The Asphalt Paving Association of Iowa (APAI) is an organization of asphalt concrete producers and their associate members from the paving industry around the state. APAI was formed in 1955 for the purpose of advancing knowledge in the use of this paving material and to provide a service to the public and to the users of asphalt.

The APAI is constantly seeking new techniques, product improvements, and design methods, all of which are made available for the benefit of pavement users. Design and construction seminars and educational reports and brochures are developed and disseminated to ensure a high-quality product. A wide variety of technical literature and audio-visual presentations are available by calling the APAI office.

The ultimate quality of your asphalt paving project is directly related to the experience, skill, and equipment of the contractor doing the work. Behind each contractor is a tremendous investment in equipment, highly skilled manpower, and a pride of workmanship in building asphalt pavement of the highest quality. Whatever the project, APAI members are your assurance of quality.

APAI’s professional staff and member firms are qualified and eager to serve you. They welcome inquiries about design procedures and cost estimates at any time.
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  Credits
  References
This Asphalt Paving & Design Guide has been prepared by the members and staff of the Asphalt Paving Association of Iowa to assist you in understanding Asphalt Concrete pavement design and construction.

This Design Guide is not intended to circumvent asphalt pavement designs by competent design engineers using actual project traffic loading data and known subgrade soil characteristics. However, it will provide the owner, architect, engineer, developer, and government official with basic guidelines to be used in the absence of professional services. Readers are cautioned that the information contained in this Design Guide may be insufficient when used alone, and other resource materials and authorities should be consulted for specific site design.

The criteria for specific pavement design applications are unpredictably varied. The examples contained in the Design Guide are composites of those designs, procedures, and applications that have proven successful in the state of Iowa. References to authorities and agencies do not constitute their endorsement of this Design Guide. Suggested references and authorities should be used by the reader if further clarification is required.

All Asphalt mixes referred to in this Design Guide comply with the Iowa Department of Transportation’s specifications for Asphalt Concrete mixes. These are proven mixes, readily available throughout the state of Iowa from companies experienced in producing and constructing quality hot mixed Asphalt Concrete pavements.

**DESIGN GUIDE FORMAT**

The purpose of this Design Guide is to present materials that provide a basic knowledge of asphalt pavement design without being too technical. Understanding some of the basic properties of asphalt and aggregates is essential when relating pavement designs to specific conditions and needs. Thickness design tables and construction details are included for various roadway and recreational uses. Pavement management and rehabilitation options are also important considerations.

The Design Guide is presented in a logical format for asphalt paving design, construction, and maintenance processes.
I.

THE

ASPHALT

ADVANTAGE
Chapter 1

The Asphalt Advantage

Paving with asphalt concrete allows you to pave faster, more efficiently, more economically, and with greater serviceability than with any other paving material in the world. That may seem like a pretty bold claim, but those who work in paving know it’s true. Asphalt Concrete has an absolute advantage in every paving application. This Design Guide will tell you about those advantages.

SMOOTHNESS

Asphalt will consistently give the driving public the smooth, quiet ride they have come to expect from this product. Asphalt Concrete is machine-placed, so it has a uniform surface unsurpassed by other pavements. Repetitive joints, noisy surface texture, and blowups are eliminated by this method of construction. These features benefit airport users, too. Asphalt Concrete runways and taxiways mean safer landings and takeoffs, because such surfaces are smoother and easier to maintain.

STAGED CONSTRUCTION

A major advantage for Asphalt Concrete is the potential for staged construction. The asphalt base course can be placed and used under traffic during initial construction. This pavement can then be overlaid with final surface courses. Staged construction improves on-site conditions, removes the aspect of muddy soils, and provides a place to store construction materials and equipment. This method also provides an opportunity to discover and correct unanticipated problem areas, such as a weak subgrade, poor drainage, or poorly compacted trenches, which can be repaired at minimal cost.
EASE OF CONSTRUCTION

Asphalt Concrete is machine-placed, removing the need for time-consuming form work and steel reinforcement. Traffic can use the pavement almost immediately – no delay is required to allow the pavement to cure. The lack of pavement joints reduces maintenance requirements. Repair of an asphalt surface is quick and easy, because there is little downtime waiting for a patch to cure.

