Asphalt Pavement Design Guide

for Low-Volume Roads and Parking Lots

South Carolina Asphalt Pavement Association

Asphalt.

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ASPHALT PAVEMENT DESIGN GUIDE

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The South Carolina Asphalt Pavement Association (SCAPA) is a non-profit trade association dedicated to the promotion of asphalt pavement. Its membership is comprised of asphalt producers and companies affiliated with the asphalt pavement industry in South Carolina.

"Together We Know More"

"Together we know more," the Association's motto, best describes the reason for the creation of this Asphalt Pavement Design Guide. This publication is designed to provide information of interest to pavement design engineers and is not to be considered a publication of standards or regulations. The views of the author expressed herein do not necessarily reflect the decision making process of SCAPA with regard to advice or opinions on the merits of certain processes, procedures, or equipment.

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INTRODUCTION

This guide has been developed by the South Carolina Asphalt Pavement Association (SCAPA) to assist engineers, architects, cities, towns, and counties in understanding the basic properties of asphalt concrete and the design of quality asphalt pavements for parking lots and low-volume roads. It is not intended that this guide be a substitution for pavement designs by experienced design engineers when actual project specific data are known for the traffic volume and subgrade soil characteristics for a particular project. Instead, this guide is intended to provide basic guidelines when such specific information is not available. In this regard, this guide uses generalizations and simplifications which result in traffic volume and subgrade soil categories and uses average values. For this reason, local conditions or special design considerations cannot be fully addressed in a publication of this type. When design considerations arise that are not covered by this guide, you are encouraged to contact a local SCAPA Contractor Member or the SCAPA office for further assistance.

The content of this guide was based on information provided by similar design guides and other technical resources including:

- The Asphalt Institute's *Asphalt Pavements for Highways and Streets, 9th Edition*
- The National Asphalt Pavement Association's *HMA Pavement Mix Type Selection Guide*
- The South Carolina Department of Transportation's (SCDOT) *Pavement Design Guidelines*
- The American Association of State Highway and Transportation Officials (AASHTO) *Guide for Design of Pavement Structures*

What is Asphalt?

Asphalt may be referred to by several names including hot mix asphalt (HMA), plant mix asphalt, asphalt concrete, bituminous concrete, blacktop, or Superpave. Asphalt is comprised of aggregate bound together into a solid mass by asphalt binder (also called asphalt cement or liquid asphalt). Approximately 93-96% of the mixture by weight consists of aggregates and the balance (approximately 4-7%) is asphalt binder. Asphalt is manufactured in a central mixing plant where the binder and aggregates are heated, properly proportioned, and mixed. The mixture is hauled by trucks to a jobsite where it is deposited into a paver that places it in a smooth layer at a controlled thickness. The fresh asphalt mat is then compacted by rollers while it is still hot. After rolling, the pavement is allowed to cool before opening to traffic.

Asphalt pavements are constructed of one or more courses (or layers) of asphalt placed directly on the subgrade or on an aggregate base.

Benefits of Asphalt

- **Versatility**. Hot mix asphalt pavements can be designed to handle virtually any traffic loading, soils and materials, and can be used to salvage old pavements as well as to build new ones. Phased construction can easily be incorporated.
- **Durability**. Asphalt pavements are long-lasting and because of their flexible nature, they can withstand overloads without serious damage. Quality control is also easy to maintain.
- **Economy**. Asphalt pavements are economical to construct; may be constructed rapidly and are immediately ready for use; require minimal maintenance; and provide outstanding performance.
- **Safety**. Asphalt pavements offer high skid resistance, provide contrast with pavement markings, and have reduced glare.
- **Sustainability**. Asphalt pavements are 100% recyclable and can be composed of recycled materials including reclaimed asphalt pavement (RAP), recycled asphalt shingles (RAS), and ground tire rubber (GTR), among others. Additionally, warm mix asphalt (WMA) can be used to reduce production and construction temperatures and reduce energy consumption.
- **Aesthetics**. Asphalt pavements are smooth and uniform and can enhance the appearance of a site.

For more facts about asphalt pavements, visit www.asphaltfacts.com.

DESIGN CONSIDERATIONS

When designing asphalt pavements, there are three main elements that must be considered: **Traffic**, **Subgrade**, and **Drainage**. Each of these design considerations are discussed in more detail in this section. The traffic and subgrade information will be necessary for the pavement thickness design covered in Section 4 of this guide.

Traffic

Pavements are designed to carry many different types of vehicles in the traffic stream including automobiles, light trucks, buses, freight trucks, construction equipment, and sanitation trucks among other vehicle types and loads. Although the main component of most traffic streams is passenger vehicles, the primary consideration in pavement design is heavy trucks. This is because heavy trucks impart far more stress on pavements compared to automobiles and thus are the primary contributors to pavement damage. Based on the axle load factors provided in the *AASHTO Guide for Design of Pavement Structures*, a loaded 5 axle tractor trailer imparts more than 1600 times more damage than a typical passenger car and more than 200 times greater than a large sport utility vehicle (SUV).

For the purposes of this guide, traffic will be categorized into four different classes as detailed in Table 2.1 along with further descriptions on the following pages. For traffic scenarios greater than Class 4, it is recommended to use the *SCDOT Pavement Design Guidelines*. If you have questions about the traffic classification for a particular application, contact your local SCAPA Member or the SCAPA office.

When designing the layout of a pavement for a particular facility, it is important to keep in mind that there may be multiple traffic classes for different pavement sections within a project. For example, the industrial facility in the photo below consists of a large area of pavement. Because of this large area and multiple uses of the pavement, it is practical to divide the entire facility into different traffic classes based on the type and number of vehicles that will be using a particular pavement section. In this case there is an employee lot that will only see passenger car traffic (Traffic Class 1 or 2). There are loading dock areas where trucks will load and unload (Traffic Class 3). There is a network of roads that loaded trucks will travel throughout the facility (Traffic Class 4). By dividing the pavement in this manner, a more practical and economical design will result for the entire pavement network.

Asphalt pavement used at an industrial facility.

Table 2.1. Traffic classes.

Class 1 (≤ 50 cars/day)	Class 2 (≤ 5 trucks/day)	Class 3 (≤ 65 trucks/day)	Class 4 (≤ 200 trucks/day)
▪ Driveways ▪ Play areas ▪ Parking lots (≤ 50 stalls) ▪ Seasonal recreation roads	▪ Residential streets ▪ Parking lots (> 50 stalls)	▪ Collector streets ▪ Industrial lots, truck stalls ▪ Bus driveways & loading zones	▪ Major arterial streets ▪ Local business streets ▪ Local industrial streets ▪ Major service drives or entrances

Traffic Class 1

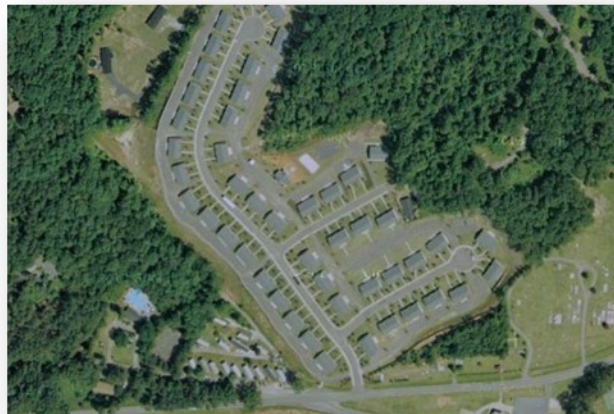
Traffic Class 1 is the lightest duty pavement application covered in this guide and will not have regular truck traffic. These light duty applications include recreation facilities (school play areas, tennis courts, running paths, etc.), residential driveways, small parking lots, and some roadways that may see seasonal passenger car traffic during a portion of the year.

Asphalt pavement used for a school play area.

Asphalt parking lot serving a small plaza.

Traffic Class 2

Traffic Class 2 will see some, but not much regular truck traffic, but not more than five trucks per day on average. This would include larger parking lots and residential streets (subdivisions, apartment complexes, etc.) serving mostly passenger cars and light trucks. Truck traffic in these cases would include local delivery trucks sanitation trucks, and school buses.



Asphalt pavement used for an apartment complex.

Asphalt pavement in a residential neighborhood.

Asphalt pavement at a large shopping plaza.

Traffic Class 3

Traffic Class 3 considers a higher volume of trucks in the traffic stream (up to approximately 65 trucks per day) as seen on local collector streets. Included in the "truck" volume would also be transit buses. In addition to local streets, pavements designed for this traffic class would also include industrial parking lots and truck stalls, as well as bus driveways and loading/ unloading zones.

Asphalt pavement used for a local collector street.

Asphalt pavement used at a transit bus stop.

