WISCONSIN ASPHALT PAVEMENT ASSOCIATION

TECHNICAL BULLETIN

CONTENTS

Common Wisconsin practice . . . 1
Causes of poor performance 2
WAPA's design proposal 2
Design methodology 3
Design parameters 3
Recommended designs 5

Subdivision Street Design

This document addresses design and construction practices for asphalt pavements in new residential subdivisions. It presents the following guidance and information:

→ A discussion of a common practice in Wisconsin and why it sometimes results in poor pavement performance and premature deterioration.

→ Wisconsin Asphalt Pavement Association's alternative design approach based on widely accepted design techniques and a recognition of real-world pavement loading conditions and soil types.

→ WAPA's design recommendations.

Common Wisconsin practice

Asphalt is commonly selected for paving the roads in residential subdivisions. A well-designed residential asphalt roadway consists of a subgrade layer, a base layer of unbound aggregate and two asphalt lifts—a thicker binder layer of asphalt and a thinner (typically 1½-inch) surface layer of asphalt.

In new neighborhood developments, a common practice in Wisconsin is to construct but not complete asphalt pavement roadways when the development of a neighborhood subdivision begins. Instead, a **staged approach** is used. The developer will construct a partially completed asphalt pavement at the start of development. This first-stage pavement (Figure 1) will typically have a binder asphalt layer of approximately 2½ inches, but it will not yet have the final 1½-inch surface asphalt layer (Figure 2).

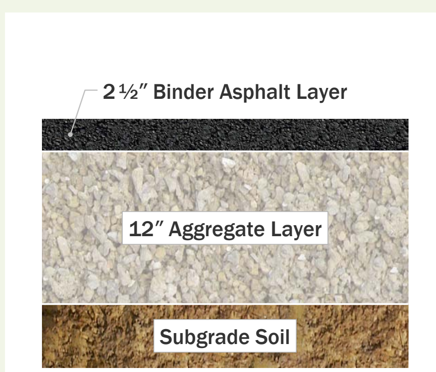

Figure 1 First-stage asphalt pavement used at the start of a subdivision project

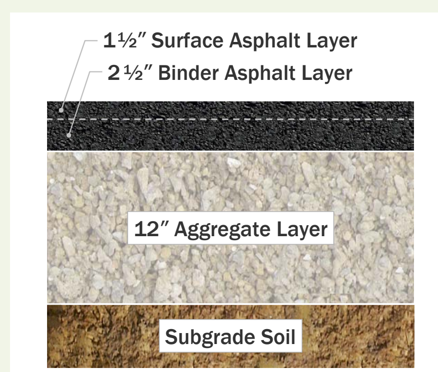

Figure 2 Completed standard 4-inch asphalt pavement

Home construction vehicles and early subdivision residents alike drive on these temporary partially completed roads. Typically after 50 percent to 70 percent of the homes have been built in the subdivision, the pavements will be completed with the construction of the surface layer of asphalt.

The significant perceived benefit of this practice is that it provides a new, smooth surface after most of the residents have moved into a neighborhood. It will cover any blemishes and nonstructural surface damage caused by construction equipment. Moreover, this practice helps defray initial costs for developers until they can generate income from home sales in the development.

Figure 3 A binder layer showing fatigue distress, which results from a first-stage pavement structure that is underdesigned for the loading conditions

Figure 4 This pavement remains incomplete. The surface layer was never built, even after all of the subdivision lots were developed.

Causes of poor performance

This practice of staged pavement construction only works when two important conditions are satisfied:

- → Traffic loading on the binder layer **does not exceed the fatigue limit of the roadway structure**.
- → The time between the placement of the binder layer and the surface layer **does not exceed two years**.

In reality, it is often impossible to meet both of these conditions. Heavy vehicles used in home construction consistently exceed the binder layer structure's fatigue limit, which results in cracking and pavement distortion in the binder layer (Figure 3). A surface layer constructed on a distressed binder layer will suffer from compromised performance.

In addition, slow residential development in the current economy has extended the time between placement of a binder layer and surface layer. As this delay stretches beyond two years, the likelihood of poor performance of the surface layer increases.

Beyond these challenges, it has also been known to happen—given the realities of the home development industry—that the final surface layer is never even constructed. The binder layer, already distressed from heavy vehicle loading, becomes the final and permanent driving surface (Figure 4).

These outcomes all suggest, incorrectly, that asphalt pavement is not up to the job. In fact, asphalt remains very well suited for residential pavements. An adjustment to the pavement design approach is needed.

WAPA's design proposal

Minor changes to these common practices for subdivision street design can mitigate premature pavement distress.

If desired by a developer and approved by a municipality, a staged approach may still be used. However, **WAPA recommends designing the binder layer to structurally accommodate anticipated loading by heavy home construction vehicles**.