DURABILITY

Asphalt Concrete is a flexible pavement, with same bridging action, which allows it to withstand occasional overloads without serious damage. Its resistance to freeze-thaw and deicing salts allows it to wear better during winter. Its lack of repetitive joints removes the possibility of blowups that plague Portland Cement Concrete during summer. Inch for inch, asphalt cement concrete performs better than Portland Cement Concrete.

ECONOMICAL

The Federal Highway Administration has shown that a dollar spent on asphalt pavements goes 26.9 percent farther than a dollar spent on concrete pavements. That’s because asphalt is cost-effective. It has a lower first cost than concrete and it lasts longer. Staged construction helps spread out the cost of placement. Because asphalt pavement has no joints to repair and is not affected by freeze-thaw actions, it is much less expensive to maintain.

SAFETY

Asphalt pavements offer high skid resistance values. The dark color of asphalt reduces glare, helps melt ice and snow, and provides a high contrast for lane markings.
**RECYCLABLE**

Another major advantage of Asphalt Concrete is its ability to be completely recycled. Not only can the aggregates be reused, but the asphalt cement binder also retains its cementing properties and can be reused in a new mix. Pavements can be recycled both on site using cold mix or via a hot mix plant. Recycled pavements have been tested and proven in both the laboratory and the field to perform at least as well as virgin aggregate mixes. Over 90% of the hot mix asphalt plants in Iowa are capable of using reclaimed asphalt pavement (RAP). Asphalt pavements are 100 percent recyclable.

**VERSATILITY**

The versatility and popularity of asphalt is evident across the state of Iowa and all America – factories and schools, office parks and playgrounds, and the overwhelming majority of our streets and roads stand as clear testimony that the advantages of asphalt make it America’s first choice for paving and rehabilitation.
II.

ASPHALT

and

ASPHALT PAVING MATERIALS
Chapter 2
Asphalt and Asphalt Paving Materials

ASPHALT DEFINED

The black cementing agent known as asphalt has been used for road construction for centuries. Although there are natural deposits of asphalt, or rock asphalt, most used today is produced by the oil refining industry. Asphalt is a constituent of most petroleums and is isolated through the refining process of distillation. (See Figure 2-1.)

Asphalt is called a bituminous material because it contains bitumen, a hydrocarbon material soluble in carbon disulfate. The tar obtained from the destructive distillation of soft coal also contains bitumen. Both petroleum asphalt and coal tar are referred to as bituminous materials. However, because their properties differ greatly, petroleum asphalt should not be confused with coal tar. Whereas petroleum asphalt is composed almost entirely of bitumen, the bitumen content in coal tar is relatively low. The two materials should be treated as separate entities.

One of the characteristics and advantages of asphalt as an engineering construction and maintenance material is its great versatility. Although a semi-solid at ordinary temperatures, asphalt may be liquified by applying heat, dissolving it in solvents, or emulsifying it. Asphalt is a strong cement that is readily adhesive and highly waterproof and durable, making it particularly useful in road building. It is also highly resistive to the actions of most acids, alkalis, and salts.

Covering more than 90 percent of the nation’s paved highways, Asphalt Concrete is the most widely used paving material in the United States. For versatility, durability, and ease of construction, it has no equal.

AGGREGATES

Aggregates (or mineral aggregates) are hard, inert materials such as sand, gravel, crushed stone, slag, or rock dust. Properly selected and graded aggregates are mixed with the cementing medium asphalt to form pavements. Aggregates are the principal load-supporting components of an Asphalt Concrete pavement. They total 90 to 95 percent of the mixture by weight and 75 to 85 percent by volume.
Classifications

Asphalt Concrete paving aggregates are classified according to source or means of preparation. A brief description of the classifications follows.

Pit or Bank-Run Aggregates

Both gravel and sand are typically pit or bank-run natural aggregates. They usually are screened to proper size and washed to remove dirt before being used for Asphalt Concrete paving purposes.

Processed Aggregates

When natural pit or bank-run aggregate has been crushed and screened to make it suitable for Asphalt Concrete pavements, it is considered a processed aggregate. Crushing typically improves the particle shape by making the rounded particles more angular. Crushing also improves the size distribution and range.