Traffic Class 4

Traffic Class 4 is the heaviest duty traffic class considered in this guide and would accommodate up to approximately 200 trucks per day in the traffic stream. Applications meeting this description would include major arterial streets that see relatively high traffic volumes as well as local streets, service drives, and entrances serving commercial and/or industrial facilities that will experience high truck volumes throughout the design life.

Asphalt pavement used at an industrial facility.

Asphalt pavement for a major arterial road.

Subgrade

The success of any structure, including a pavement structure, is highly dependent on the quality of the foundation upon which it is built. In the case of a pavement structure, the foundation refers to the soil (or subgrade) that the pavement is constructed upon. A higher quality (or stronger) subgrade can withstand greater stresses, which means that the thickness of the pavement structure can be reduced compared to that needed for a weaker subgrade. For this reason, ***it is important that the subgrade soil be thoroughly examined and understood before developing a pavement design***.

To simplify the design process, three main subgrade soil categories have been created for the designs outlined in this guide based on the quality of the soil being used as the pavement subgrade material. As summarized in Table 2.2, the three soil categories are **Poor**, **Medium**, and **Good** and are based on the soli classification, plasticity, and relative strength. At a minimum, the soil should be evaluated by a geotechnical engineer to determine the following information:

- Particle size distribution (ASTM D422 & D1140 or AASHTO T11 & T27)
- Liquid limit (*LL*) and plasticity index (*PI*) (ASTM D4318 or AASHTO T89 & T90)
- Soil classification (ASTM D2487 or AASHTO M145)
- California bearing ratio (*CBR*) (ASTM D1883 or AASHTO T193)

After determining this information, the appropriate subgrade category can be selected from Table 2.2 to move forward with the design. As noted in Table 2.2, the Group Index (*GI*) can be calculated using the equation below and used to categorize soils based on their suitability as a pavement subgrade material.

$$GI = (F_{200} - 35)[0.2 + 0.005(LL - 40)] + 0.01(F_{200} - 15)(PI - 10)$$

where,

F_{200} = Percent of subgrade soil passing the No. 200 sieve
LL = Liquid limit of subgrade soil
PI = Plasticity index of subgrade soil

For soils classified as A-2-6 and A-2-7, the following equation should be used:

$$GI = 0.01(F_{200} - 15)(PI - 10)$$

Table 2.2. Subgrade categories.

	Poor	Medium	Good
Description	✓ Becomes soft and plastic when wet. ✓ Clays and fine silts ▪ ≥50% passing No. 200 ✓ Coarse silts and sandy loams ▪ Deep frost penetration ▪ High water table	✓ Retains a moderate degree of firmness under adverse moisture conditions. ✓ Loams, silty sands, and sandy-gravels containing moderate amounts of fine silts.	✓ Retains a substantial amount of load-supporting capacity when wet. ✓ Clean sands, sand-gravels, and those free of detrimental amounts of plastic fines. ▪ ≤10% passing No. 200 ✓ Relatively unaffected by moisture or frost.
Typical Properties	CBR < 6 LL > 40 PI > 10 GI > 4	CBR: 6–9 LL: 25–40 PI: 6–10 GI: 2–4	CBR ≥ 10 LL < 25 PI < 6 GI < 2

Drainage

Some have said that there are three main keys for a successful pavement: **Drainage**, **drainage**, and **drainage**. Needless to say, providing proper drainage is essential for a long-lasting asphalt pavement. Without adequate drainage to divert water away from the pavement structure, the chances of subgrade failure increase due to the fact that many soils become weaker as the moisture content increases. How strong or stable is mud anyway? In addition to reducing the strength of the soil, moisture can also cause expansive soils to increase in volume which could result in heaving of the pavement structure above. There are two categories of drainage for pavements: **Surface drainage** and **subsurface drainage**.

"Bird bath" due to inadequate pavement slope.

Surface Drainage

Surface drainage refers to the removal of any water present on the surface of the pavement, shoulder, and adjacent ground. For good surface drainage, the pavement and shoulders must be properly crowned or sloped to ensure the rapid flow of water off the roadway to curbs and gutters or to adjacent drainage ditches or swales. It is recommended to use a crown with a cross-slope of at least 2% for roads and longer driveways with two or more lanes. For parking lots and other large paved areas, a minimum cross-slope of 1.5% is recommended to help ensure adequate drainage of surface water and avoid standing water.

Cross-slopes less than 1% are not practical because there are many factors that make it difficult to construct pavements with such low slopes without forming flat spots or depressions that could result in areas where water may puddle ("bird baths") and not be removed from the pavement surface. If bird baths are present on a pavement surface, then there is a possibility that the water will be able to seep into the pavement structure through cracks in the surface of the pavement depending on the condition.

When designing roadways and parking lots, ensuring proper crown or cross-slope is typically accounted for in the design. However, there is a tendency among designers to overlook the need for grade information at key points in intersections, cross-overs, and transitions between grade lines.

With adequate flow of water across the pavement surface, it is important to ensure that water does not accumulate at the pavement edge. Depending on the situation, runoff should be collected with a curb and gutter and channeled off the pavement to a properly designed stormwater collection system. Curb and gutter cross sections should be built so that water flows within the designed flow line and not along the interface between the asphalt pavement and the curb face. This will minimize the chance of water seeping into the pavement structure or subgrade.

When a pavement is not surrounded by a curb, drainage ditches should be constructed adjacent to the pavement to collect and divert water away from the pavement. As seen in Figure 2.1, water flows from the pavement and shoulder surfaces down the pavement foreslope into a rounded ditch area. A backslope leads from the bottom of the ditch up to intercept runoff from the adjacent land. The adjacent land is frequently sloped toward the ditch and can contribute to a significant portion of the flow in the drainage ditch.

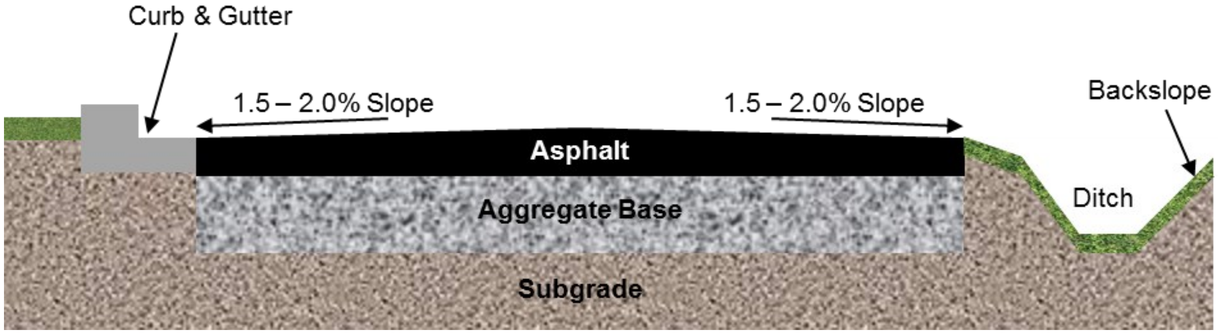


Figure 2.1. Schematic of surface drainage off of a pavement surface into a roadside drainage ditch or curb and gutter (not to scale).

Subsurface Drainage

Subsurface drainage refers to measures used to remove water contained in, or moving through the various layers of material that make up the pavement structure or the adjacent soil. As previously discussed, the accumulation of water in the pavement foundation can be problematic as a high moisture content can substantially reduce the load carrying capacity of the soil and base material and some soils can undergo volumetric changes as the moisture content fluctuates. Additionally, water accumulation within asphalt layers can cause stripping of the asphalt binder from the aggregate, which can deteriorate the pavement.

Water can enter the pavement structure in a number of ways. If the pavement surface becomes cracked, then water can penetrate the pavement surface and infiltrate into the pavement structure and subgrade. Water can also rise from the subgrade beneath the pavement structure due to changes in water table elevations and water draining into the subgrade from adjacent areas.

In situations when water accumulates within the pavement structure, it is necessary to include underdrains, interceptor drains, edge drains, and/or drainage layers with the purpose of diverting water from the pavement structure and preventing water accumulation. Figure 2.2 provides some general schematics of typical subsurface drainage solutions. It should be noted that these are only generic schematics and the technical expertise of an engineer is required to identify areas that need subsurface drainage and to ensure proper functioning of a long-lasting drainage system.

Installation of a pavement underdrain.

