Implementation of the 1986 AASHTO Guide at the City and County Levels

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Many cities and counties have not yet implemented the 1986 AASHTO Guide, mostly because of its sophistication and wide scope. This paper provides guidelines and recommendations to narrow the scope of the guide to match the local conditions. The paper summarizes the main steps recommended by the guide for the design and rehabilitation of flexible pavements. The paper discusses some of the obstacles that might face design engineers at the city and county levels due to budget and equipment limitations. Local designers need training to adopt the mechanistic concepts of the guide, such as the use of nondestructive testing data and of resilient modulus values, the choice of reliability levels, and the use of life-cycle cost analysis. Engineering judgment and previous experience are still needed to implement the guide properly, especially during the transition between the old and new guides. The experience of the City of Phoenix in implementing the 1986 AASHTO Guide is presented.

Although the new AASHTO Guide was published in 1986, many cities and counties across the nation are still using the old version of the AASHTO Guide (1981) with or without some modifications in the design of their flexible pavements. The scope of the old guide is quite limited and does not cover all facets of pavement design and rehabilitation.

The *AASHTO Guide for Design of Pavement Structures* has been published by the American Association of State Highway and Transportation Officials in an effort to update the pavement design process (*1*). Although the new guide is still based on data obtained at the AASHTO Road Test in the late 1950s and early 1960s, the scope of the guide has been largely extended to cover many areas and applications in pavement design and rehabilitation. New mechanistic-empirical approaches have been introduced to provide better prediction of pavement life and performance. Among the new elements that the guide incorporates are the use of the reliability approach, of nondestructive testing (NDT) in pavement evaluation, of resilient modulus in material characterization, and of overlay design procedure. In fact, the new AASHTO Guide is considered one of the most comprehensive and rational handbooks currently available in the literature.

The new AASHTO Guide, however, is not the "ultimate" goal in pavement design and rehabilitation. In several design steps engineering judgment is still needed, and some assumptions have to be made. In addition, the large-volume guide and its sophisticated nature intimidate many design engineers and technicians and prevent them from fully using the available new concepts.

The objective of this paper is to assist city and county personnel in incorporating the 1986 AASHTO Guide in the design and rehabilitation of asphalt pavements. The paper sets guidelines to simplify the AASHTO Guide and reduce its scope to match local conditions. The paper discusses specific design parameters, nondestructive testing, lab testing, and computer programming that need to be considered for proper implementation of the guide. Obstacles and problems associated with use of the guide are also addressed.

The AASHTO Guide covers many areas, ranging from low-volume roads to rigid pavements. The scope of this paper is limited to design and rehabilitation of asphalt pavements.

MAIN DIFFERENCES BETWEEN NEW AND OLD GUIDES

The main differences between the 1986 version of the AASHTO Guide and previous versions, as far as flexible pavements are concerned, are as follows:

1. Consideration of the reliability concept,
2. Use of elastic (resilient) modulus in material characterization,
3. Consideration of drainage condition,
4. Consideration of the effect of frost heave, swelling soils, and thaw-weakening on pavement performance,
5. Use of NDT in pavement evaluation, and
6. Use of life-cycle cost analysis in determining the most cost-effective construction/rehabilitation strategy.

Both soil support value and regional factor have been deleted from the new guide and substituted by the effective roadbed soil resilient modulus. The following sections present the main design parameters and methods of pavement evaluation that characterize the new guide.

Reliability

The reliability of a pavement design-performance process is the probability that a pavement section designed using the process will perform satisfactorily for the traffic and the environmental conditions of the design period.

The selection of an appropriate level of reliability for the design of a particular facility depends primarily upon the projected level of usage and the consequences (risk) associated

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with constructing an initially thinner pavement structure. In general, larger reliability values increase the required pavement thickness and its associated initial cost, and decrease the future distress-related costs (maintenance, rehabilitation, user-delay, etc.).

The reliability level varies from 50 percent to 99.9 percent. The guide recommends a set of wide ranges of reliability for various road classes. Depending on local experience and needs, cities and counties should specify more specific ranges of reliability.

When considering reliability in stage construction or "planned rehabilitation" design alternatives, it is important to consider the effects of compound reliability. The overall reliability is the product of reliabilities of all stages.

Another parameter associated with reliability is the overall standard deviation (S_o). The selection of the overall standard deviation is dependent on the variability of various factors associated with the performance prediction model, such as future traffic, soil modulus, and so forth. Obviously, the larger the variability of various performance factors, the larger the overall standard deviation and the larger the required pavement thickness. According to AASHTO, an approximate range of S_o is 0.40 to 0.50 for flexible pavements.

Traffic Analysis

Similar to that of the old AASHTO Guide, the design procedure is based on the cumulative expected 18-kip, equivalent single-axle load (ESAL) during the design (performance) period in the design lane. To convert mixed traffic into 18-kip ESAL units, the AASHTO equivalency factors can be used. Note that the load equivalency factors have been extended in the new guide to include heavier loads, more axles, and terminal serviceability levels up to 3.0 (see AASHTO, Appendix D). If the cumulative two-directional, 18-kip ESAL expected on the road is known, the designer must factor the design traffic by directions and then by lanes to calculate the axle repetitions in the design lane (W_{18}).

Effective Roadbed Soil Resilient Modulus

The basis for material characterization in the 1986 AASHTO Guide is the elastic or resilient modulus. The roadbed soil resilient modulus can either be measured in the lab using the AASHTO T274 test procedure on representative samples or backcalculated from nondestructive deflection measurements.