Crushed stone is also a processed aggregate. It is created when the fragments of bedrock and large stones are crushed so that all particle faces are fractured. Variation in size of particles is achieved by screening. Aggregates that have received little or no screening are known as crusher run. These aggregates are generally more economical than screened aggregates and can be used in Asphalt Concrete pavements in many instances.

In the processing of crushed limestone, the rock dust produced is separated from the other crushed aggregate and may be used as crushed sand or as a mineral filler in Asphalt Concrete pavements.
Asphalt Paving Materials

2. Cleanliness. Foreign or deleterious substances make some materials unsuitable for paving mixtures.

3. Toughness. Toughness or hardness is the ability of the aggregate to resist crushing or disintegration during mixing, placing, and compacting; or under traffic loading.

4. Soundness. Although similar to toughness, soundness is the aggregate’s ability to resist deterioration caused by natural elements such as the weather.

5. Particle shape. The shapes of aggregate particles influence the asphalt mixture’s overall strength and workability as well as the density achieved during compaction. When compacted, irregular particles such as crushed stone tend to “lock” together and resist displacement.

6. Surface texture. Workability and pavement strength are influenced by surface texture. A rough, sandpapery texture results in a higher strength than a smooth texture. Although smooth-faced aggregates are easy to coat with an asphalt film, they are generally not as good as rough surfaces. It is harder for the asphalt to “grip” the smooth surface.

7. Absorption. The porosity of an aggregate permits the aggregate to absorb asphalt and form a bond between the particle and the asphalt. A degree of porosity is desired, but aggregates that are highly absorbant are generally not used.

8. Stripping. When the asphalt film separates from the aggregate because of the action of water, it is called stripping. Aggregates coated with too much dust also can cause poor bonding which results in stripping. Aggregates readily susceptible to stripping action usually are not suitable for asphalt paving mixes unless an anti-stripping agent is used.

Synthetic Aggregates
Aggregates produced by altering both physical and chemical properties of a parent material are called synthetic or artificial aggregates. Some are produced and processed specifically for use as aggregates; others are the byproduct of manufacturing and a final burning process. Blast furnace slag is an example of a synthetic aggregate.

Desirable Properties of Aggregates
Selection of an aggregate material for use in an Asphalt Concrete pavement depends on the availability, cost, and quality of the material, as well as the type of construction for which it is intended. To determine if an aggregate material is suitable for use in asphalt construction, evaluate it in terms of the following properties:

1. Size and grading. The maximum size of an aggregate is the smallest sieve through which 100 percent of the material will pass. How the Asphalt Concrete is to be used determines not only the maximum aggregate size, but also the desired gradation (distribution of sizes smaller than the maximum).
**ASPHALT CEMENT**

Asphalt is produced in a variety of types and grades ranging from hard-brittle solids to near water-thin liquids. The semi-solid form known as asphalt cement is the basic material used in Asphalt Concrete pavements. Liquid asphalt is produced when asphalt cement is blended or “cut back” with petroleum distillates or emulsified with water and an emulsifying agent. Liquid asphalt products may be produced for various uses and applications.

Some of the types and characteristics of asphalt are noted in the following table.