Compared with the practice described above, the recommended approach involves designing and building a thicker binder layer upon an aggregate construction platform. The construction platform will generally vary from 6 to 12 inches depending on a municipality's preference. The developer and municipality may choose to follow the common practice of constructing the 1½-inch surface layer only after 50 percent to 75 percent of the subdivision is completed. Alternatively, that surface layer may be applied immediately, if desired.

Design methodology

WAPA's design methodology is based on established engineering principles and best practices for pavement design (Figure 5). The approach considers such factors as expected traffic and loading, season, subgrade condition and pavement layer materials.

The methodology uses the Asphalt Institute's Thickness Design Program (see details on the Asphalt Institute's SW-1 software at **www.asphaltinstitute.org/thicknessdesignsw**), which is based on the well-documented **elastic layer theory**, to calculate stresses and strains in pavement layers.

Standard **transfer functions**, similar to those used in the Mechanistic-Empirical Pavement Design Guide (**onlinepubs.trb.org/onlinepubs/archive/mepdg/home.htm**), predict pavement fatigue and deformation (rutting). **Miner's cumulative damage model** then predicts overall pavement performance given the design parameters.

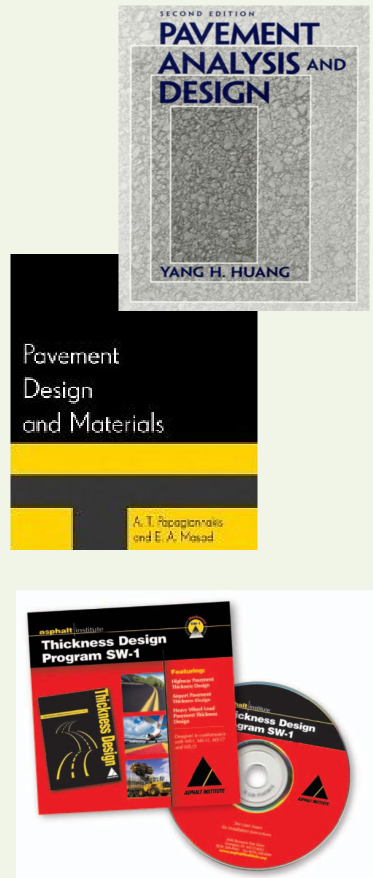

Figure 5 WAPA's design methodology is based on established industry practices and design tools.

Design parameters

WAPA's design methodology takes several parameters into account. Where possible, WAPA assumes a standard value for selected design parameters. This provides for design recommendations (see **Recommended designs** on page 5) that require a designer to supply only the most critical project-specific inputs.

→ **Hot mix asphalt**

The dynamic modulus **|E*|** of unmodified asphalt pavement can range from 30,000 to 3,000,000 psi. Commonly used HMA in Wisconsin residential paving projects are Superpave grades PG 58-28 and PG 64-22. Based on this, WAPA uses a conservative design value of **400,000 psi** as an input to its recommendations.

→ **Aggregate base**

The elastic modulus **E** of crushed aggregate base course typically ranges from 5,000 to 40,000 psi. This design methodology uses a standard value of **20,000 psi**.

→ **Subgrade soil**

The composition and associated quality of the subgrade soil have a significant impact on pavement performance. The affected parameters are the **soil stability value**, or **SSV**, and the **resilient modulus**, or $\mathbf{M_r}$. Table 1 shows three common soil types and the resulting representative SSV and M_r values.

Table 1 Pavement Design Values Based on Soil Type and Soil Components

Soil Type	Components	SSV	M_r (psi)
Good	Fine-grained materials: gravel and sand	4.8	9,000
Moderate	Components of good soil mixed with clay	4.2	6,000
Poor	Components of good or moderate soil mixed with silt	3.6	3,000

Figure 6 Heavy construction vehicles account for most of the distress that a residential pavement will ever encounter.

→ Heavy home construction vehicle loading

Repeated loadings by heavy home construction vehicles (Figure 6) are a primary cause of premature pavement damage. Subdivision pavements will not bear similar heavy loads after construction is completed.

This design methodology requires an understanding of the **equivalent single axle loads**, or **ESALs**, that these heavy vehicles will apply on residential pavements.

ESALs per truck

A typical heavy home construction vehicle can weigh 80,000 pounds. These 80 kips are distributed over several axles—some single and some paired. Using a standard method to sum all the ESAL load factors for the vehicle (Figure 7), a representative truck applies **2.4 ESALs** upon a pavement in a single trip.

