavior of the AASHO Road Test pavements subjected to only 2 years of traffic.

The end results of the two Illinois procedures are presented as design nomographs that include a traffic factor scale, a soil support scale, and a structural design scale. Shown in Figure 3 is the design nomograph for flexible pavements with a terminal PSI of 2.0. A straight line passing through determined values on the traffic factor scale and on the soil support scale will intersect the structural number scale at the required

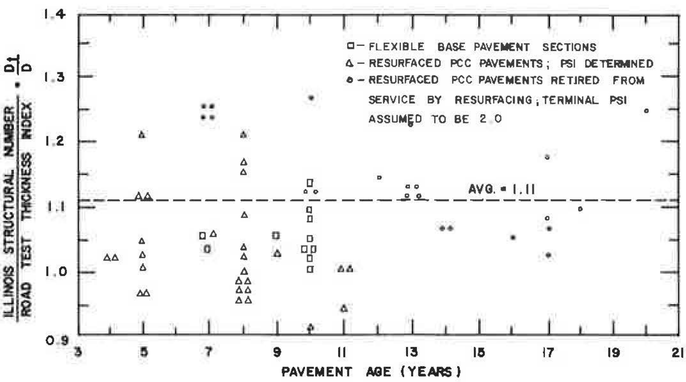


Figure 1. Time-traffic exposure factor vs pavement age—flexible pavement.

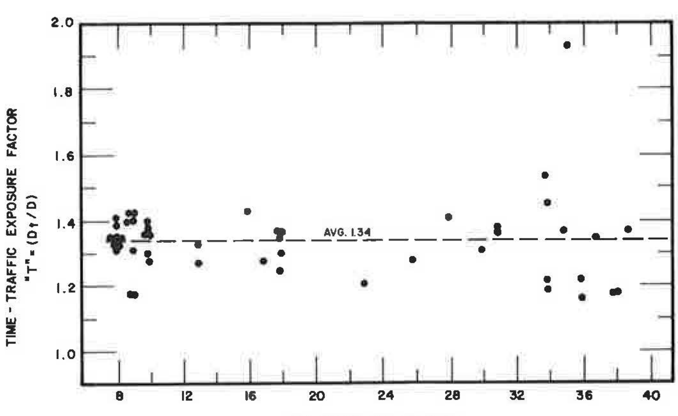


Figure 2. Time-traffic exposure factor vs pavement age—rigid pavement.

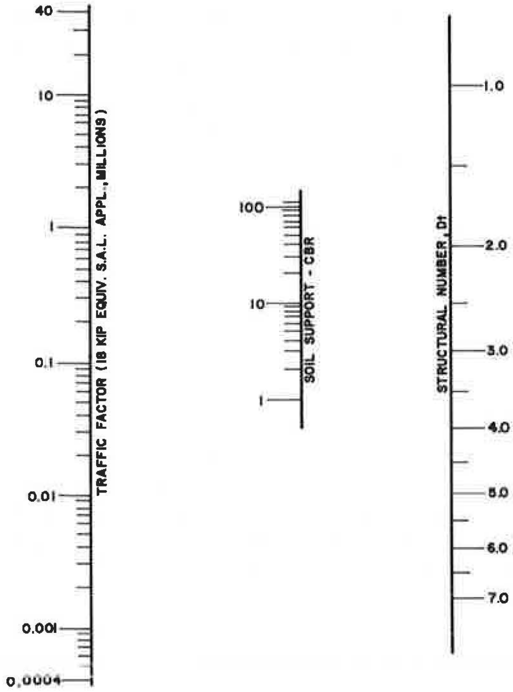


Figure 3. Design nomograph for flexible pavements with terminal PSI of 2.0 on Classes II, III, and IV roads.

structural number. This value is then used in the structural number equation in conjunction with minimum thicknesses, established by the design procedure, to determine the most economical design. The design nomograph for rigid pavement with a terminal PSI of 2.5 is shown in Figure 4. The thickness of pavement is read directly from the slab thickness scale.

One major consideration in the development of a composite pavement design procedure was that the information already developed in the other two procedures should be used as much as possible. Thus, the intent was to modify the design nomographs in one of the two procedures for use in composite pavement design. Because a composite pavement involves a rigid base and a flexible surface, however, the the problem was which of the two procedures should be followed. The design procedure, as envisioned, would be one of determining the total structural requirements, determining the portion of the total requirements that would be satisfied by the existing pavement structure when used as the base course, and, finally, determining the thickness of new surfacing needed to completely satisfy the requirements.