### Table 2-1. Asphalt Types, Characteristics and General Uses

<table>
<thead>
<tr>
<th>Type/Grade*</th>
<th>Percent Asphalt (Min)</th>
<th>Types-Percent Cutback</th>
<th>Penetration (Min-Max)</th>
<th>Flash Point (Min)</th>
<th>Applic. Temp.</th>
<th>General Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS- 1</td>
<td>57</td>
<td>Water 43</td>
<td>100-200</td>
<td>70-160</td>
<td>70-160</td>
<td>Tack</td>
</tr>
<tr>
<td>SS-1 H</td>
<td>57</td>
<td>Water 43</td>
<td>40-90</td>
<td>70-160</td>
<td>70-160</td>
<td>Tack, Slurry Surface Treatment</td>
</tr>
<tr>
<td>CSS- 1</td>
<td>57</td>
<td>Water 43</td>
<td>100-250</td>
<td>70-160</td>
<td>70-160</td>
<td>Tack</td>
</tr>
<tr>
<td>CSS-1 H</td>
<td>57</td>
<td>Water 43</td>
<td>40-90</td>
<td>70-160</td>
<td>70-160</td>
<td>Tack, Slurry Surface Treatment</td>
</tr>
<tr>
<td>RS-1</td>
<td>55</td>
<td>Water 45</td>
<td>100-200</td>
<td>125-185</td>
<td>70-140</td>
<td>Bituminous Seal Coat</td>
</tr>
<tr>
<td>RS-2</td>
<td>63</td>
<td>Water 37</td>
<td>100-200</td>
<td>125-185</td>
<td>Bituminous Seal Coat</td>
<td></td>
</tr>
<tr>
<td>CRS-1</td>
<td>60</td>
<td>Water 40</td>
<td>100-250</td>
<td>125-170</td>
<td>Bituminous Seal Coat</td>
<td></td>
</tr>
<tr>
<td>CRS-2</td>
<td>65</td>
<td>Water 35</td>
<td>100-250</td>
<td>125-170</td>
<td>Bituminous Seal Coat</td>
<td></td>
</tr>
<tr>
<td>RC-70</td>
<td>55</td>
<td>Naphtha 45</td>
<td>70-140</td>
<td>80°F</td>
<td>70-150</td>
<td>Tack</td>
</tr>
<tr>
<td>MC-30</td>
<td>55</td>
<td>Kerosene 45</td>
<td>120-250</td>
<td>70-150</td>
<td>Prime</td>
<td></td>
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<tr>
<td>MC-70</td>
<td>55</td>
<td>Kerosene 45</td>
<td>70-140</td>
<td>145-165</td>
<td>Bit. Seal Coat, Tack, Cold Mix, Patch Mix</td>
<td></td>
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<tr>
<td>MC-250</td>
<td>67</td>
<td>Kerosene 33</td>
<td>250-500</td>
<td>165-200</td>
<td>Bit. Seal Coat, Tack, Cold Mix, Patch Mix</td>
<td></td>
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<tr>
<td>MC-800</td>
<td>75</td>
<td>Kerosene 25</td>
<td>800-1600</td>
<td>175-255</td>
<td>Bit. Seal Coat, Tack, Cold Mix, Patch Mix</td>
<td></td>
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<tr>
<td>MC-3000</td>
<td>80</td>
<td>Kerosene 20</td>
<td>3000-6000</td>
<td>215-290</td>
<td>Bituminous Seal Coat</td>
<td></td>
</tr>
</tbody>
</table>

Note: Flashpoint does not necessarily indicate burning or explosive point. However, care should be exercised when heating all RC and MC asphalts because the cutback used reacts the same as gasoline. All material used as cold patch should be mixed at the lowest temperature possible to prevent loss of cutback causing the mixture to harden before use.
ASPHALT CONCRETE

Asphalt Concrete is known by many different names: hot mix asphalt, plant mix, bituminous mix, bituminous concrete, and many others. It is a combination of two primary ingredients - aggregates and asphalt cement. The aggregates total 90 to 95 percent of the total mixture by weight. They are mixed with 5 to 10 percent asphalt cement to form Asphalt Concrete.

The aggregates and asphalt are combined in an efficient manufacturing plant capable of
producing specified materials. Plant equipment includes: cold bins for storage of graded aggregate; a dryer for drying and heating aggregates to the required mixing temperature; a pug mill for combining the graded, heated aggregate and liquid asphalt cement according to specified mix formulas; and tanks for storing the liquid asphalt.

Asphalt Concrete is transported by truck to the paving site where it is spread to a uniform thickness with a mechanical paving or finishing machine. Then the material is compacted to the required degree by heavy, self-propelled rollers, producing a smooth, well-compacted pavement course.

The paving or finishing machine places the Asphalt Concrete at temperatures above 225° F. The material should be compacted before the mix temperature falls below 175° F to achieve adequate density.

**COLD MIX ASPHALT CONCRETE**

Cold mix Asphalt Concrete, or cold placed mixture, is generally a mix made with emulsified or cutback asphalt. Emulsified asphalts may be anionic or cationic MS or SS grades. Aggregate material may be anything from a dense-graded crushed aggregate to a granular soil having a relatively high percentage of dust. At the time of mixing, the aggregate may either be damp, air-dried, or artificially heated and dried.