Figure 1 shows the laboratory device used to determine the resilient modulus of soils and unbound base and subbase materials. The device is commercially available for between $35,000 and $70,000, depending on whether it is driven by compressed air or electrohydraulic power. The compressed air-driven device can be assembled locally from its basic components.

In both lab testing and backcalculation cases, it is important to determine the elastic (resilient) modulus of the roadbed soil in the different seasons of the year, such as the wet and dry seasons. In addition to determining the seasonal moduli, it is also necessary to determine the length of time in each season during which the different moduli are effective. The

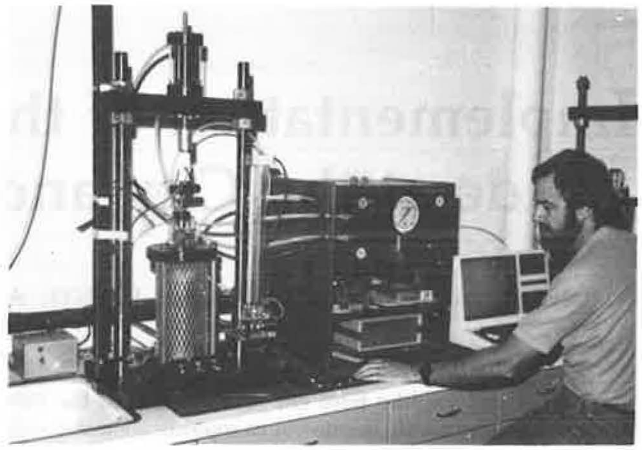

FIGURE 1 Triaxial resilient modulus machine for soils and unbound base and subbase materials.

effective roadbed soil resilient modulus can be determined using the procedure presented in the guide if the different moduli of the roadbed soil and the time interval associated with each modulus are known.

Serviceability

The serviceability concept in the new AASHTO Guide, similar to that in the old AASHTO Guide, is still the basis of evaluating the condition of the pavement.

Structural Layer Coefficients

The new guide followed the concept of the old guide in assigning a structural layer coefficient (a_i) to each layer material in the pavement structure in order to convert actual layer thicknesses into structural number (SN). The resilient modulus has been recommended as the parameter to be used in assigning layer coefficients to both stabilized and destabilized materials. Direct lab measurement of resilient modulus can be performed using AASHTO Method T274 for subbase and unbound granular materials and ASTM D4123 for asphalt concrete and other stabilized materials (Figure 2). Layer moduli can also be backcalculated from the NDT data.

Research and field studies indicate that many factors influence the layer coefficients; thus previous experience might be used to assign the layer coefficients. For example, the layer coefficient may vary with thickness, underlying support, position in the pavement structure, and so on.

One figure was added to the new guide to convert the resilient modulus of asphalt concrete to its layer coefficient a_i. Four other charts were adopted from the old guide to convert various material properties to the layer coefficients a_2 and a_3 of granular bases and subbases as well as cement- and bituminous-treated bases. These charts, however, have to be used with caution since the correlations among various material properties might not be very accurate, as discussed later.

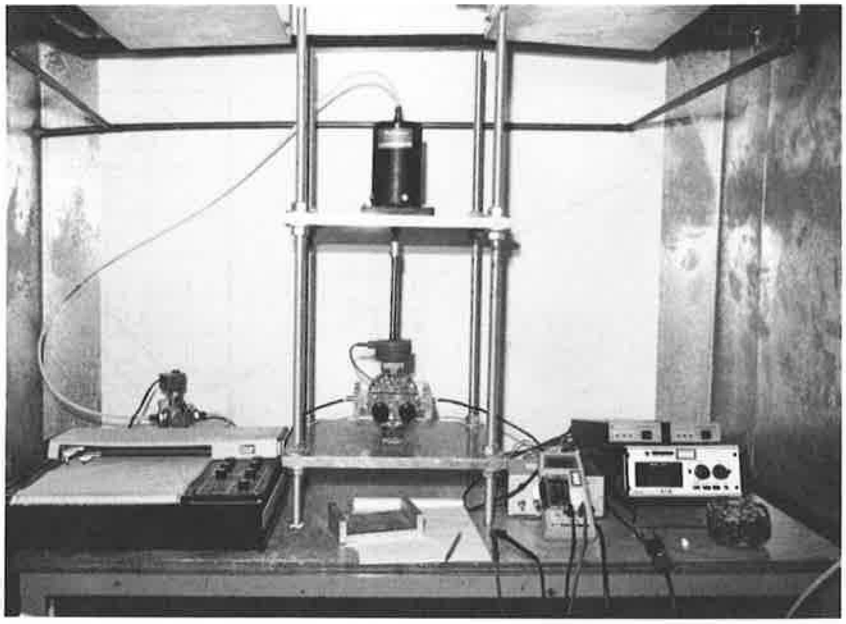

FIGURE 2 Diametral resilient modulus machine for asphalt concrete and other stabilized materials.

Structural Number and Drainage Conditions

Similar to that of the old guide, the structural number (*SN*) adopted is an index number that may be converted to thickness of various flexible pavement layers through use of the structural layer coefficients. The new guide, however, introduced drainage coefficients (m_2 and m_3) to modify the layer coefficients of bases and subbases, depending on the expected level of drainage in the pavement section. The guide includes a table showing the value of the drainage coefficients if both quality of drainage and percent of time when pavement is approaching saturation are known.