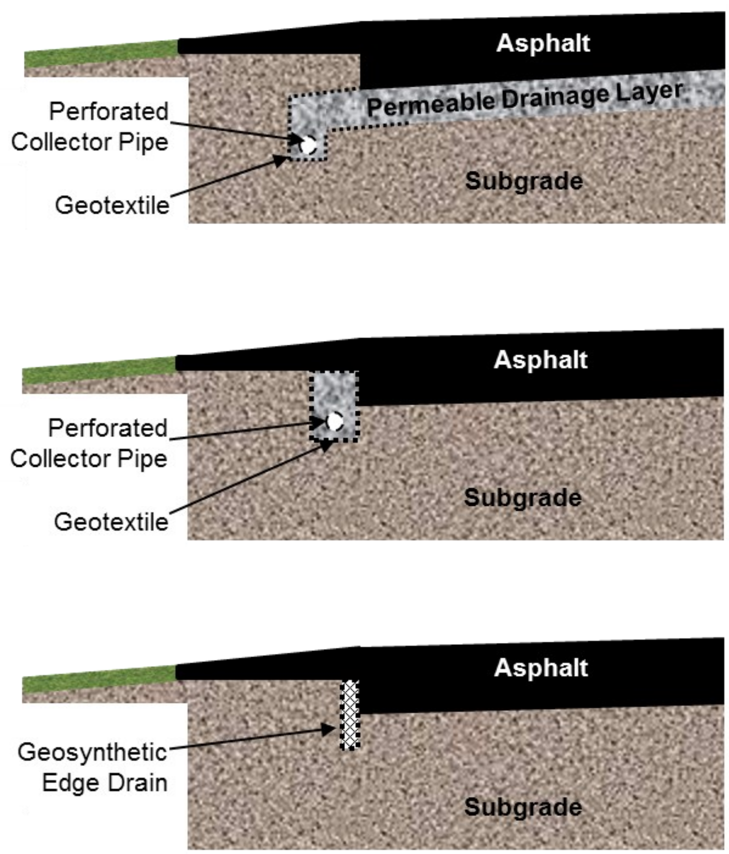


Figure 2.2. Schematics of typical subsurface drainage solutions (not to scale).

PAVEMENT MATERIALS

In this guide, the pavement structure is defined as all of the components of a pavement above the subgrade. For a given situation, there are multiple combinations of materials and pavement layers that will provide the required load carrying capacity based on the amount of traffic and the subgrade quality. However, there are two basic categories that this guide will cover with respect to material selection: Pavements designed as **full-depth asphalt** (i.e., all pavement layers above the subgrade are asphalt) and those designed with an **aggregate base course** (also referred to as a Macadam base course) directly above the subgrade followed by one or more layers of asphalt. Figure 3.1 provides a generic schematic of typical pavement sections for each category.

The decision of what type of asphalt pavement to design lies with the designer, but is typically based on the quality and cost of available materials as well as the quality of the subgrade. In cases where the subgrade is very poor, the use of an aggregate base course is recommended as it will provide a working platform that will help support the heavy equipment used for the subsequent asphalt paving operations. If an aggregate base course is not used in these situations, then there could be constructability issues and the quality and service life of the pavement could suffer.

Selection of the proper materials for each layer of a pavement structure is important because inferior materials will not possess the necessary strength and will lead to premature failure of the pavement. This guide recommends the use of specific materials based on specifications set forth by the South Carolina Department of Transportation (SCDOT) for roadway construction. These specifications are based on decades of research and experience in South Carolina and are used by most asphalt paving contractors. Additionally, the quality of the materials increases the closer they are located to the pavement surface because higher quality materials will be able to withstand the higher stresses in the upper portions of the pavement structure.

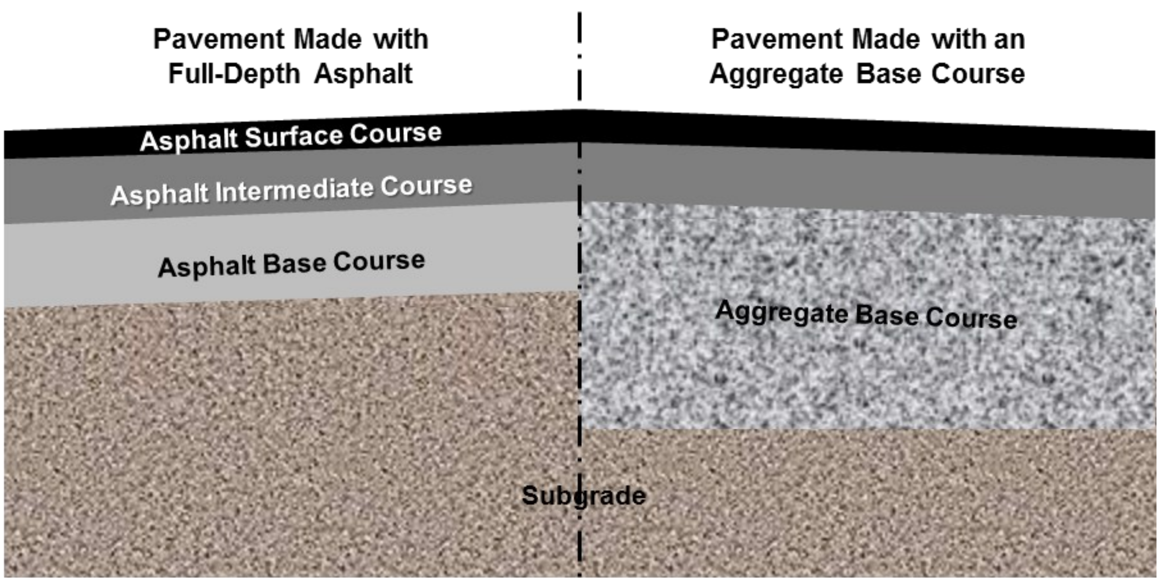


Figure 3.1. Typical cross-sections for full-depth asphalt pavements (on left) and asphalt pavements designed with an aggregate (or Macadam) base course (on right) (not to scale).

When using an aggregate base course in a pavement design, it is recommended to use a crushed aggregate material meeting the gradation requirements in Table 3.1. Most areas of South Carolina have access to crushed aggregate that meets the requirements of the graded aggregate base (GAB) course in Table 3.1. However, in the coastal plain area of the state, the availability of this type of material is limited, so the use of crushed marine limestone as a base course may be necessary as long as it meets the specifications in Table 3.1. In addition to aggregate gradation, it is also very important that the aggregate material be free of vegetative matter, sand, lumps or balls of clay, or other deleterious materials that may reduce the strength of the base course.

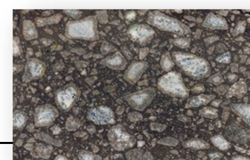
Table 3.1. Aggregate base course specifications.

	Graded Aggregate Base	Marine Limestone Base
Gradation *(% passing)*		
2 in	100	100
1½ in	95 - 100	95 - 100
1 in	70 - 100	70 - 100
½ in	48 - 75	50 - 85
No. 4	30 - 60	30 - 60
No. 30	11 - 30	17 - 38
No. 200	0 - 12	0 - 20
Liquid Limit	≤ 25	≤ 25
Plasticity Index	≤ 6	≤ 6
Single Lift Thickness	≤ 10 in	≤ 10 in

The lift thickness provided in Table 3.1 and the tables that follow in this section refers to the maximum recommended thickness that a single lift of material should be placed and compacted. In situations when the total design thickness exceeds the maximum recommended lift thickness for a single lift, then the material should be placed in two or more lifts of equal thickness that are less than or equal to the maximum recommended thickness. This will help to ensure proper compaction of the material.

Table 3.2. Asphalt base course specifications.

	SCDOT Base Type B
Gradation *(% passing)*	
1½ in	100
1 in	85 - 100
½ in	60 - 80
No. 4	40 - 55
No. 8	30 - 45
Binder	
Grade	PG 64-22
Content	4.0 - 5.5%
RAP Content *(% aged binder)*	0 - 40%
Single Lift Thickness	Minimum: 3 in Maximum: 4½ in



When full-depth asphalt is selected for a pavement design, an asphalt base course will be used instead of an aggregate base course. When this option is selected, the mix design for the asphalt base course should meet the specifications for an SCDOT Base Type B mix included in Table 3.2. An asphalt base course mix is also recommended to be used in asphalt sections greater than 7 in thick, even when an aggregate base course is used.

As indicated in Table 3.2 (and Tables 3.3 and 3.4), reclaimed asphalt pavement (RAP) can be incorporated into an asphalt mixture. RAP is asphalt mix that has been reclaimed from an older pavement, typically using a milling machine, and then crushed and screened at an asphalt plant. It is common practice to include RAP (a recycled material) in new asphalt mixtures. The tables list recommended ranges for RAP content for a particular mix. The RAP content of an asphalt mix will vary from producer to producer based on the specific asphalt plant setup, RAP material, mix design, and experience. The RAP content in these tables refers to the percent of aged binder (from RAP) in the mixture. For example, if the RAP content is 25%, this means that 25% of the total binder content comes from the aged binder in the RAP. You are encouraged to contact your local SCAPA Contractor Member to learn more about their specific practices related to the use of RAP and other recycled materials and potential LEED credits related to asphalt pavement.