Mixing methods may be performed either in the roadway, on the side of the roadway, or in a stationary mixing facility. The resultant mixtures usually are spread and compacted at atmospheric temperatures.

Cold mix asphalt may be used for surface, base, or subbase courses if the pavement is properly designed. Cold mix surface courses are suitable for light and medium traffic; however, they normally require a seal coat or hot Asphalt Concrete overlay as surface protection. When used in the base or subbase, they may be suitable for all types of traffic.

**Bituminous Treated Aggregate Base**

Bituminous treated aggregate base is one type of cold mix Asphalt Concrete. It can consist of processing gravels; crushed stones; or blends of gravel, sand, and crushed stone materials – each stabilized with a specified percentage of asphalt. Job mix formulas (mentioned in Chapter 3) are not required. These mixtures are placed as a base course and stabilized-shoulder surfacing, although other uses may be assigned by special design. All designs should provide for a seal coat or surface course to provide protection from traffic abrasion and weathering.
Table 2-2 acts as a guide to uses of asphalt in cold mixes.

For additional information on asphalt and asphalt paving materials, refer to The Asphalt Handbook. Other references are listed in Appendix D.

**Table 2.2. General Uses of Emulsified Asphalt**

<table>
<thead>
<tr>
<th>Type of Construction</th>
<th>RS-1</th>
<th>RS-2</th>
<th>MS-1, HFMS-1</th>
<th>MS-2, HFMS-2</th>
<th>MS-2h, HFMS-2h</th>
<th>MS-2s</th>
<th>SS-1</th>
<th>SS-1h</th>
<th>CRS-1</th>
<th>CRS-2</th>
<th>CMS-2</th>
<th>CMS-2h</th>
<th>CSS-1</th>
<th>CSS-1h</th>
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<tr>
<td><strong>Asphalt-aggregate mixtures:</strong></td>
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<td>For pavement bases and surfaces:</td>
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<td>Plant mix (hot)</td>
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<td>Plant mix (cold)</td>
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<td>Open-graded aggregate</td>
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<td>Dense-graded aggregate</td>
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<td><strong>Mixed-in-place:</strong></td>
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<td>Sandy soil</td>
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<td>Slurry seal</td>
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<td><strong>Asphalt-aggregate applications:</strong></td>
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<td>Treatment and seals:</td>
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<tr>
<td>Single surface treatment (Chip Seal)</td>
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<td></td>
<td>X</td>
<td>X</td>
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<td>Multiple surface treatment</td>
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<tr>
<td>Sand seal</td>
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<tr>
<td><strong>Asphalt applications:</strong></td>
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<tr>
<td>Fog seal</td>
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<td>X</td>
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<td>X</td>
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<td>X</td>
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<td>Prime coat-penetrable surface</td>
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<td>X</td>
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<td>X</td>
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<td>X</td>
<td>X</td>
<td></td>
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<td>X</td>
<td></td>
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<tr>
<td>Tack coat</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
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<td>X</td>
<td></td>
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<tr>
<td>Dust binder</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
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<td>Mulch treatment</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
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<tr>
<td>Crack filler</td>
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<td>X</td>
<td>X</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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<td><strong>Maintenance mix:</strong></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Immediate use</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

A Grade of emulsion other than FHMS-2h may be used where experience has shown that they give satisfactory performance.
B Diluted with water by the manufacturer.
C Diluted with water
D Mixed in prime only.
III.

DESIGN

CONSIDERATIONS
Chapter 3
Design Considerations

FUNDAMENTALS OF DESIGN

Many types of asphalt pavement structures exist, along with a number of different methods for designing the thickness of each element in any pavement. Fundamental to each design are the following:

1. Traffic loading (volume and weight)
2. Soil-support capability (including drainage considerations)
3. Material specifications (aggregate and asphalt)

Each element is an important variable in the structural design process. The economic life of the final product could depend on the close attention given to detail when analyzing traffic loadings, soil-support capability, and material specifications.

The degree of detail needed in a specific design situation is related to the type of use intended for the pavement and the sensitivity of each variable. For example, a freeway design with large traffic volumes and heavily-loaded trucks requires a careful estimate of traffic; however, the number of bicycles and the loading on a bicycle path would not be significant factors in the path’s structural design.