Design of New Pavements

The basic equation and nomograph used to design the required structural number above subgrade, subbase, and base are shown in Figure 3. It can be seen that new parameters have been introduced in the design process instead of those in the old guide, such as the reliability factor (R), overall standard deviation (S_o) and resilient modulus (M_r). Note also that the designer has the ability to design for different design serviceability losses ΔPSI where ΔPSI is the difference between the initial serviceability and the terminal serviceability. Therefore, the designer is not limited to a terminal serviceability of 2.0 or 2.5, as is the case in the old guide. Using Figure 3, the structural number above each layer can be obtained and the thicknesses of various layers can be determined.

Effect of Seasonal Variation on Performance

Improvements in the new guide have been made to adjust designs as a function of environment (e.g., frost heave, swelling soils, and thaw-weakening). If one or more of these environmental conditions are applicable, a graph of serviceability loss versus time needs to be developed under the local conditions, as shown in Figure 4. The serviceability loss due to environment must be added to that resulting from cumulative axle loads. An iteration process is needed to predict the pavement performance period under both traffic loads and environmental conditions.

Structural Evaluation of Existing Pavements

The new guide recommends the use of NDT devices such as the Falling Weight Deflectometer (FWD) or Dynaflect to evaluate the structural capability of existing pavements.

The inverse problem of determining material properties from the response of the pavement structure to surface loading is not a straightforward process. The AASHTO Guide includes two methods: backcalculation of layer moduli (NDT Method 1) and prediction of subgrade modulus (NDT Method 2). Method 1 (backcalculation) can be used with all types of loading devices, while Method 2 is applicable only to the FWD. Using the backcalculation technique, it is necessary to employ iterative schemes based on the fact that surface deflections remote from the loaded area are primarily governed by the stiffness of the deeper layers.

Several mainframe and microcomputer programs are available to backcalculate the layer moduli if the load, surface deflections, layer thicknesses, and Poisson's ratios are known. Some of the available backcalculation programs are BISDEF, ELSDEF, CHEVDEF, and MODCOMP2.

Typically, many NDT readings would be available for each pavement section. For a uniform pavement section, only a few backcalculation processes are needed. The question that arises is which NDT readings to use in backcalculation out of the many available data. Two methods are usually used: to select a "representative" reading or to use the average of all

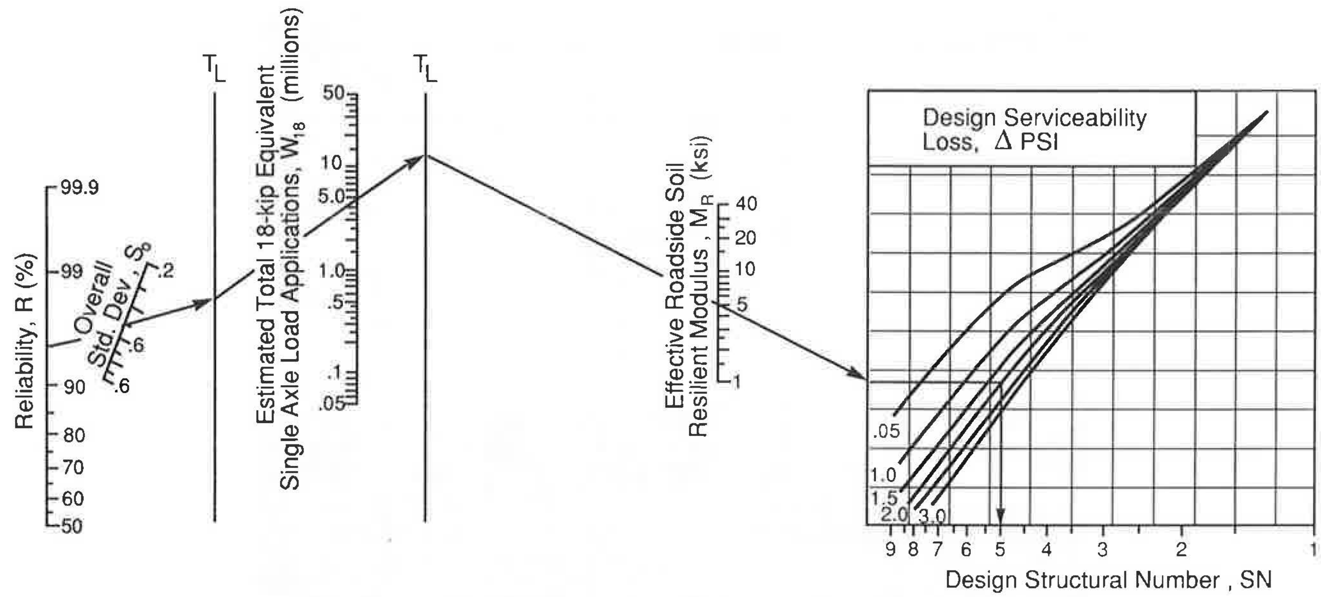

FIGURE 3 Design chart for flexible pavements based on using mean values for each input (AASHTO, Fig. II, 3.1).

