Debunking Streetpave's Claim of an "Equivalent" Asphalt Design

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The American Concrete Pavement Association (ACPA) publishes and distributes a pavement design software program called Streetpave. The ACPA describes the program on the back of the CD-ROM jacket as follows:

"Streetpave is the latest in thickness design technology for streets and local road pavements. This software utilizes new engineering analyses to produce optimized concrete pavement thicknesses for city, municipal, county, and state roadways. It includes an asphalt cross-section design process (based on the Asphalt Institute method) to create an equivalent asphalt design for the load carrying capacity requirement…."

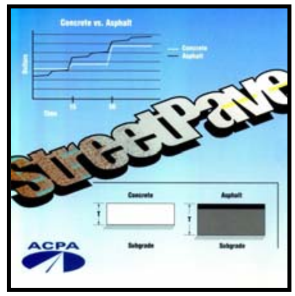

Figure 1—Streetpave

The CD-ROM jacket goes on to say:

"With one pavement design tool, you can design equivalent concrete and asphalt sections and evaluate the best possible solution(s) for your pavement needs."

The ACPA's claim that Streetpave is "based on the Asphalt Institute method" cannot be verified at this time. The Asphalt Institute (AI) pavement design methodology has been published and analyzed in numerous technical publications including our own manuals, so it is well within the realm of possibilities that Streetpave's programmers found a way to duplicate our design methodology inside the program. The purpose of this paper is not to challenge the basis of Streetpave's hot-mix asphalt (HMA) design calculations. That will be reserved for another effort.

Rather, this paper will take issue with the ACPA claim that it offers an "equivalent" asphalt section to compare to a concrete pavement section. Twice on the CD-ROM jacket and within the program itself, the ACPA claims that its software creates "equivalent" pavement designs for concrete and asphalt sections based on the load carrying capacity. If this were true, it would indeed be a powerful way to compare competing pavement sections.

The problem with this claim is that it is demonstrably false. As will be shown in the paragraphs that follow, the ACPA's Streetpave software deliberately reduces the user's design input for subgrade strength prior running the asphalt pavement design calculation. The result is that HMA designs are calculated to be thicker than necessary. Thicker HMA sections are more costly than standard sections, which gives the concrete section an advantage when Streetpave presents the user with a false comparison between its concrete section and a thicker-than-necessary HMA section.

The Asphalt Institute Design Method

In order to understand the manipulation that occurs within Streetpave, we must first review some the design principles that underpin the Asphalt Institute thickness design procedure, specifically *MS-1*, *Thickness Design—Asphalt Pavements for Highways and Streets* and *SW-1, Asphalt Pavement Thickness Design Software for Highways, Airports, Heavy Wheel Loads and Other Applications.* These design principles are detailed in *Research Report RR-82-2, Research and Development of the Asphalt Institute's Thickness Design Manual (MS-1) Ninth Edition.*

Of particular interest in the present discussion is the AI method for characterizing subgrade strength and handling variability in sampling and testing. First, subgrade strength is defined by its Design Subgrade Resilient Modulus, M_r. The engineer selects the Design Subgrade M_r and uses this value to enter the design curves in MS-1 or the input box on the Subgrade screen in SW-1.

For highways and streets, the Design Subgrade M_r is defined as the modulus value that is less than 60, 75, or 87.5 percent of the test values (see Table 1).

Table 1—Recommended Subgrade Design Values for Highways and Streets

Pavement Use	Traffic Level	Design Subgrade Value, Percent
Highways, Roadways, and Streets	10^4 ESALs or less	60
	Between 10^4 and 10^6 ESALs	75
	10^6 ESALs or more	87.5

Secondly, on the topic of variability as it relates to sampling and testing, MS-1 states:

> "Individual subgrade test values (six to eight tests) are used to find a Design Subgrade M_r. For any given set of test values, M_r should be selected as the traffic varies. If a high volume of traffic is anticipated, M_r is adjusted to a lower value than if a low volume is expected. This is done to ensure a more conservative design for a larger traffic volume."

In other words, the AI method is founded on the understanding that numerous data points are used to determine the Design Subgrade M_r. By requiring 6-8 test values and assuming that the data is normally distributed, the user can reliably select the Design Subgrade M_r and conduct a pavement design with confidence.