Depending on the overall thickness of the pavement section, one or two additional asphalt layers will be placed on top of the base course. For thicker sections, an intermediate course will be placed over the base course. When an intermediate asphalt course is used, it is recommended that a SCDOT Intermediate Type C mix design be used meeting the specifications included in Table 3.3.

Table 3.3. Asphalt intermediate course specifications.

	SCDOT Intermediate Type C
Gradation ***(% passing)***	
1 in	100
¾ in	90 - 100
½ in	80 - 95
⅜ in	68 - 87
No. 4	45 - 68
No. 8	30 - 46
No. 30	12 - 29
No. 100	4 - 13
No. 200	2 - 8
Binder	
Grade	PG 64-22
Content	4.0 - 6.0%
RAP Content *(% aged binder)*	0 - 35%
Single Lift Thickness	Minimum: 2 in Maximum: 3 in

The final layer of asphalt included in a pavement design will be an asphalt surface course. There are several functions of the surface course that set these mixtures apart from the intermediate and base mixtures. First off, the surface course will be the driving surface, therefore, it must be smooth. These mixtures are made with a finer gradation than the intermediate or base mixtures, which reduces the surface texture of the finished pavement, thus creating a smoother ride. The smoother finish of the surface course also looks more appealing than coarser mixes, which is important for certain pavement applications (e.g., businesses, subdivisions, city streets, etc.). As these surface mixtures are directly exposed to the environment, it is important that they are durable and resist aging due to oxidation over time as well as provide a waterproof barrier to keep water from infiltrating the coarser and more permeable materials (intermediate asphalt, base asphalt, and/ or aggregate base courses) comprising the pavement structure below. In addition to having a finer gradation, these mixtures also have higher asphalt binder contents compared to intermediate and base course mixtures which improves durability and water resistance. The surface mix types discussed in this guide include SCDOT Surface Course Types B, C, D, and E and the specifications are included in Table 3.4. The surface course most frequently recommended in this guide is the Surface Course Type C as it is the industry standard mix in South Carolina, however, the other mix types may be used for special applications. Surface type E is mainly used for leveling and preventive maintenance that will be discussed in Section 5 of this guide.

Table 3.4. Asphalt surface course specifications.

	SCDOT Surface Type B	SCDOT Surface Type C	SCDOT Surface Type D	SCDOT Surface Type E
Gradation ***(% passing)***				
¾ in	100	100	100	—
½ in	97 - 100	97 - 100	97 - 100	—
⅜ in	76 - 100	83 - 100	90 - 100	100
No. 4	52 - 75	58 - 80	70 - 95	90 - 100
No. 8	36 - 56	42 - 62	50 - 82	70 - 100
No. 30	16 - 36	20 - 40	20 - 50	36 - 70
No. 100	5 - 18	5 - 20	6 - 20	4 - 28
No. 200	2 - 8	2 - 9	2 - 10	2 - 10
Binder				
Grade	PG 64-22	PG 64-22	PG 64-22	PG 64-22
Content	4.8 - 6.0%	5.0 - 6.8%	5.0 - 6.8%	6.0 - 7.0%
RAP Content *(% aged binder)*	0 - 25%	0 - 30%	0 - 30%	0 - 30%
Single Lift Thickness	Minimum: 2 in Maximum: 2½ in	Minimum: 1½ in Maximum: 2½ in	Minimum: 1 in Maximum: 1½ in	Minimum: ½ in Maximum: 1 in
Recommended for Traffic Class	4	1, 2, 3, & 4	1 & 2	1, 2, & Preventive Maintenance

The selection of the appropriate surface course mixture should be based on two main criteria: **Traffic volume** and desired **smoothness**. Figure 3.2 can be used to aid in the selection of the appropriate surface mix type for a particular pavement design. As shown in Figure 3.2, surface type B is the strongest mix and is only recommended for heavy traffic applications such as pavements designed for Traffic Class 4 in accordance with this guide, or areas that will experience frequent heavy truck traffic such as loading docks. Surface type B is also the coarsest mix and will have the roughest texture of the mix types as indicated in Figure 3.2 and shown in Figure 3.3.

As previously discussed, a Type C surface course is recommended for most other traffic scenarios, but surface types D and E mixes can be used for certain light duty pavements where a thinner asphalt lift is required or a smoother texture is desired such as play areas, tennis courts, running tracks, etc.

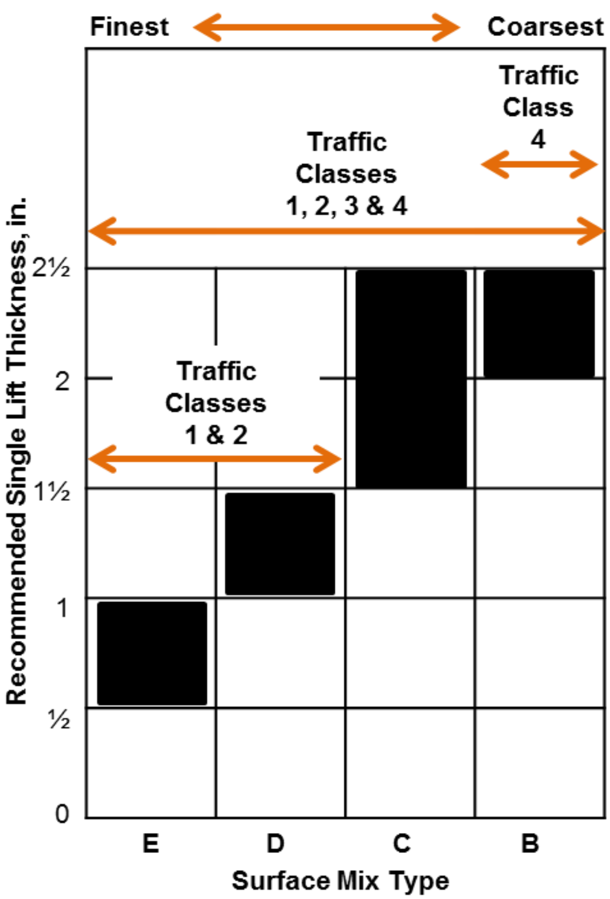


Figure 3.2. Asphalt surface course type selection chart.

Figure 3.3. Surface texture comparison for surface course types B, C, and D. The inlay photos show a cross-sectional view of each mix type. A US quarter is used as a scale reference.

THICKNESS DESIGN

The thickness of a pavement structure is dependent upon the **Traffic Class** and the **Subgrade Category** discussed in Section 2 of this guide. Having this information, the designer can refer to Figures 4.2 through 4.4 for the asphalt and aggregate base course thicknesses when the pavement is constructed on **Poor**, **Medium**, and **Good** subgrades, respectively. The pavement designs included in this section are recommended minimum pavement designs for given traffic and subgrade conditions. Thickness values less than those recommended should be evaluated by an experienced engineer. It should also be noted that the pavement designs in this section are for new construction and do not cover overlay design.

Thickness Equivalency

This guide includes asphalt pavement designs for both full-depth asphalt pavements and asphalt pavements that include an aggregate base course. As shown in the thickness design figures (Figures 4.2 through 4.4), the total thickness of a pavement structure made with an aggregate base is thicker than its full-depth asphalt counterpart. This difference can be explained by the concept of thickness equivalency, which considers the relative load carrying capability of different materials. For example, a 4 in thick layer of compacted asphalt is much stronger than a 4 in thick layer of unbound graded aggregate base course and it can, therefore, withstand a greater number of load repetitions before failure occurs (see Figure 4.1). For this reason, 1 in of asphalt cannot be replaced with just 1 in of aggregate base.

The thickness design options in this guide were based on the thickness equivalences established by the SCDOT, which are based on decades of research and experience with the asphalt and aggregate base materials in South Carolina. These equivalence coefficients indicate that a 1 in thick layer of asphalt is equivalent to approximately 2½ in of graded aggregate base material.