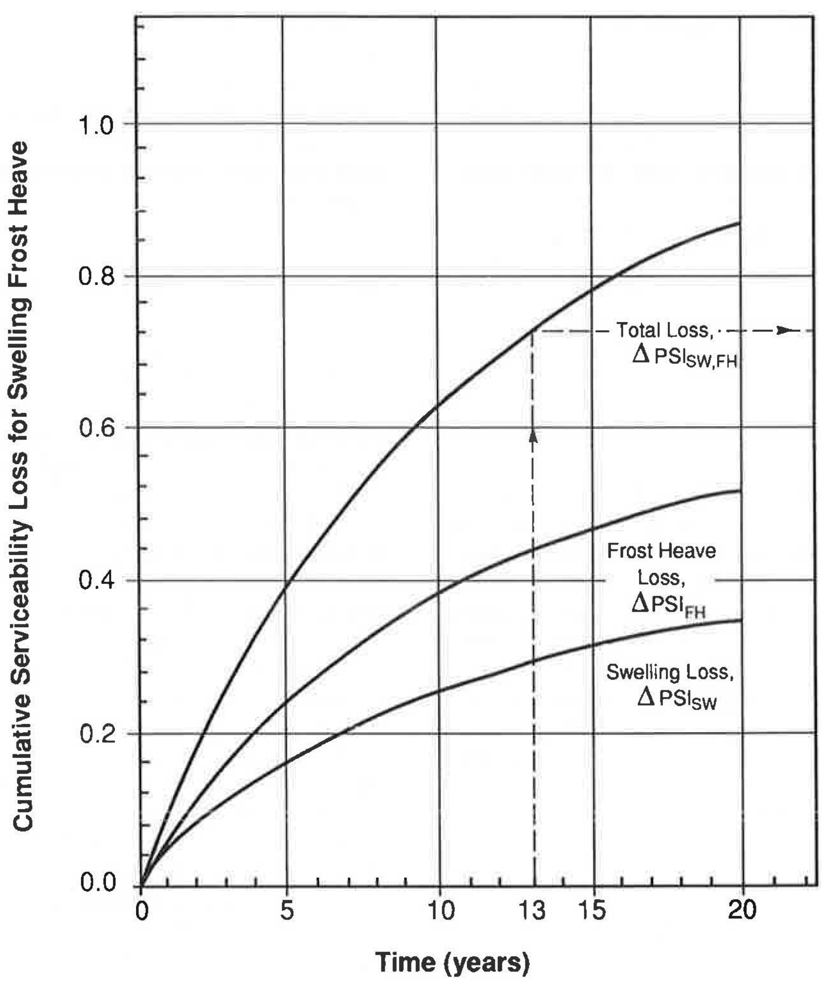

FIGURE 4 Conceptual example of the environmental serviceability loss versus time graph that may be developed for a specific location (AASHTO, Fig. II, 2.2).

readings for each geophone. The first method is recommended since the latter might result in an unreasonable deflection basin. Note that the less uniform the pavement section is, the more backcalculations would be needed. In this case, the designer should satisfy the weak spots as well as possible depending on the amount of reliability needed.

Resilient modulus lab testing can also be performed to verify the results of nondestructive testing.

Since asphalt is highly temperature-susceptible, it is important to correct (normalize) either the NDT readings or the backcalculated moduli of asphalt-bound layers to a standard temperature. The AASHTO Guide includes two procedures for correcting either the first deflection reading at the load center or the moduli of asphalt-bound layers. Correcting the deflection reading seems to be more empirical and applicable to plate-loading devices such as the FWD.

Once the layer moduli of the existing pavement structures are determined, the designer can determine the type of rehabilitation needed; if overlay is needed, its thickness can be determined.

Overlay Design

The procedure of overlay design consists of seven steps, as summarized below:

1. The rehabilitation project has to be subdivided into statistically homogenous pavement units possessing uniform pavement cross-section, subgrade support, construction histories, and subsequent pavement conditions.

2. Figure 5 shows the relationship between serviceability/structural number and traffic. The cumulative 18-kip ESAL repetitions (y) that will be applied in the design lane along the pavement section during its design life need to be estimated.

3. The material properties of existing pavement layers, subgrade, and overlay need to be evaluated. The NDT readings can be used to obtain the elastic moduli of the existing pavement layers and subgrade as discussed earlier. Limited destructive testing/sampling is encouraged to provide spot verification of the backcalculated moduli.