The exact statistical approach that underpins these methods is spelled out in RR 82-2, where it describes that this method is based on an analysis of three populations of subgrade test data. These normally distributed data sets had mean resilient modulus values of 10,050 psi, 19,950 psi, and 30,000 psi, all at a coefficient of variation of 30 percent. By examining the "limit of accuracy" of these subgrade data sets, the researchers determined that when 6-8 data points were available, a 95 percent confidence level was achieved when selecting the Design Subgrade M_r.

In summary, input data in the AI method is assumed to be reliable and no further statistical analysis is required. Graphical and computational methods are provided in MS-1 and SW-1, respectively, to handle individual test data and allow the user to determine the final subgrade input to be used in the pavement design. Because of the understood reliability of the input data, once selected by the engineer, the Design Subgrade M_r is not altered in the AI methods.

A Brief Description of Streetpave

Streetpave consists of six screens that are used to input data calculate pavement thickness, and estimate life cycle costs. The six screens are listed below:

- Project
- Traffic
- Pavement Properties
- Existing Pavement Analysis
- New Pavement Analysis
- Life Cycle Cost

In order to complete an "equivalent" asphalt design, the user must select the check box entitled "Determine Equivalent Asphalt Thickness" on the Project screen. By doing this, Streetpave activates the asphalt design module located on the right sides of the Pavement Properties and New Pavement Analysis screens. On the Project screen the user also enters the design life and the desired level of reliability for the project.

Note: Desired level of reliability is entered in the ACPA concrete pavement design method to account for variability. Variability is treated in different manner in the AI method, as discussed in the previous section. Consequently, the reliability input is not necessary, nor recommended, nor useful in the AI method.

Once this is done, the user can input traffic information in the form of average daily traffic (ADT) with percent trucks or average daily truck traffic (ADTT) on the Traffic screen.

It is on the Pavement Properties screen where the user enters a single value used to characterize subgrade strength in the form of a resilient modulus. There is also an input box for coefficient of variation (COV) that contains a default value of 38 percent. This value can be changed. The third input on the Pavement Properties screen is to select the Design Type from three choices: full-depth asphalt, HMA over a 6-inch granular base, and HMA over a 12-inch thick granular base course.

How Streetpave Manipulates Users' Subgrade Strength Inputs

On the Streetpave Pavement Properties screen for asphalt design, the user will see three input boxes: subgrade M_r, coefficient of variation (COV), and design type. Resilient modulus and design type are relatively straightforward. What is out-of-place on this asphalt design module is the input for COV.

Essentially, Streetpave applies a reliability calculation to reduce the input for subgrade M_r, ignoring the fact that the AI method specifies the Design M_r as the subgrade input. Streetpave uses the COV and the z-score (based on the user-defined level of reliability) to automatically reduce the user's entry for Subgrade M_r using the following equation:

$$\text{Design } M_r = \text{User-entered } M_r - (\text{COV} \times Z_R)$$

Note: In the equation above, Streetpave incorrectly defines the term Design M_r. We already know from an earlier discussion that the Design Subgrade M_r is defined in the AI methods based on a statistical analysis of 6-8 individual test values.

For example, if a pavement designer has determined that the Design Subgrade M_r is 3,000 psi, he or she might enter that value on the Pavement Properties screen in Streetpave (see Figure 3). Unbeknownst to the user, unless he or she views the companion help screen, Streetpave uses the COV (default value is 38 percent) to reduce the Design Subgrade M_r to 1,818.5 psi, a drop of 39 percent (see Figure 4).

There are at least two problems with this approach. First, it does not conform to the Asphalt Institute procedure, which requires a Design Subgrade M_r input. Remember that the AI procedure assumes that variability has already been accounted for by using either a graphical or computation statistical determination using 6-8 data points and the Design Subgrade Value shown in Table 1. There is no need to further adjust the Design Subgrade M_r.