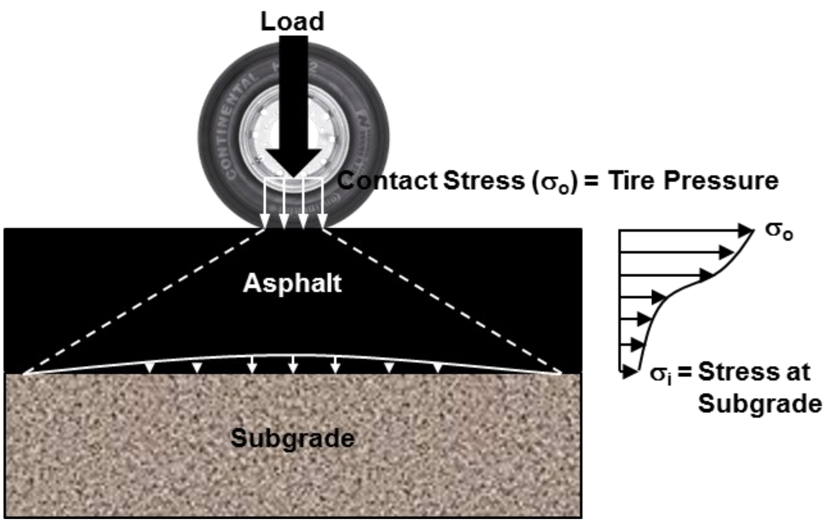
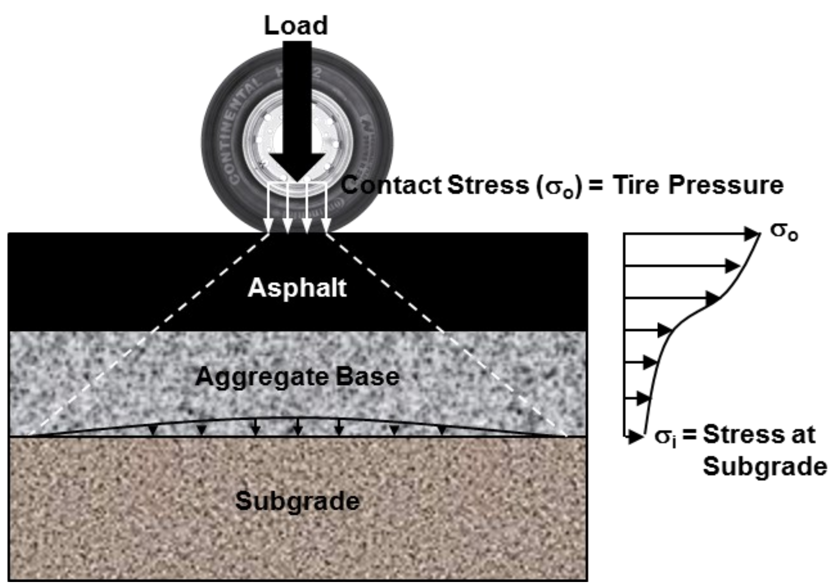


Figure 4.1. Spread of a wheel load through a full-depth asphalt pavement structure (above) and an asphalt pavement with an aggregate base course (at right).



Poor Subgrade

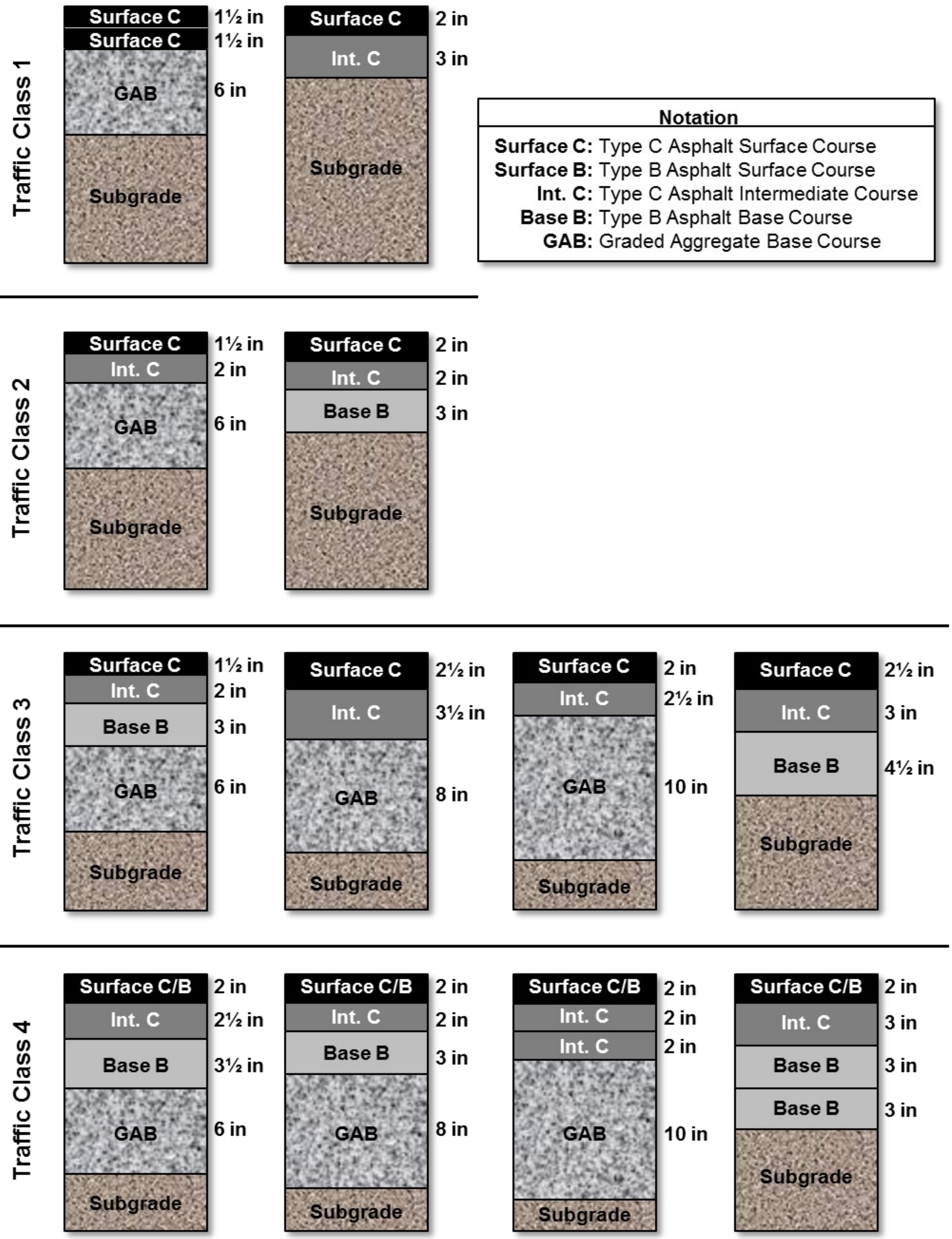


*Figure 4.2. Recommended asphalt pavement thickness design options for different traffic classes on a **Poor Subgrade**.*