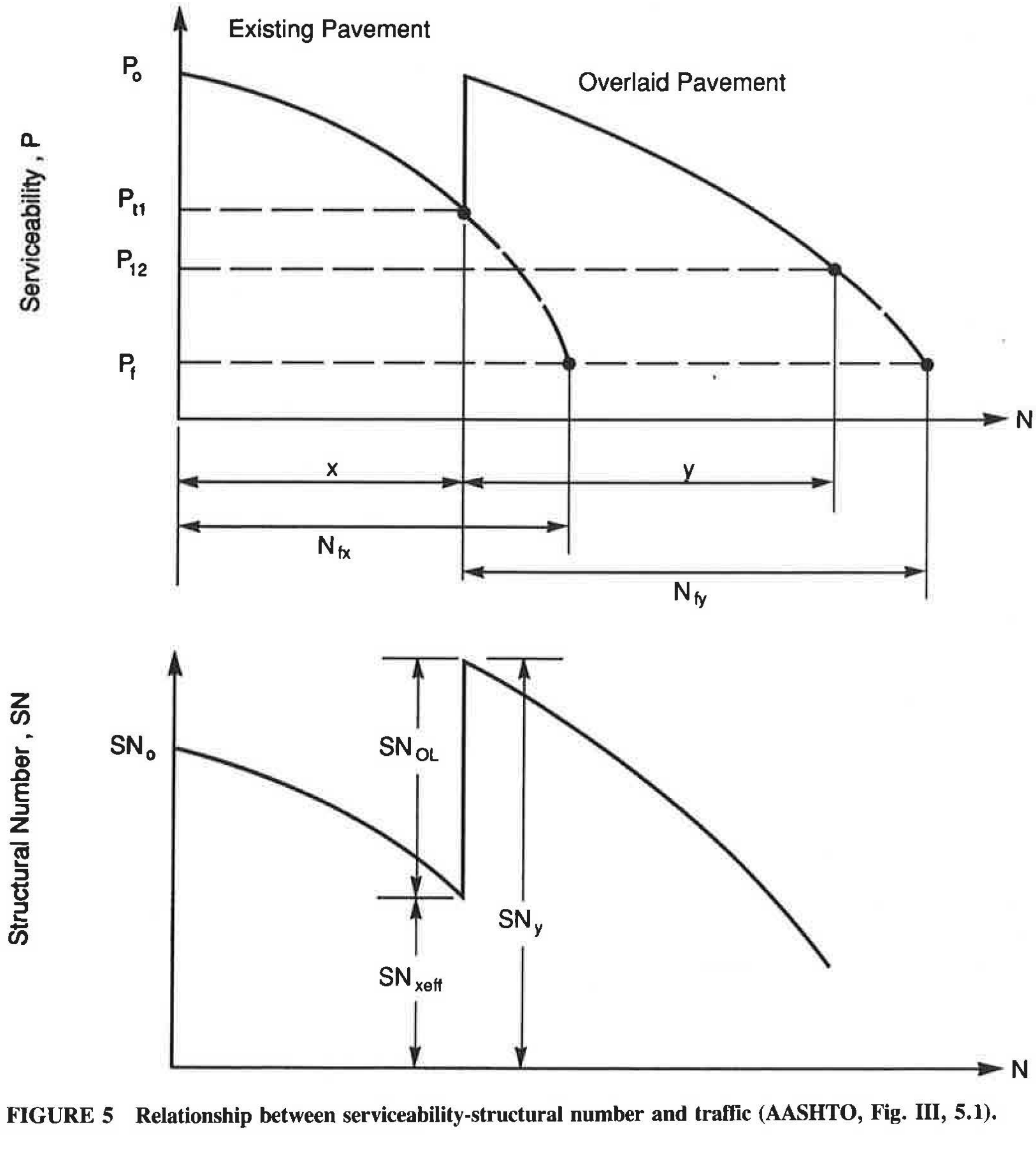

FIGURE 5 Relationship between serviceability-structural number and traffic (AASHTO, Fig. III, 5.1).

4. The effective (in situ) structural number (SN_{xeff}) needs to be determined as follows:

$$SN_{xeff} = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

where

a_1, a_2, and a_3 are the layer coefficients of surface, base, and subbase;

D_1, D_2, and D_3 are the layer thicknesses; and

m_2 and m_3 are the drainage coefficients.

5. The required structural number of the overlaid pavement (SN_y) is determined according to the procedure used for the design of new pavements shown in Figure 3.

6. The remaining life factor (F_{RL}) is an adjustment factor applied to the effective structural number (SN_{xeff}) to reflect a more realistic assessment of the weighted effective capacity during the overlay period. This factor is dependent upon the remaining life factor (percent) of the existing pavement before overlay (R_{Lx}) and the remaining life factor (percent) of the overlaid pavement system after the overlay traffic has been reached (R_{Ly}). As a consequence, both of these values (R_{Lx} and R_{Ly}) must be determined.

Five possible methods are available in the guide to determine R_{Lx}, depending on the available data. R_{Ly} can be determined by knowing both the expected 18-kip ESAL applications on the overlay until failure using Figure 3 and the expected 18-kip ESAL applications on the overlay until the time of the next overlay.

7. The required overlay thickness, h_o, is determined from:

$$h_{ol} = \frac{SN_y - F_{RL}\, SN_{xeff}}{a_{ol}}$$

where

SN_y = structural number of overlaid pavement (Step 5),
F_{RL} = remaining life factor (Step 6),
SN_{xeff} = effective (in situ) structural number (Step 4), and
a_{ol} = structural coefficient of the overlay material.

Life-Cycle Cost Analysis

Information has been added in the new AASHTO Guide relative to economic analysis and economic comparisons of alternate designs based on life-cycle costs. The objective of the life-cycle cost analysis is to achieve the maximum economy within a project. For example, should the pavement be designed to last for 10 years and then overlaid afterward or for only 7 years before the next overlay (see Figure 6)? Obviously, the first strategy (10-year life) requires larger pavement thickness and consequently larger initial construction costs than the second strategy (7-year life). On the other hand, the second strategy will require earlier resurfacing, earlier traffic control during resurfacing, and more frequent time delays for users, and it may entail more maintenance costs. The choice between these two alternatives and others should depend not only on the initial construction cost but on all costs (and benefits) that are involved in provision of the pavement during the analysis period.

There are several methods of economic analysis that can be used to compare alternatives. One of the common methods is the present worth method; it compares alternatives after discounting all future costs to their present worth using an appropriate discount rate.

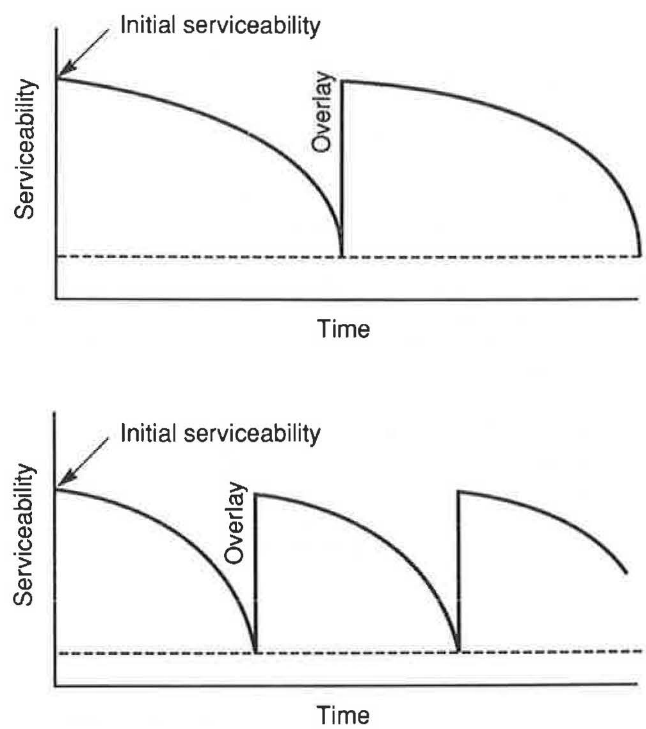

FIGURE 6 Performance curves for two initial pavement structural sections and subsequent overlay strategy alternatives.