In developing the flexible pavement procedure, performance data from resurfaced PCC pavements were used to supplement data from flexible pavements because not enough data were available for flexible pavement sections. Therefore, it was certain that the flexible pavement design procedure could be suitably modified for use in composite pavement design. On the other hand, there appeared to be certain distinct advantages in following the rigid pavement procedure. Because the existing PCC pavement should continue to provide a slab-type support to the pavement structure after resurfacing, it was considered that the soil support scale in the rigid pavement procedure should require little, if any, modification for use in composite pavement design. This scale provides a means for adjusting structural design to compensate for differences in support strength of the subgrade soils.

The final decision was to investigate both procedures for their suitability to further modification. A further decision was that, regardless of the procedure followed, the structural design of the resurfaced pavement would be expressed as an index, or structural number, as in the flexible pavement procedure; e.g., it would be equal to a coefficient times the surfacing thickness plus a coefficient times the thickness of the existing pavement as the base. This required revisions to the slab thickness scale in the rigid pavement design nomographs, which presented no problem because estimations from the AASHO Road Test data indicate that a 0.5 coefficient could be applied to the slab thickness to make it equivalent to the flexible pavement thickness

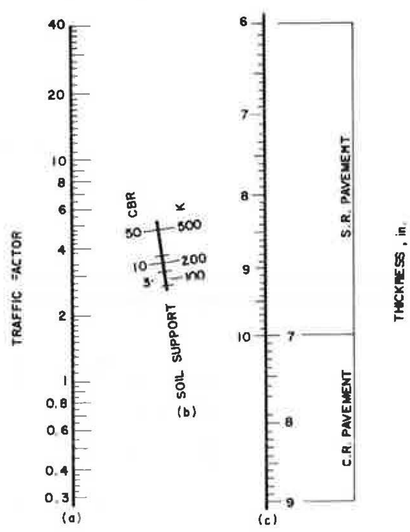


Figure 4. Design nomograph for rigid pavements with terminal PSI of 2.5 on Class I roads.

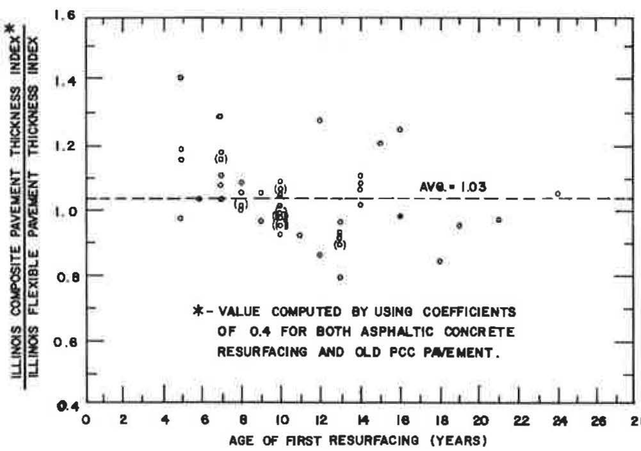


Figure 5. Resurfacing age vs thickness index ratios using coefficient of 0.40 for pavement and resurfacing and the flexible pavement procedure.

index. Previous experience in Illinois with evaluating performance of resurfaced pavements also had shown that separate analyses would be required for the first resurfacing and for second and subsequent resurfacings.

The first phase of the study was to test the rigid and flexible pavement procedures for application in the development of the composite pavement design procedure. Fifty-three representative pavement sections were selected for analyses in this phase. Only pavement sections that had been resurfaced once and were approaching the end of their lives were selected. A soils map of the state also was used in selecting the sections in an effort to obtain reasonably uniform subgrade soil support similar to that of the AASHO Road Test pavements. The present serviceability index (PSI) value was determined for each section, and the traffic history obtained from traffic maps for each resurfaced section was converted into the total number of equivalent 18-kip single axle-load applications following the procedures established in both the rigid and flexible pavement procedures.

The composite pavement thickness index was then estimated for each section in the study, using 0.4 as the coefficient value in the thickness index equation for both the resurfacing and the existing pavement. These coefficient values are the ones that were used in developing the flexible pavement procedure and correspond closely to those recommended by AASHO. The rigid and flexible pavement procedures were then used to determine the structural designs that could be expected to give the same performance as that of the selected pavement sections, and these designs were compared to the estimated thickness indexes. The results of the analysis using the flexible pavement procedure are shown in Figure 5 where the ratios of the estimated thickness indexes to the designs, determined by the flexible pavement procedure to give the same performance, are plotted against pavement age. These results show conclusively that

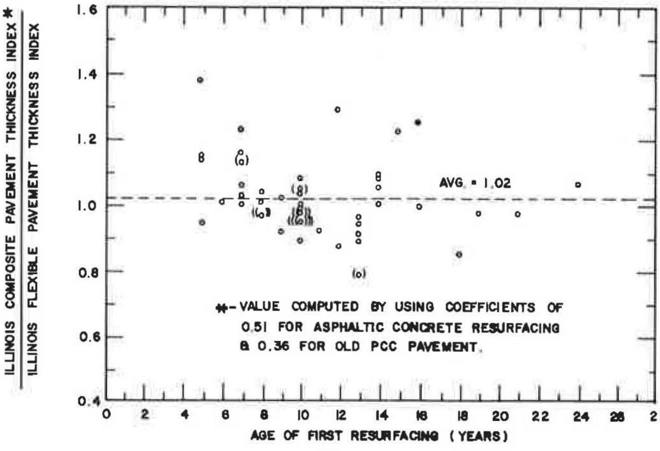


Figure 6. Resurfacing age vs thickness index ratios using coefficients of 0.36 for pavement and 0.51 for resurfacing and the flexible pavement procedure.