Medium Subgrade

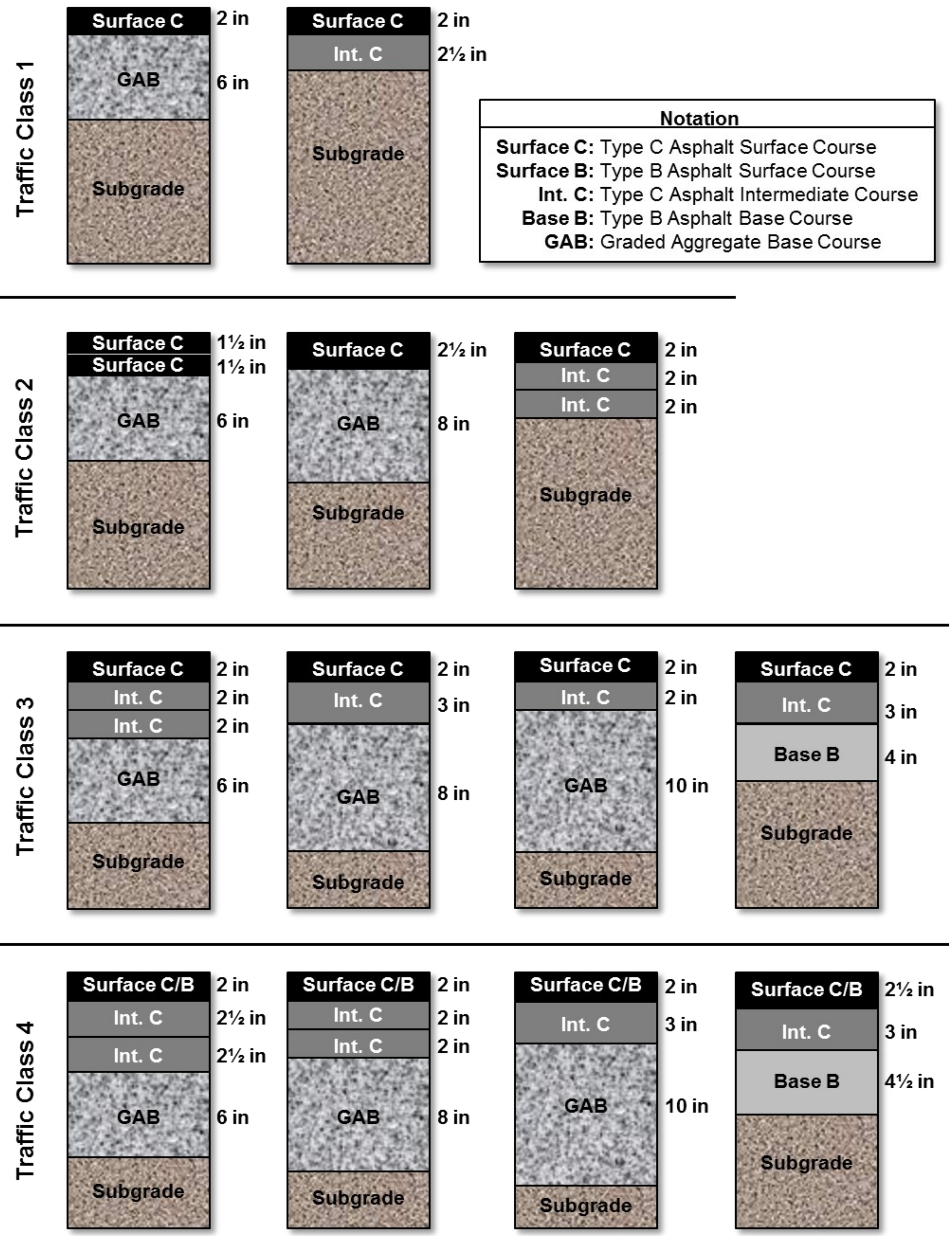


*Figure 4.3. Recommended asphalt pavement thickness design options for different traffic classes on a **Medium Subgrade**.*

Good Subgrade

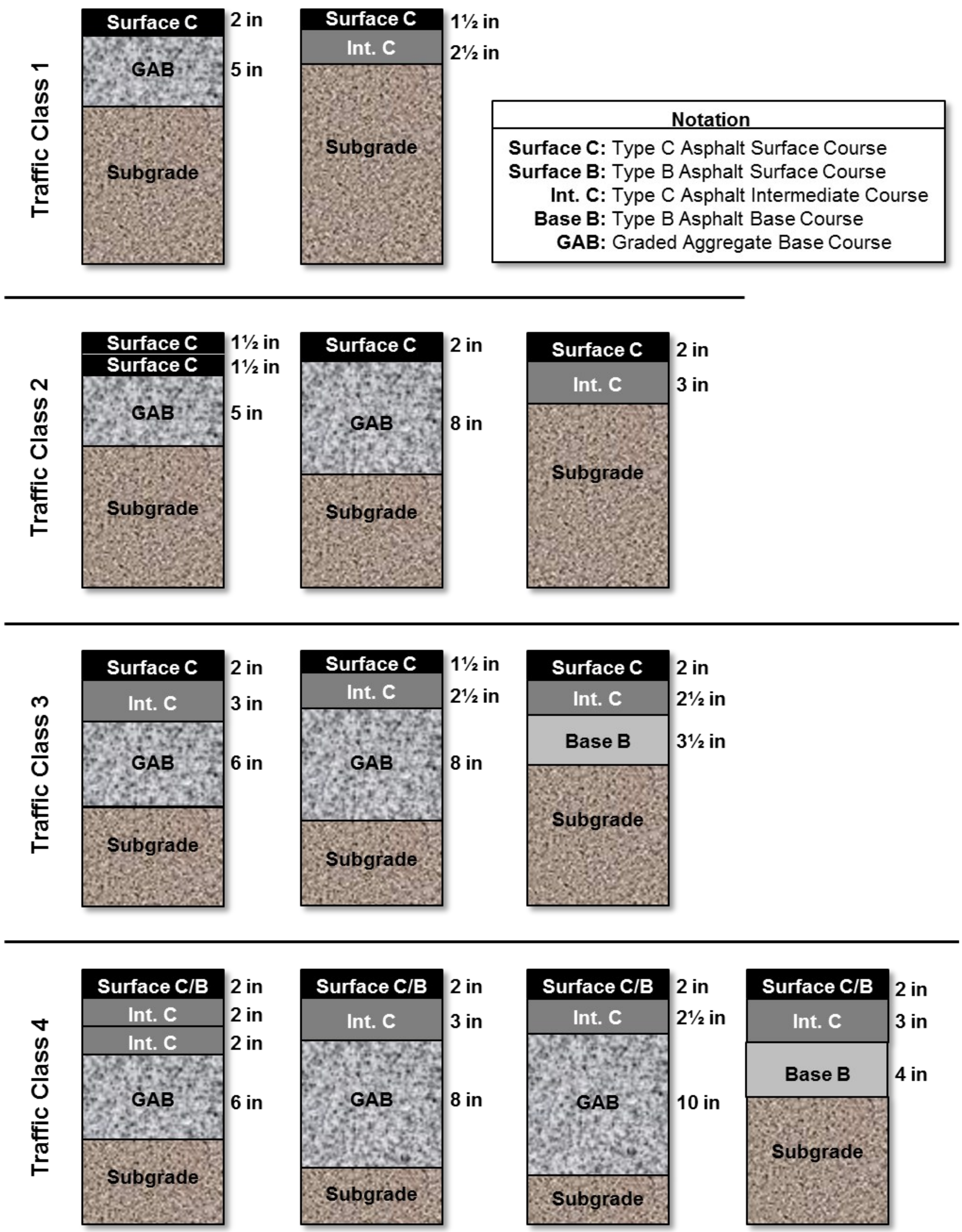


*Figure 4.4. Recommended asphalt pavement thickness design options for different traffic classes on a **Good Subgrade**.*

ASPHALT PAVEMENT CONSTRUCTION

To achieve a high quality asphalt pavement, the owner should select a contractor with trained personnel and who has demonstrated high quality workmanship on similar projects. For a list of qualified contractors, please contact the SCAPA office or view the membership listing on the SCAPA website (www.scasphalt.org) or at the end of this guide.

Subgrade and Aggregate Base

The subgrade is of the utmost importance because it must serve both as a working platform to support construction equipment and as the foundation for the final pavement structure. During construction, the native soils may be evaluated by proofrolling the area using heavy construction equipment. This is done to identify any unsuitable or soft areas that need to be removed or improved prior to placing subsequent layers. Unsuitable soils can be improved by blending aggregates with soil; by chemical stabilization using cement, kiln dust, or hydrated lime; or by mechanical stabilization using geosynthetics. All debris, topsoil, vegetation, or unsuitable materials should be removed and replaced with quality materials.

Fill materials should be placed in lifts no greater than 8 inches (loose thickness) at the proper moisture content and compacted prior to placement of the next lift. A properly prepared subgrade will not deflect excessively under the weight of a loaded tandem axle truck. Prior to the start of paving operations, the subgrade soils should be checked for stability, moisture content, density, and proper grade. For projects designed with an aggregate base between the subgrade and the asphalt pavement, the layer of stone must also be placed and compacted at the proper moisture content to the required density and grade and then proofrolled.

Quality Workmanship

It is important that the owner or prime contractor select a local asphalt paving contractor familiar with the materials that perform best in the region and who is experienced in constructing quality asphalt pavements. The paving contractor is responsible for quality control on the project and will be responsible for the quality of the asphalt mixture and the finished pavement surface. All SCAPA Contractor Members have personnel and facilities that have been certified by the SCDOT.

The paving contractor should utilize a self propelled asphalt paving machine capable of producing a smooth and consistent layer of material. Best practices at the asphalt plant and during trucking operations, will minimize the potential for material segregation (physical separation of the larger aggregates and smaller aggregates) of the mixture. The contractor must also ensure adequate compaction equipment is available to meet the project specifications while achieving a smooth finish.

Preparation of subgrade and aggregate base course.

Haul truck depositing asphalt into a paver.

Asphalt Base Construction

The asphalt base course should be placed directly on the soil subgrade (full-depth design) or on the prepared aggregate base (aggregate base design). Asphalt mixtures used in base applications have larger aggregates and are typically placed in thicker lifts (3-4½ in). The base layer should be placed and compacted to the thickness indicated on the plans, which represent the finished and compacted pavement thickness—not the loose thickness prior to compaction. Compaction of the base layer(s) is critical to the performance of the pavement because it provides the structural foundation to support the weight of the traffic. To achieve compaction of a base mixture, research and experience indicates that the thickness of the layer must be at least three times the size of the largest aggregate in the mixture.

Following the placement of an asphalt base or intermediate course, it is a best practice to not allow it to remain exposed to the environment for long periods of time because water can more easily penetrate the surface of these mixtures. The combination of a coarse aggregate gradation and relatively low binder content makes these mixtures more permeable than surface type mixtures. For this reason, it is recommended to place a surface course over the asphalt base and intermediate courses as soon as possible to protect the integrity of the pavement structure.