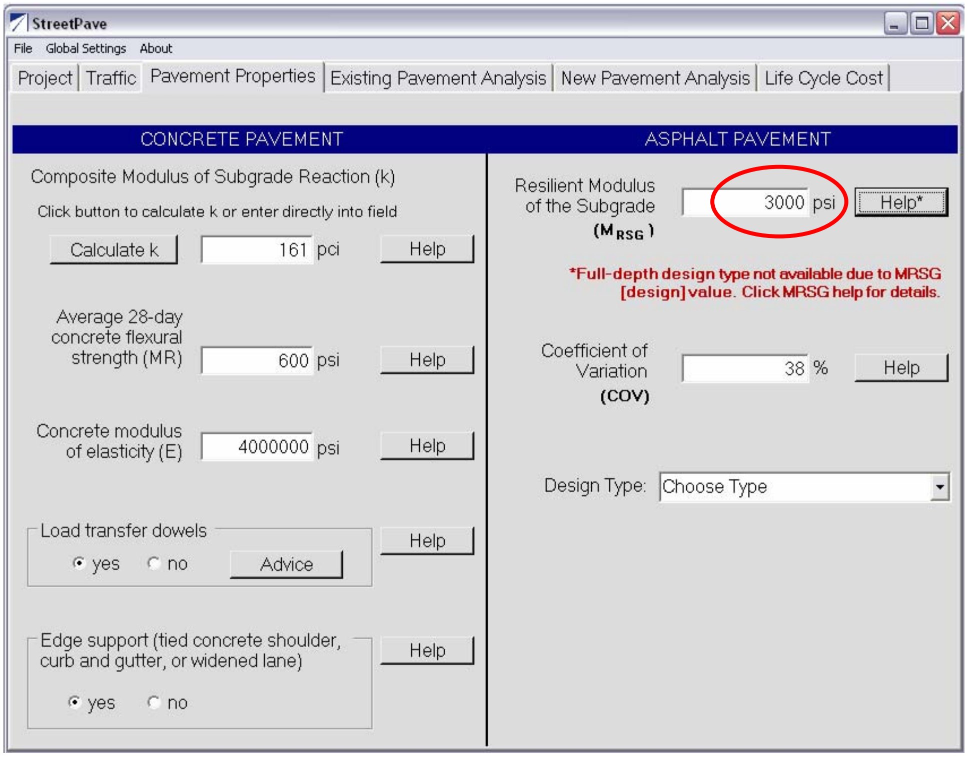

Figure 2—User inputs 3,000 psi for Design Subgrade M_r

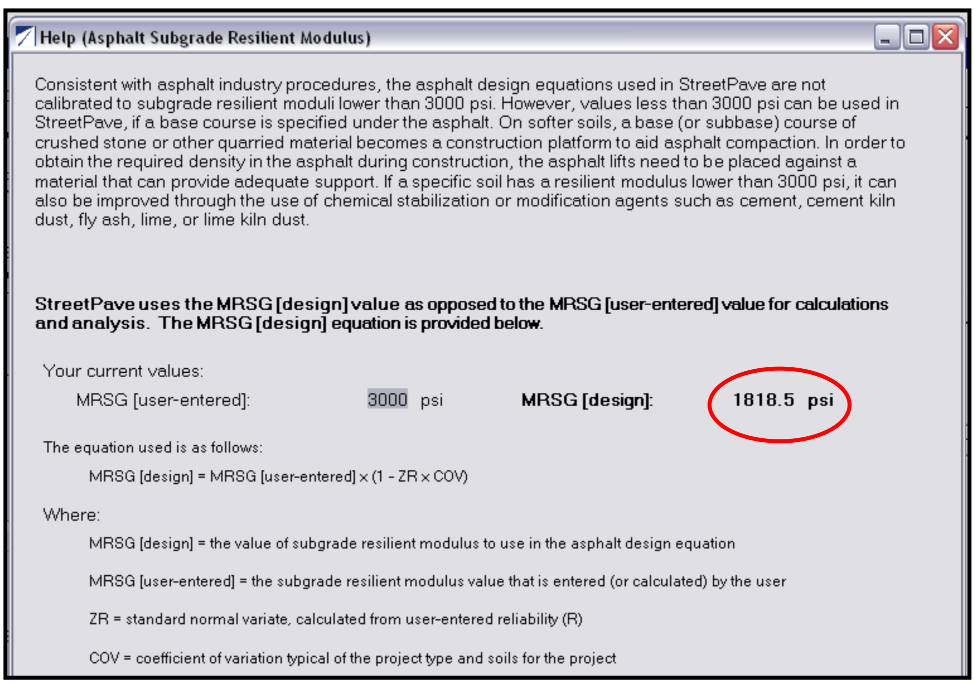

Figure 3—Streetpave Reduces Design Subgrade M_r to 1,818.5 psi using hidden reliability calculation described on secondary help screen