OBSTACLES FACING SMALL AGENCIES AND POSSIBLE SOLUTIONS

Several obstacles exist that make implementation of the new AASHTO Guide difficult for some highway agencies, especially at the city and county levels. Some of these obstacles are discussed in the following sections.

Nondestructive Testing (NDT) Equipment

Some highway agencies at the city and county levels do not own any NDT devices, while others own Benkelman beams or Dynaflects. Obviously, Benkelman beams are obsolete, while Dynaflects apply light loads with a specific frequency that do not match the load applied by heavy trucks. Very few cities or counties, if any, own FWDs.

The fact that FWD devices are not available should not prevent cities and counties from using the concepts in the new AASHTO Guide. The Dynaflect results, if available, can still be used to backcalculate the layer moduli with reasonable accuracy. Typical material properties and correlation from previous experience can also be used in lieu of NDT.

Laboratory Resilient Modulus Testing

The new AASHTO Guide calls for some asphalt concrete, base/subbase, and subgrade resilient modulus testing according to ASTM D4123 and AASHTO T274 procedures. Since these tests are very sophisticated and require a great deal of experience, most cities and counties do not have the test equipment or the personnel qualified to perform these tests.

One of the solutions to this problem is to contract some tests on typical local materials to commercial labs. Correlations provided in the guide or other correlations developed by research agencies can also be used to estimate the material modulus from the results of other commonly used tests, such as *CBR* and *R*-value tests.

It should be noted, however, that the correlations available in the AASHTO Guide and in other references between the resilient modulus and other material properties are generally poor. The main reason for these poor correlations is that each test measures a specific material property, and different properties of the same material may not be well correlated. For example, Marshall stability and flow values are empirical parameters related to the resistance of the asphalt concrete material to deformation under certain temperature and loading conditions, while the diametral resilient modulus (ASTM D4123) is a measure of the elastic stiffness of the material under different conditions. Likewise, the *CBR* value is an empirical measure of the ratio of penetration resistance of the soil to that of a standard rock material under specific conditions, while the triaxial resilient modulus (AASHTO T274) is a measure of the elastic stiffness under certain confining and deviator stresses. Trying to correlate these properties may be like trying to correlate the color of a material with its strength. In a few cases, reasonable correlations might be obtained, but in most cases the correlations would be poor.

Backcalculation of Moduli

There is no "closed-form" solution to calculate the layer moduli of a multilayer pavement system if the surface deflections and layer thicknesses are known. Therefore, an inverse or "backcalculation" process is commonly used in which initial layer moduli are assumed and an iteration process is used to adjust these moduli until the computed deflections match the measured deflections. This process is an "ill-conditioned" problem in which no unique solution is guaranteed. Thus, any error in deflection measurements or in load and system modeling (i.e., static load, linear elastic isotropic behavior, and assumed Poisson's ratio) is magnified and reflected in the results. Also, self-compensation among layer moduli may develop, which may result in several possible solutions.

Another problem with backcalculation of moduli is the assumption of a homogeneous semi-infinite subgrade in some cases or a bedrock (or rigid layer) at a specific depth. Actual conditions in the field may not exactly match one of these two extreme cases. The stiffness of the subgrade material usually increases with depth, with no consistent trend. Thus, the backcalculation process results in an "equivalent subgrade modulus" if a semi-infinite subgrade is assumed or an "equivalent subgrade/bedrock modulus" if a bedrock is assumed at a specific depth. This difference between the actual and the idealized backcalculation cases explains the disagreement found between the laboratory-obtained subgrade modulus and the backcalculated subgrade modulus in many cases. The lab modulus represents the subgrade modulus at a specific depth, while the backcalculated modulus represents a weighted average subgrade modulus. These two moduli may not necessarily be the same in most cases.

Until the problems associated with backcalculation are solved, the design engineer should use the backcalculation results as rough estimates and may modify them if they are unreasonable.

Need for Training and Engineering Judgment

The transition between the old and new guides is not expected to be sudden. Design personnel must practice use of the new guide and design a number of projects using both guides to understand the difference between the two design concepts.

It should be noted that the pavement design process is in a continuously evolving process. Some problems still exist that are beyond the ability of current pavement literature. For example, the resilient modulus is not always well correlated to other material properties, the backcalculation process is not always accurate, and temperature correction is not very accurate. Therefore, the new guide should not be treated as a "black box" or a "cookbook" that can be applied without thinking. Engineering judgment and previous experience are always needed to guarantee sound engineering designs.

CITY OF PHOENIX EXPERIENCE

A study has been performed by the authors at Arizona State University for the City of Phoenix to simplify the 1986 AASHTO Guide for its direct use by city personnel. The City of Phoenix covers a large road network ranging from principal arteries to local streets. Previously, the city's personnel followed the old (1981) version of the AASHTO Guide in the design of city streets (*2*).

The study included selection of typical flexible pavement sites, Dynaflect testing, material sample acquisition, laboratory resilient modulus testing, and backcalculation of layer moduli. A report simplifying the AASHTO Guide for local use and a final report presenting the study results have been prepared (*3,4*).