Tack Coat

The purpose of a tack coat is to promote bonding between pavement layers. A tack coat may not be required if the asphalt layers are placed in subsequent days and the surface remains clean and free of dust. Older pavement surfaces and milled surfaces that will receive an overlay will often utilize a tack coat.

The tack coat material is typically placed just prior to paving and must be applied to an asphalt surface that is clean and free of dust, debris, or loose materials. When tack coat is used, it is important to uniformly coat the paving surface.
Most tack coat products are asphalt emulsions which require time to "break" or cure. When the emulsion is initially sprayed on the paving surface, it has a brown color. After the tack coat breaks, the product will turn black in color and become sticky indicating that it is ready for the next layer of asphalt. The time necessary for the tack coat to break is dependent on the type of emulsion and the weather conditions at the time of placement.

Application of a tack coat prior to paving.

Intermediate Course Construction

If an asphalt base course is not included in a pavement design, then the intermediate course should be placed directly on the soil subgrade (full-depth design) or on the prepared aggregate base (aggregate base design). Asphalt intermediate course mixtures are comprised of smaller aggregates than asphalt base mixtures, but larger than surface course mixtures, therefore, the layer thickness will be adjusted accordingly so the lift thickness is at least three times the size of the maximum aggregate size. As with all asphalt layers, proper compaction of the asphalt intermediate course is critical to the performance of the pavement.

When an intermediate course is included in the pavement design, it is important not to keep it exposed to the elements for an extended duration. As with an asphalt base mix, an intermediate mixture is more permeable than a surface course, so it is susceptible to water intrusion over time. Therefore, it is recommended to place a surface course over the intermediate course as soon as possible to protect the pavement structure.

Surface Course Construction

The asphalt surface layer is typically placed in one layer and compacted to the finish grade shown on the plans. The finished surface should not vary from the established grade by more than ¼ inch in 10 feet when measured in any direction. Rolling and compaction should start as soon as the asphalt material can be compacted without displacement and continue until it is thoroughly compacted and all the roller marks are removed. Proper compaction of the surface course will ensure a strong, smooth, and watertight pavement wearing course.

Placement of an asphalt surface course.

Initial breakdown compaction of an asphalt surface course.

Asphalt Pavement Quality Checklist

The following checklist identifies several items that are critical to constructing a long-lasting asphalt pavement.

- ✓ The asphalt plant is approved by the SCDOT to produce plant mixed asphalt material.
- ✓ The job mix formula (JMF) for the specified asphalt mix is approved by the SCDOT.
- ✓ The laboratory and field QC personnel are certified by the SCDOT.
- ✓ The asphalt content of the mix is within the specified tolerance compared to the JMF.
- ✓ The gradation of the aggregate comprising the asphalt mixture is within the specified tolerances compared to the JMF.
- ✓ A tack coat has been applied to the paving surface as necessary.
- ✓ The paving contractor established a roller pattern to ensure proper, consistent compaction of the asphalt courses and is following the roller pattern throughout construction.
- ✓ Pavement layer density is monitored with the use of a calibrated density gauge.
- ✓ The pavement thickness is within the specified tolerance.

Measuring pavement density with a nuclear density gauge.

Asphalt Pavement Maintenance and Resurfacing

Pavement maintenance is the routine work performed to keep a pavement, which is exposed to normal conditions of traffic and nature, as near to its original condition as possible. Pavements are constantly exposed to traffic and environmental forces that lead to deterioration. For this reason, pavements require maintenance over time.

Addressing pavement deterioration at the proper time and in the proper manner can significantly increase the life of a pavement. Early detection and repair of minor defects are among the most important activities of road maintenance crews. In their first stages, cracks and other surface breaks are almost unnoticeable, but they may develop into serious defects if not repaired in a timely manner. Open joints and cracks allow water to enter the subgrade and can lead to structural failure.

Pavement maintenance involves the identification of pavement distress types and the determination of appropriate maintenance activities. Common maintenance activities for asphalt pavements include patching, overlays, and preventive maintenance treatments.

Patching

At some point in time, most pavements will require patching whether it is due to pavement deterioration or utility cuts. As patching is a common pavement maintenance activity, it is important to use quality materials and best practices. There are two main types of patching: **Full-depth patching** and **surface patching**.

Full-Depth Patching

Full-depth patching is used to make permanent pavement repairs for isolated areas of pavement distress such as fatigue cracking and potholes due to subgrade failure. When using full-depth patching, the entire thickness of asphalt over the affected area is removed. This exposes the aggregate base or subgrade, which can also be repaired if required. After proper repair and compaction of the pavement foundation, the boundary of the patch area should be sprayed with tack coat, then the asphalt patch should be placed using a surface course mixture and proper compaction techniques.

Finished full-depth patch.

Surface Patching

Surface patches are intended to be for temporary repairs on pavements that are in relatively good condition and are structurally sound. These patches can be placed without excavating the existing surface, but milling a portion of the pavement in the affected area can also be done to improve the quality of the patch.

Before placing the patch mix, it is important to be sure that the area is clean and dry before applying a tack coat to the entire area. The asphalt should then be placed in such a manner that the patch thickness is feathered to a zero thickness at the edges. After proper compaction, it is recommended to apply a seal coat to the feathered edges to reduce the potential for raveling and moisture intrusion.

Overlays

Asphalt overlays are used to extend the life of a pavement as either preventive maintenance on a pavement in good condition, or to improve the structural capacity of a pavement reaching the end of its design life. Overlays also improve riding quality, the cross section, and they increase a pavement's resistance to water intrusion and deicing chemicals. The result is a better riding surface and stronger pavement than the original.

An asphalt overlay offers the following advantages:

- **<u>Convenience</u>**. The pavement may remain in use while it is being upgraded.
- **<u>Economy</u>**. An old pavement may be improved and returned to service more quickly and for less cost than a new road can be constructed.
- **<u>Durability</u>**. Well-designed, well-constructed improvements provide a pavement that is stronger than new, which reduces maintenance requirements.

Before constructing an asphalt overlay, the existing pavement must be properly prepared by repairing distressed areas, sealing cracks, correcting drainage deficiencies, and/or leveling the existing pavement to make slope corrections or fill ruts. In some cases, it may be necessary to remove a certain thickness of the existing pavement using a milling machine.

Removal of a controlled thickness of asphalt pavement using a milling machine.

Each resurfacing project must be designed on an individual basis. The thickness of the overlay is based on the intended purpose of the overlay (preventive maintenance or structural upgrade), structure and condition of the existing pavement, and anticipated traffic. The overlay will consist of an asphalt surface course (typically surface type C, D, or E). Selection of the mix type will be based on the overlay thickness, the expected traffic, and the desired texture.

Compaction of an asphalt overlay.

Preventive Maintenance Treatments

Preventive maintenance is a broad term including several types and combinations of asphalt and asphalt aggregate applications, which are usually less than 1 in thick and can be applied to any kind of asphalt pavement surface. The primary objectives of a preventive maintenance treatment are to prolong a pavement's lifespan by protecting it from exposure, mechanical wear, and water. However, most of these treatments do not enhance the structural capacity of the pavement, so it is important that preventive maintenance treatments are applied to pavements that are structurally sound.

There are different types of preventive maintenance treatments, but the most common are ultra-thin asphalt overlays, chip seals, and other options. Ultra-thin asphalt overlays consists of a ½ to 1 in layer of a surface type E mix. These overlays can be used on parking lots and low-volume roads and because they are made with a plant-mixed asphalt, they provide some level of structural value to the pavement.

Chip seals are typically used for low-volume roads and consist of a polymer modified asphalt emulsion sprayed on the road then covered with a layer of single-sized aggregate. In addition to sealing the pavement surface, chip seals can also improve the skid resistance.

ASPHALT PAVEMENT GLOSSARY

Aggregate. A hard inert material of mineral composition such as sand, gravel, slag, or crushed stone, used in pavement applications either by itself or for mixing with asphalt.

Aggregate Gradation. Distribution of aggregate particle sizes.

Anti-Stripping Additive. Material added to an asphalt mixture to reduce or eliminate the moisture susceptibility of the mixture by promoting adhesion between the binder and the aggregate surface. The most common additives are hydrated lime that is added to the aggregate and amine-based liquid additives added to binders.

Asphalt Concrete. A mixture of mineral aggregate and asphalt binder. Often referred to as asphalt.

Asphalt Binder. Asphalt cement that is classified according to the Standard Specification for Performance Graded Asphalt Binder, AASHTO Designation M320. It can be either unmodified or modified asphalt cement, as long as it complies with the specifications.

Asphalt Emulsion. A combination of asphalt cement, water and a small amount of an emulsifying agent. It is a heterogeneous system (containing two normally immiscible substanous phases: asphalt and water), in which the water forms the continuous phase of the emulsion, and the minute globules of asphalt form the discontinuous phase. Emulsified asphalt may be either anionic globules—electronegatively charged asphalt—or cationic—electropostively charged asphalt globules—depending upon the emulsifying agent.