The second problem is the "behind-the-scene" nature of the reduction in subgrade strength. If the user does not access the help screens pertaining to these procedures, he or she may not be aware that the Design Subgrade M_r has even been reduced! It is interesting that the ACPA provides this procedure on a secondary help screen that is out of the view of the user.

In summary, by covertly applying reliability concepts to the Design Subgrade M_r input value, Streetpave reduces the subgrade input value in preparation for running asphalt pavement design calculations. By forcing the use of this calculation, Streetpave is essentially applying a factor of safety upon the inherent factor of safety in the AI method.

A Comparison of "Equivalent" Asphalt Sections—Streetpave vs. SW-1

Perhaps the best way to reveal the problem with Streetpave is to apply it to its own examples. In a recent ACPA marketing brochure, Streetpave is used to design "equivalent" concrete and asphalt pavement sections for three applications: a residential street, a collector street, and a minor arterial. In the following pages, we will show how SW-1 and Streetpave use the same input values to arrive at different results in all three cases.

<u>Residential Street</u>
2-lane street
MAAT = 45ºF
M_r = 3,000 psi
ESALs = 11,500
Granular base
thickness = 6 inches

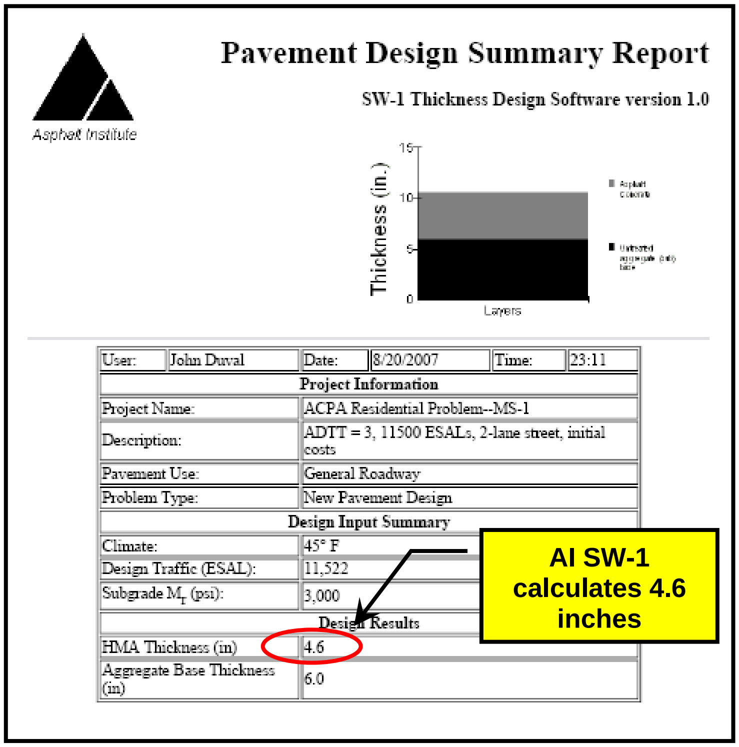

Figure 4—AI SW-1 Report for Residential Street Design

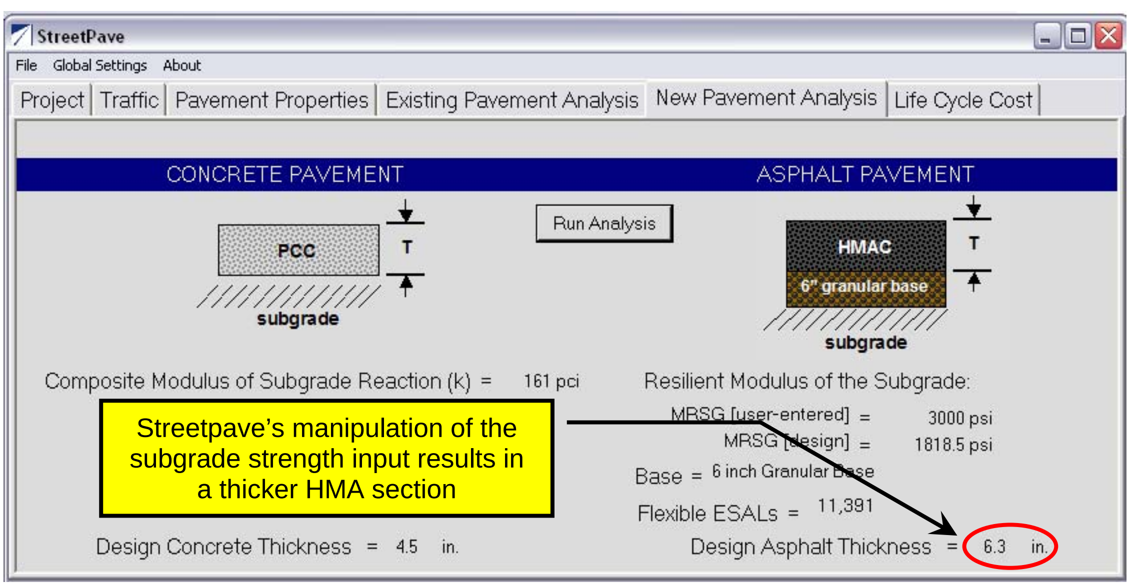

Figure 5—Streetpave Calculates a 6.3 inch HMA Section

For the residential street, Streetpave calculates that the "equivalent" HMA section is 6.3 inches, 1.7 inches greater than the 4.6 inch layer calculated by SW-1. This is not a trivial example because 1.7 inches represents **a 37 percent increase in thickness** over the actual equivalent section calculated by SW-1.

Collector Street:
2-lane with curbs
MAAT = 45ºF
M_r = 3,000 psi
ESALs = 405,000
Granular base
thickness = 6 inches