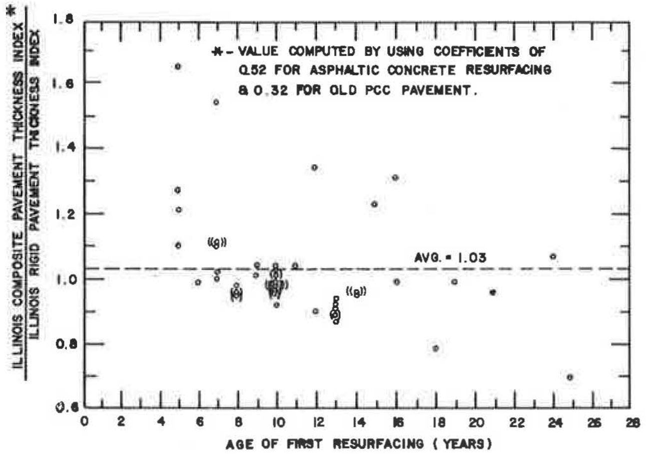


Figure 7. Resurfacing age vs thickness index ratios using coefficients of 0.32 for pavement and 0.52 for resurfacing and the rigid pavement procedure.

the flexible pavement procedure can be used in developing a composite pavement design procedure. Further, the average ratio of 1.03 shows that the time-traffic exposure factor modifying the design term in the flexible pavement performance equation can be used without further modification. Similar results were obtained from the analysis using the rigid pavement procedure.

A linear multiple-regression analysis was then conducted to compute coefficient values for the resurfacing and existing PCC pavement that would provide the line of best fit to the data for the 53 sections included in the study. When the flexible pavement procedure was followed, the coefficients were determined to be 0.36 for the existing pavement and 0.51 for the resurfacing. For the rigid pavement procedure, the coefficients were 0.32 for the existing pavement and 0.52 for the resurfacing. A plot of the thickness index ratios vs pavement age, using the computed coefficient values and the flexible pavement procedure, is shown in Figure 6 in which the average ratio is 1.02. A similar plot using the rigid pavement procedure is shown in Figure 7 where the average ratio is 1.03.

In a final analysis to determine which of the two procedures actually appears to provide the better fit, the resurfacing thickness required by the developed procedure was computed and compared with the actual thickness for each pavement section included in the study. The results, given in Table 2, indicate that the computed coefficients and the rigid pavement procedure provide the better fit.

At the present time, this is as far as the study has progressed. Data available on the structural conditions of existing selected pavements at the time of resurfacing are being reviewed with the hope of being able to develop a method for evaluating the effect of the structural condition of the existing PCC pavement on the performance of the resurfaced pavement. Differences in structural condition could then be reflected in the coefficient value assigned to the existing pavement as the base course for the new resurfaced pavement.

A limited amount of work has been done to develop design coefficients for second resurfacings. The results obtained thus far have been based on a limited quantity of data. Although a considerable mileage of Illinois highways has been resurfaced a second time, thus far only 14 sections have been found to be suitable for inclusion in the study.

Work is also getting under way on a third phase of the study that will involve the analysis of new composite pavements, i.e., new, plain PCC base course covered with asphalt concrete during the initial construction. Performance data are being gathered and the same development technique being used in the other two phases will be followed. After completing the data collection and analysis for second resurfacing and for new composite

TABLE 2

COMPARISON OF COMPUTED RESURFACING THICKNESS TO ACTUAL RESURFACING THICKNESS FOR THE 53 PAVEMENT SECTIONS

| Pavement Design Procedure | Coefficient Values | | Percent of Sections Where Computed Thickness is Within | | |
|---|---|---|---|---|---|
| | Pavement | Resurfacing | ½ in. of Actual | 1 in. of Actual | 2 in. of Actual |
| Flexible | 0.40 | 0.40 | 38 | 66 | 94 |
| Flexible | 0.36 | 0.51 | 51 | 74 | 98 |
| Rigid | 0.32 | 0.52 | 62 | 79 | 94 |

pavements, we will have sufficient information available to complete the development of the structural design procedure.

## REFERENCES

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