California Bearing Ratio (CBR). A simple strength test comparing the bearing capacity of a material to that of a well-graded crushed stone. The test uses a 1.95 in penetration piston to measure the strength.

Compaction. The process used to densify a mass of material.

Cross-slope. The slope (change in elevation over length) of the pavement surface expressed as a percent designed to promote surface drainage.

Crown. A crowned pavement section slopes from the centerline of the pavement to each edge to promote surface drainage.

Crushed Stone. Angular aggregate produced by mining a suitable rock deposit and breaking the rock down to the desired size using crushers.

Drum Mix Plant. A manufacturing facility for producing asphalt paving mixtures that proportions aggregate, then dries and mixes the aggregate with a proportional amount of asphalt in the same drum. Variations of this type of plant use several types of drum modifications, separate (and smaller) mixing drums, and coating units (coater) to accomplish the mixing process.

Fatigue Cracking. Interconnected cracks forming a series of small blocks resembling an alligator's skin or chicken-wire, and caused by excessive deflection of the surface over unstable subgrade or lower courses of the pavement structure. Also referred to as alligator cracking.

Full-Depth Asphalt Pavement. An asphalt pavement in which asphalt mixtures are employed for all courses above the prepared subgrade.

Full-Depth Patching. Patching that extends from the pavement surface to the subgrade.

Geosynthetics. Polymeric products used in a variety of civil engineering applications. The most common geosynthetics used in pavement applications include geotextiles, geogrids, and geocomposites.

Gravel. Aggregate produced by natural processes of weathering and erosion, and typically has a rounded shape.

Hot Mix Asphalt (HMA). Asphalt mixture produced by heating the asphalt binder to decrease its viscosity, and drying the aggregate to remove moisture from it prior to mixing. Mixing is generally performed at temperatures ranging from 300 -350^{o}F depending on the mix type.

Job Mix Formula (JMF). The specific material composition, or recipe, for an asphalt mixture including the aggregate type and gradation, binder type and content, additives, and tolerances.

Liquid Limit. The water content at which the behavior of a soil changes from plastic to liquid.

Milling Machine. Primary method used to remove old asphalt pavement surface material prior to overlay.

Overlay. Placement of a layer of asphalt over an existing pavement structure.

Oxidation. The reaction of oxygen with asphalt binder, which has a stiffening effect on the binder.

Paver. A self-propelled fromless laydown machine with a floating screed that is used to place asphalt on a roadway prior to compaction.

Performance Graded (PG). Asphalt binder grade designation used in Superpave; based on the binder's mechanical performance at critical temperatures and aging conditions. This system directly correlates laboratory testing to field performance through engineering principles.

Planned Stage Construction. Construction of roads and streets by applying successive layers of asphalt according to design and a predetermined time schedule.

Plasticity Index. Range of water contents in which a soil exhibits plastic properties.

Pneumatic Tire Roller. Self-propelled compaction device that uses pneumatic tires to compact the underlying asphalt layer.

Proof Rolling. A method of ensuring that a prepared subgrade or aggregate base has no unstable areas. This is performed by driving a tandem axle truck loaded to a specific weight over the prepared area and the ground surface is observed to identify any pumping or movement, which is an indication of an unstable area.

Reclaimed Asphalt Pavement (RAP). Asphalt that has been removed from an old asphalt pavement. The material is typically crushed and processed and then used in new asphalt pavements.

Reflective Cracking. Cracks in asphalt overlays that reflect the crack pattern in the pavement structure underneath. They are caused by vertical or horizontal movements in the pavement beneath the overlay and brought on by expansion and contraction with temperature or moisture changes.

Roller Pattern. A specific plan created by a paving contractor to consistently achieve the target pavement density. The roller pattern includes the number of passes of each specific roller used on a project.

Segregation. Non-uniform distribution of the coarse and fine aggregate components within an asphalt mix.

Soil Stabilization. Permanent physical and/or chemical alteration of soils to enhance their physical properties.

Steel Wheel Roller. Self-propelled compaction devise that uses steel drums to compress the underlying asphalt. They can be either static or vibratory rollers.

Stripping. Breaking of the adhesive bond between the binder and aggregate in an asphalt mixture caused by water or water vapor getting between the binder film and aggregate surface.

Subgrade. The soil prepared to support a pavement structure or a pavement system. It is the foundation of the pavement structure.

Swale. A low tract of land designed to manage water runoff, filter pollutants, and increase rainwater infiltration.

Tack Coat. A low viscosity asphalt emulsion used to create a bond between an existing pavement surface and a new asphalt layer or overlay.

Warm Mix Asphalt (WMA). Production of an asphalt mixture at significantly lower temperatures (50-100^{o}F lower than HMA).

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For your Next Paving Project, Contact One of These

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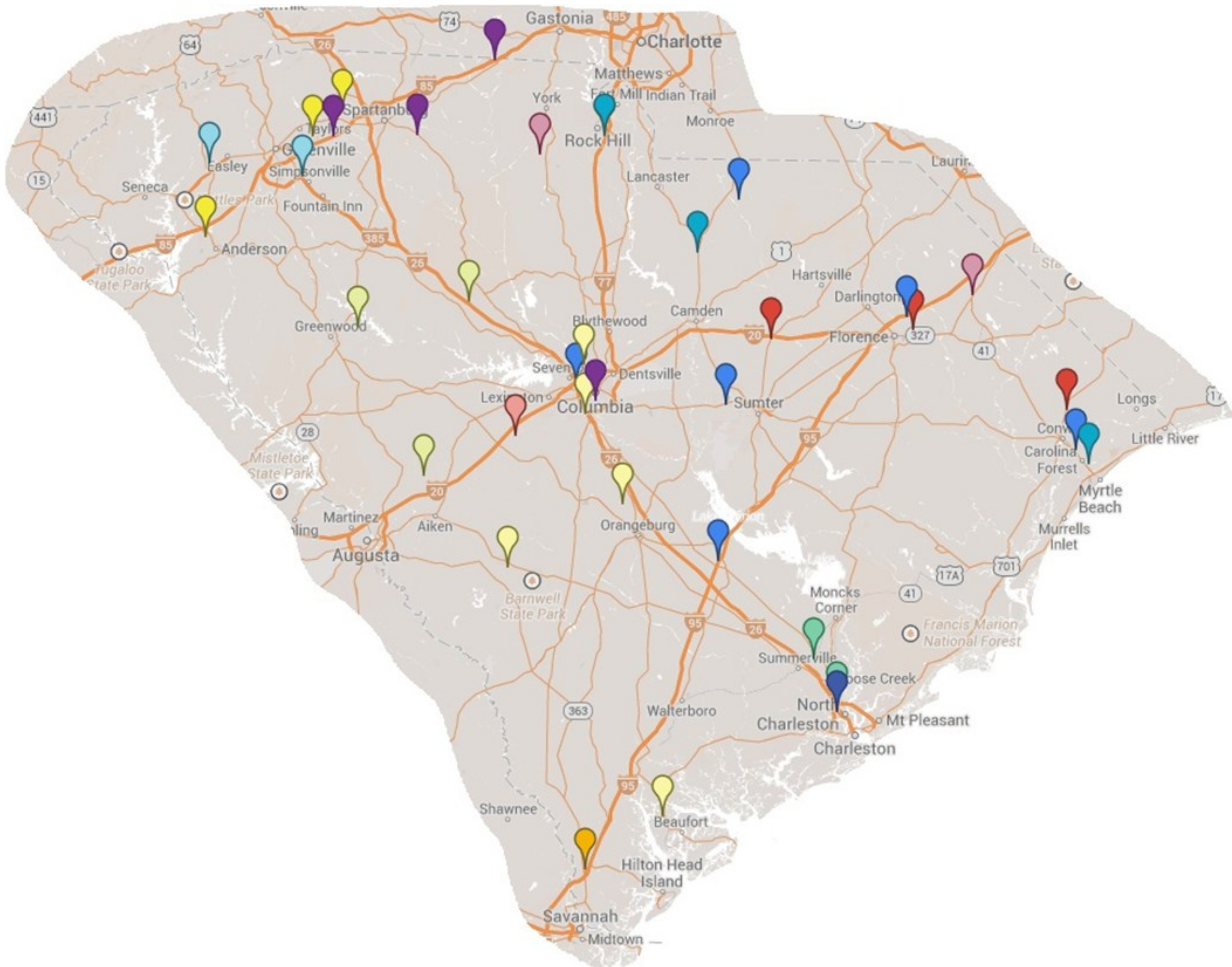
SCAPA CONTRACTOR MEMBER PLANT LOCATIONS



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