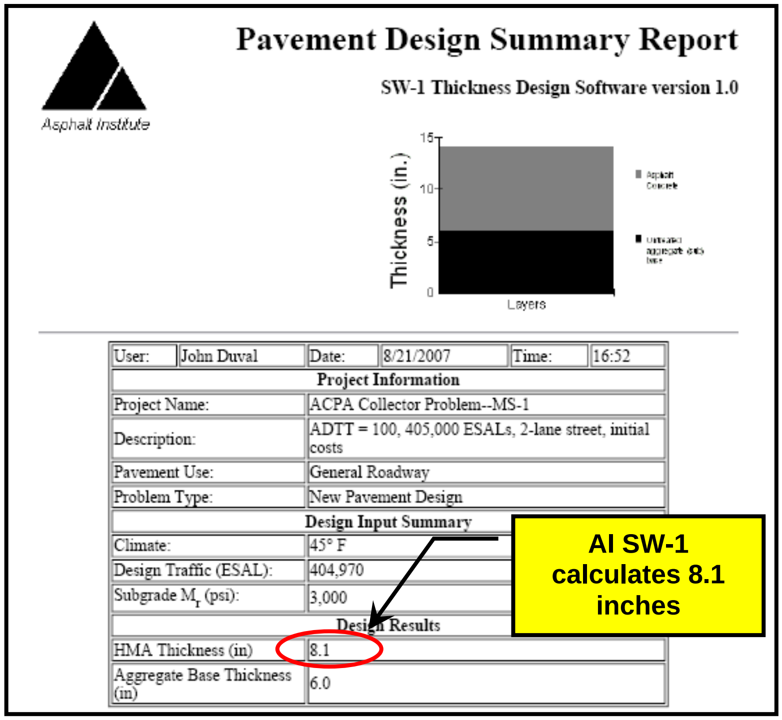

Figure 6—AI SW-1 Report for Collector Street Design

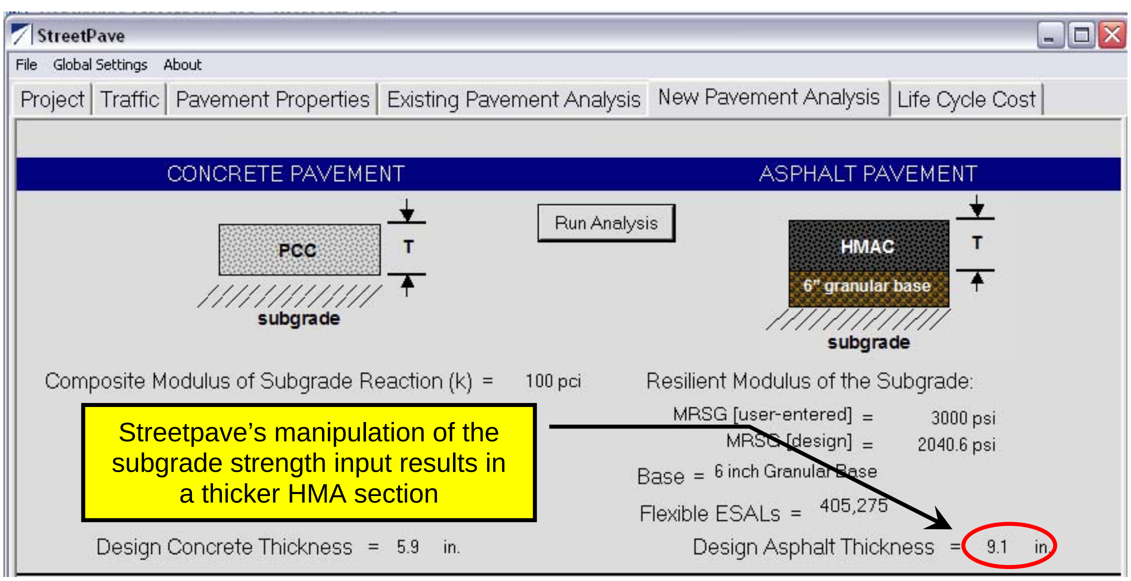

Figure 7—Streetpave Calculates a 9.1 inch HMA Section for Collector Street

For the collector street, Streetpave calculates that the "equivalent" HMA section is 9.1 inches, 1.0 inch greater than the 8.1 inch layer calculated by SW-1. This amounts to **a 12 percent increase in thickness** over the actual equivalent section calculated by SW-1.

Minor Arterial Street:
2-lane with curbs
MAAT = 45ºF
M_r = 3,000 psi
ESALs = 405,000
Granular base
thickness = 6 inches