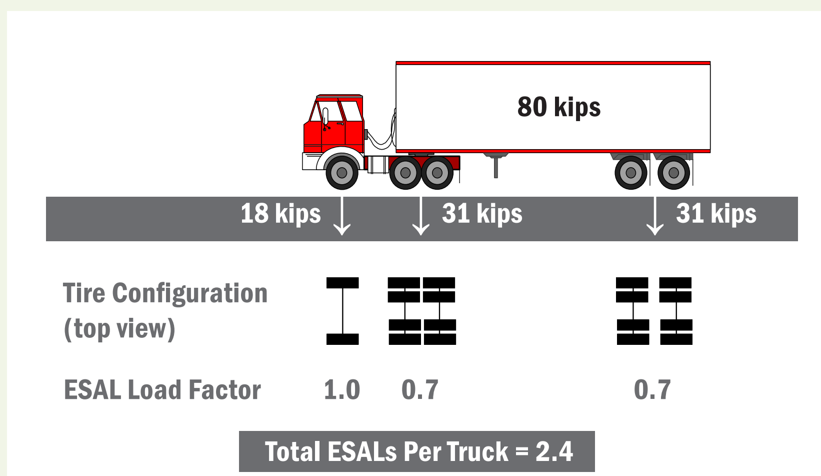

Figure 7 Calculating the ESALs for a single heavy construction and delivery vehicle

ESALs per new home built

The next consideration is the number of heavy vehicle trips that are typically required in the construction of a single home. The information summarized in Table 2 puts the estimate at **80 ESALs per home**.

Table 2 ESALs in the Construction of a Single Home

Activity	Number of Truck Trips	Total ESALs (2.4 per trip)
Excavation	3	7.2
Footings	1	2.4
Basement Walls	10	24.0
Lumber Delivery	3	7.2
Basement Floors	2	4.8
Siding and Shingles	2	4.8
Drywall	2	4.8
Garage Floor	2	4.8
Flooring	1	2.4
Cabinets and Appliances	1	2.4
Landscaping	2	4.8
Driveway	2	4.8
Moving Van	2	4.8
Total	**33**	**79.2**

The approximately 80 ESALs per home are compounded by the total number of homes to be constructed in the subdivision.

During construction of a 100-home subdivision, for example, the pavement will be subjected to 8,000 ESALs in a period as short as four months. If a developer follows the practice of not building the surface asphalt layer until 75 percent of the subdivision is complete, the binder asphalt layer will be subjected to 6,000 ESALs.

For comparison, upon completion of a subdivision the same pavements will see approximately 200 ESALs in an entire year from garbage trucks and buses.

Recommended designs

Using these key pavement parameters as inputs to the **Advanced Structural Analysis (DAMA)** component of the Asphalt Institute's SW-1 software (Figure 8), WAPA developed recommended designs for residential asphalt pavements.

The following tables present recommended binder layer thicknesses. Table 3 assumes the use of a 12-inch crushed aggregate base course. Table 4 assumes a 6-inch CABC.

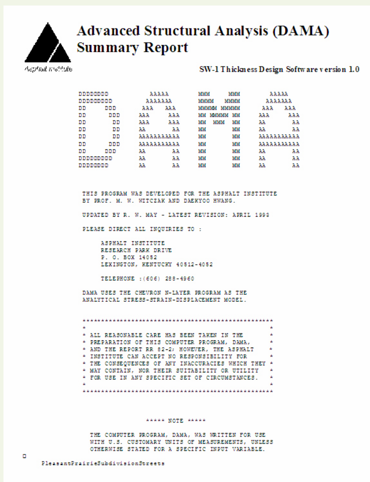

Figure 8 A report from the Asphalt Institute's SW-1 design software

To make use of these tables, only the following information is required:

- → **Number of houses in the subdivision**
- → **Soil type** (good, moderate or poor)

The recommended values for the binder layer thickness remain valid regardless of when the final 1½-inch surface layer is constructed.

Table 3 Recommended Binder Layer Thickness with a 12-inch CABC Construction Platform (in inches)

Total Houses in Subdivision	Soil Type		
	Good	Moderate	Poor
10	2.50	2.75	3.00
20	2.75	3.00	3.25
30	3.00	3.25	3.50
40	3.25	3.50	3.75
50	3.50	3.75	4.00
60	3.75	4.00	4.25
80	4.00	4.25	4.50
100	4.25	4.50	4.75

Table 4 Recommended Binder Layer Thickness with a 6-inch CABC Construction Platform (in inches)

Total Houses in Subdivision	Soil Type		
	Good	Moderate	Poor
10	3.00	3.75	4.25
20	3.00	3.75	4.75
30	3.25	4.00	5.00
40	3.50	4.25	5.25
50	3.75	4.50	5.50
60	4.00	4.50	5.75
80	4.25	4.75	6.00
100	4.75	5.00	6.00

Using these recommendations will help provide for residential pavements that meet expectations and continue to perform long after the completion of new home construction.

As noted previously, these recommendations are based on typical Wisconsin values for selected design parameters. WAPA can also provide customized assistance to municipalities that have specialized needs for subdivision pavement design. For more information, please contact WAPA at 608-255-3114, **strand@wispave.org** or **wispave.org**.