The first step in the study was to consider specific conditions in Phoenix, such as the following:

1. No freeze or thaw develops;
2. Swelling of soils is neglected;
3. The Dynaflect is currently the only available deflection device;
4. Resilient modulus equipment for asphalt concrete and soil is not available; and
5. The in situ moisture content of the subgrade is close to the optimum moisture content and is fairly constant throughout the year unless an external problem exists, such as a leaking irrigation ditch or broken water line.

Computer Programming

Four microcomputer programs have been developed to solve several AASHTO equations using the Lotus spreadsheet program. These computer programs can be used to determine the required structural number, the cumulative ESAL until failure, and the required overlay without the need for nomographs.

Development of NDT and Backcalculation Strategy

A strategy was developed for using the available Dynaflect to evaluate the structural condition of existing pavements. Two computer programs were recommended to backcalculate the moduli: CHEVDEF (mainframe) and ELSDEF (microcomputer) (*5*). Typical pavement sections have been tested, and moduli have been estimated. A set of rules and guidelines has been developed to be followed by city personnel in running the programs.

Resilient Modulus Soil Testing

Eight soil samples were tested for resilient modulus at Arizona State University, according to the AASHTO T274-82 test procedure. City personnel provided the disturbed soils, which were taken from five bore holes at 75th Avenue (B-5, B-7, B-9, B-12, and B-15). Five samples (one from each bore hole) were compacted in the lab, matching 95 percent of the maximum dry density (AASHTO T99) and the optimum moisture content. Each sample was compacted in ten layers to guarantee uniform density. After the test was completed, both density and moisture content were determined in the lab to compare the actual with the target values. The other three samples were taken from bore holes B-5, B-9, and B-15 and were compacted in a saturated condition to match the density and the moisture content of the *R*-value test samples. Figure 7 shows a typical example of test results.

Lab Moduli Versus Backcalculated Moduli and *R* Values

To determine the laboratory resilient modulus corresponding to the in situ condition, the octahedral normal stress and octahedral shear stress (*6*) in the field were computed using the Chevron program (*7*) at the top of the subgrade due to a load of 9000 lb. By matching both octahedral normal and shear stresses in the lab and field, the resilient modulus in the lab can be determined. Table 1 shows the lab moduli, backcalculated moduli, and *R* values. Note that the backcalculated moduli are in the in situ condition, while *R* values are at the saturated condition. No good correlations could be derived, mostly because of the small number of observations and because the resilient modulus and the *R* value are different and uncorrelated parameters.

Development of Typical Design Parameters for City of Phoenix

The 1986 AASHTO Guide includes a wide range of design parameters to cover all climatic, traffic, and material conditions. In this study, specific ranges of design parameters applicable to the City of Phoenix were recommended mostly through the experience of city personnel. Among these parameters

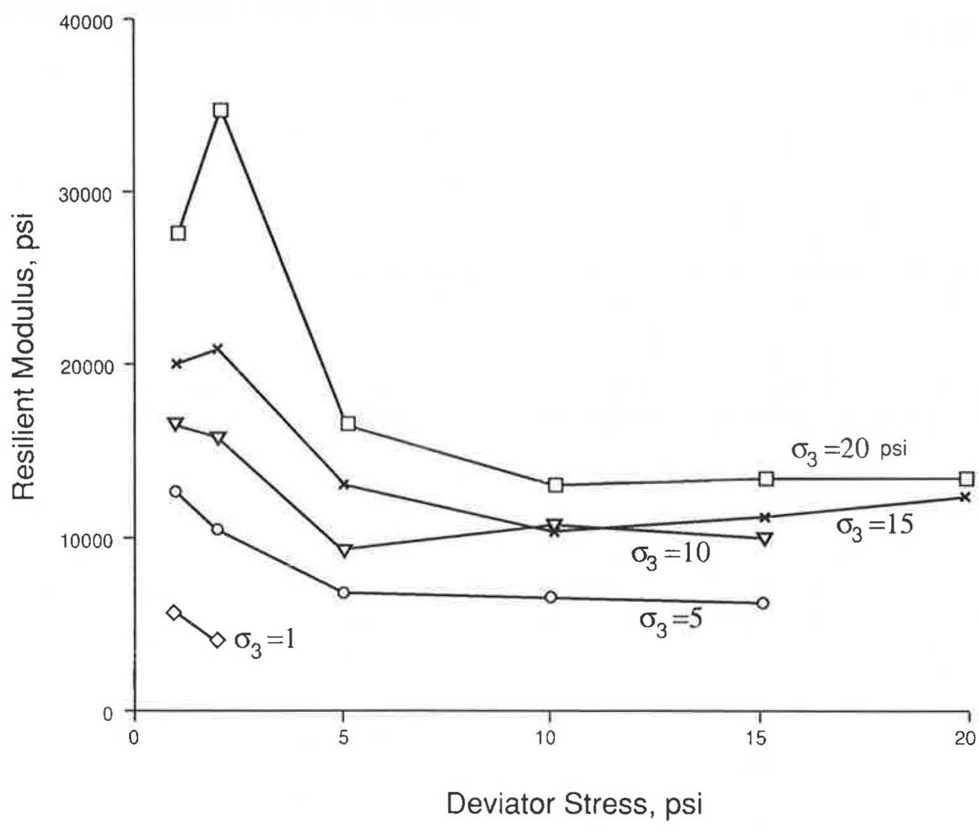

FIGURE 7 Typical resilient modulus test results on subgrade materials according to AASHTO T274 procedure.