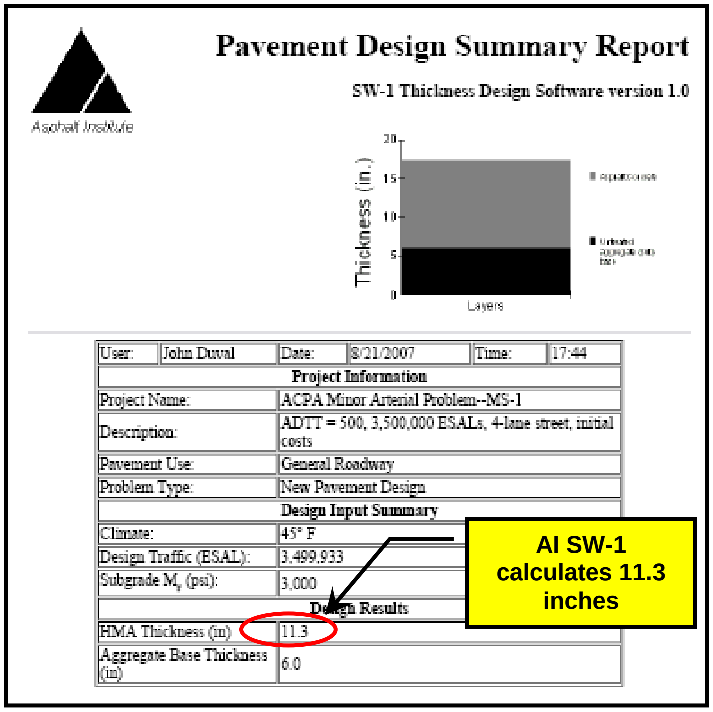

Figure 8—AI SW-1 Report for Minor Arterial Street

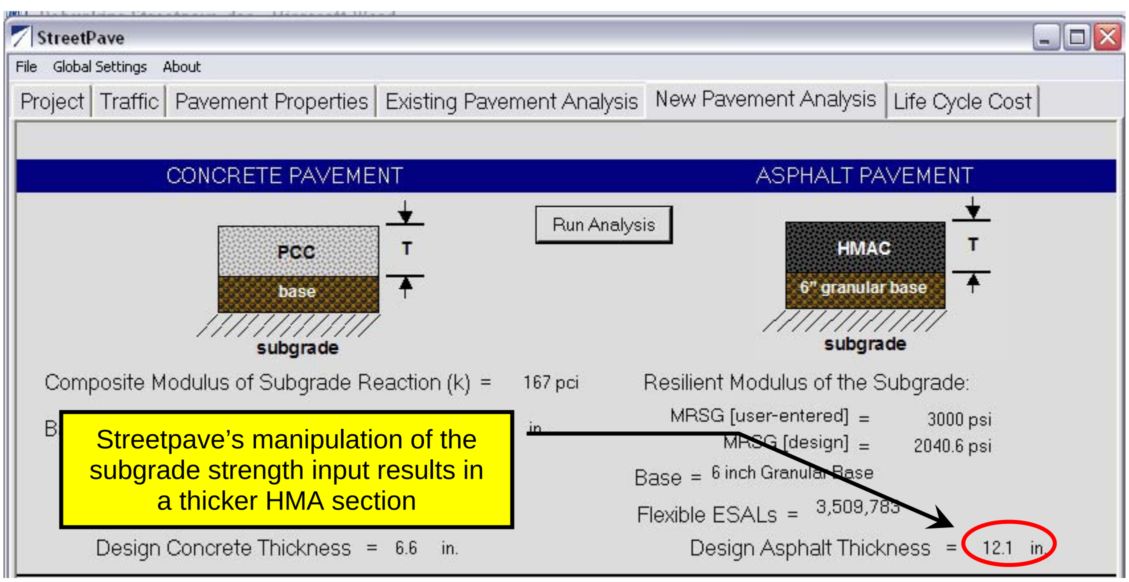

Figure 9—Streetpave Calculates a 12.1 inch HMA Section for Minor Arterial Street

For the minor arterial street, Streetpave calculates that the "equivalent" HMA section is 12.1 inches, 0.8 inch greater than the 11.3 inch layer calculated by SW-1. This amounts to **a 7 percent increase in thickness** over the actual equivalent section calculated by SW-1.

Summary and Conclusions

A summary of the results is shown in Table of this comparative analysis of the designs used in the ACPA marketing brochure

Table 2—Comparison Between SW-1 and Streetpave Design Calculations

	Resilient Modulus	Residential	Collector	Minor Arterial
SW-1	3,000 psi	4.6 in	8.1 in	11.3 in
Streetpave	1,818.5 psi	6.3 in	9.1 in	12.1 in
Percent Difference	- 39 %	37 %	12 %	7 %

A comparison of the results in Table 2 shows that Streetpave's inappropriate reduction of the Design Subgrade M_r value consistently results in overly thick asphalt pavement sections compared to the bona fide Asphalt Institute designs. The result is more alarming for the residential street application where Streetpave resulted in an HMA section that was 37 percent thicker than the AI designed section. As the pavement sections became thicker for the collector and minor arterial applications, the Streetpave still designed overly-thick pavement sections, but the percentage difference between Streetpave and SW-1 fell to 12 percent and 7 percent for collectors and minor arterials, respectively.

These examples show that the ACPA Streetpave software consistently errs by reducing the Design Subgrade M_r input in the asphalt design calculations. Users may not be knowledgeable enough about asphalt pavement design to recognize that Streetpave's process is nonstandard. They may not realize the impact of this error in designing overly thick asphalt pavement sections.

In this paper we have shown that the ACPA Streetpave software does not design an "equivalent" asphalt section based on its load carrying capability. Rather, Streetpave's asphalt designs are thicker than those accomplished using a bona fide Asphalt Institute design method.

We can conclude that the Streetpave software is seriously flawed and cannot produce reliable asphalt pavement section thicknesses. Furthermore, it is clear that the ACPA's claim of comparing the "equivalent" asphalt design is plainly false.

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