TABLE 1 COMPARISON BETWEEN SUBGRADE LAB MODULI, BACKCALCULATED MODULI, AND *R* VALUES

Boring No.	Material Type	Condition	Lab E(ksi)	Back-calculated E(ksi)	R-Value
5	SM	In-Situ	25	19	--
		Saturated	21	--	55
7	SM	In-Situ	24	23	--
		Saturated	--	--	24
9	SM	In-Situ	16	30	--
		Saturated	25	--	38
12	ML	In-Situ	8	19	--
		Saturated	--	--	17
15	ML	In-Situ	11	19	--
		Saturated	8	--	47

are reliability levels, overall standard deviation, lane distribution factors, structural layer coefficients, drainage condition coefficients, and minimum layer thicknesses, as discussed in the following paragraphs.

Reliability

To reduce the amount of risk in pavement performance, the City of Phoenix recommends the use of reliability levels of 95 percent for principal arteries, 90–95 percent for collectors, and 80 percent for local streets. Continuous monitoring of pavement conditions, together with the use of pavement management programs, is recommended for further optimization and refinement of these reliability levels. In addition, the City of Phoenix recommends, based on historical experience, a typical standard deviation of 0.4 for flexible pavements.

Traffic Analysis

The average daily traffic (ADT) for the design period is predicted by the city Streets and Traffic Department. The classification of vehicles is obtained from the weigh studies conducted by the Arizona Department of Transportation.

Effective Roadbed Soil Resilient Modulus

Based on historical data, it was found that the in situ moisture content of subgrade materials in Phoenix does not significantly change from one season to another; it remains fairly close to the optimum moisture content. In addition, the rainy season in Phoenix is very short. Therefore, it was recommended that the effective roadbed soil resilient modulus could be assumed to be equal to the resilient modulus measured at any time of the year. Following this recommendation significantly reduces the effort made in determining the effective modulus throughout the year.

It was also recommended that there is no current need for the city to acquire costly resilient modulus machines or an FWD device. In the future, when these devices are better established and less expensive, the city might consider obtaining them and training its personnel for their use.

Structural Layer Coefficients

If the elastic modulus and/or other material properties are known, the charts in the AASHTO Guide can be used to estimate the structural layer coefficients a_1, a_2, and a_3 for surface, base, and subbase materials, respectively. If no previous data are available, the City of Phoenix recommends the following structural coefficients:

Pavement Component	*Structural Coefficient*	*Range*
Plant-mixed asphalt concrete and recycled AC:		
3 in. or less	0.40	0.40–0.44
4 in. or more	0.42	0.40–0.44
Cement-treated base	0.27	0.15–0.29
Aggregate base	0.12	0.08–0.14
Select material	0.11	0.05–0.12

Drainage Coefficients

In Phoenix, the typical time during which pavement is exposed to moisture levels approaching saturation is less than 1 percent. Also, the quality of drainage varies from "excellent" to "good." Therefore, the m_2 and m_3 values vary from 1.25 to 1.40, as recommended by the AASHTO Guide.

Minimum Layer Thicknesses

Considering the specific climatic conditions and stop-and-go traffic in the city streets, the following are provided as minimum practical thicknesses for various pavement courses. (Note that in a CTB design 5-in. minimum aggregate base thickness is required.)

Pavement Component	Minimum Thickness (in.)
Major Streets	
Asphaltic concrete	5
Cement-treated base (CTB)	6
Aggregate base	4
Select material	4
All Other Streets	
Asphaltic concrete	2
Cement-treated base (CTB)	6
Aggregate base	4

Impact of the Use of the 1986 AASHTO Guide in Phoenix

On the basis of the preceding investigations, the City of Phoenix adopted the 1986 AASHTO Guide for the design of city's streets in August 1988. Since then a number of streets have been designed using this new design procedure. For the initial period pavement designs of the streets using both the new AASHTO 1986 and the old AASHTO 1981 procedures are being carried out. It has been determined that both designs are comparable for streets with coarse sand and gravel subgrades. For streets with silt and clay subgrades, however, the new designs result in a reduction in the required pavement thickness of approximately 15 to 20 percent. This difference is due mainly to the use of a rather conservative resistance *R* value to characterize the subgrade material when the old guide was used, whereas the soil modulus backcalculated from the Dynaflect test was used in the new guide. This indicates that the new guide may provide some saving in the initial cost of pavement materials when compared to the old guide as previously used by the city.

Also, since the new guide is based on more rational concepts than the old guide, it is believed that the new guide will provide better prediction of pavement performance than did the old guide.

CONCLUSIONS

Cities and counties that currently follow the old version of the AASHTO Guide can gradually adopt the 1986 guide for the design and rehabilitation of their streets. This paper provides guidelines and recommendations to simplify the task of design personnel in adopting the guide. Specific conditions that are locally applicable should be considered in order to reduce the scope of the guide. Training is needed by local designers to adopt concepts of the guide, such as use of NDT data, use of resilient modulus values, choice of reliability levels, and use of life-cycle cost analysis. Engineering judgment and previous experience are still needed to overcome obstacles that might arise at city and county levels.

ACKNOWLEDGMENTS

The authors would like to thank City of Phoenix personnel Syn Anderson and Dong-Chie Wong for their valuable input and assistance during the course of the project. The City of Phoenix is also acknowledged for its financial support of this study. Sincere thanks go to Masood Mirza, who performed the resilient modulus tests. Finally, thanks also go to the Center for Advanced Research in Transportation and the Department of Civil Engineering at Arizona State University for making their facilities available for this study.

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Publication of this paper sponsored by Committee on Pavement Management Systems.