An obviously unstable soil condition (noted, perhaps, from previous experiences) indicates the need for a soil analysis during the thickness design process of almost any type of pavement. Because drainage and soil-support values are major factors in pavement life, it is important to know the quality of the supporting soil. This is especially true for a facility that will require a large construction investment.

On the other hand, a specific traffic study or soil analysis for a residential street or parking lot may not be deemed necessary in a certain location. For example, a location having a long and successful record of asphalt pavements constructed for a specific use (e.g., driveways and residential streets) provides the designer with a background for selecting acceptable values.

For the users of this Design Guide, much of the design work has been done – design charts are presented for selecting pavement thickness. Traditionally, many designers group pavements according to use and “use tables” are commonly applied throughout the United States. Chapter 4 provides design tables by specific type of facility use.

TRAFFIC

Because the primary function of a pavement is to transmit and distribute wheel loads of vehicles to the supporting subgrade, information about the traffic stream is required. Pavement must be designed to serve traffic needs over a period of years. Therefore, the volume of traffic and the various types of vehicles using the facility must be estimated for the pavement’s anticipated life.

A traffic assignment is made based on: (1) historic records of traffic volumes on comparable types of highways and the anticipated function of the highway under consideration, and (2) the percentage of trucks. The traffic analysis procedure determines the repetitions of an equivalent single axle load (ESAL). This parameter is defined as the equivalent number of applications of an 18,000-pound, single-axle load during the pavement’s design life.

The effects of truck traffic on a pavement can be dramatic. Tests have shown that a single-unit, fully loaded, 80,000-pound truck can cause pavement damage equivalent to that caused by 6,000 automobiles. This illustrates why carefully made estimates of expected traffic are critical to proper pavement design.
In The Asphalt Institute’s *Asphalt Pavement Thickness Design (IS-181)*, traffic is separated into classes. This Design Guide follows the Institute’s traffic class style by breaking traffic into six classes, I through VI. Each class is defined by an average daily traffic range, the average number of heavy trucks expected on the pavement during the design period, and the appropriate type of street or highway.

**TRAFFIC CLASSIFICATIONS**

**Class I**  
(Very Light) Less than 50 autos per day, less than 7,000 heavy trucks expected during design period.  
- Parking lots, driveways  
- Light traffic farm roads  
- School areas and playgrounds  
- Seasonal recreational roads  
- Sidewalks and bicycle paths  
- Golf cart paths  
- Tennis courts

**Class II**  
(Light) Up to 200 autos per day, 7,000 to 15,000 trucks expected during the design period.  
- Residential streets  
- Rural farm roads  
- Parking lots of less than 500 stalls  
- Airports - 7,500 pound maximum gross weight

**Class III**  
(Medium) Up to 700 autos per day, 70,000 to 150,000 trucks expected during design period.  
- Urban minor collector streets  
- Rural minor collector streets  
- Parking lots - more than 500 stalls  
- Airports - 15,000 pound maximum gross weight.
Class IV
(Medium) Up to 4,500 autos per day, 700,000 to 1,500,000 trucks expected during design period.
Urban minor arterial and light industrial streets
Rural major collector and minor arterial highways
Industrial lots, truck stalls
Bus driveways and loading zones
Airports - 30,000 pound maximum gross weight.

Class V
(Heavy) Up to 9,500 autos per day, 2,000,000 to 4,500,000 trucks expected during design period.
Urban freeways, expressways and other principal arterial highways
Rural interstate and other principal arterial highways
Local industrial streets
Major service drives or entrances
Airports - 60,000 pound maximum gross weight

Class VI
(Very Heavy) Unlimited autos, 7,000,000 to 15,000,000 trucks expected during design period.
Urban interstate highways
Some industrial roads
Airports - over 60,000 pounds maximum gross weight

For more information on this subject refer to the Asphalt Institute’s publications *Thickness Design-Asphalt Pavements for Highways and Streets* (MS-1) and *Asphalt Pavement Thickness Design* (IS-181).
SOIL SUPPORT CAPABILITY

The ability of the subgrade to support loads transmitted from the pavement is one of the most important factors in determining pavement thickness. The subgrade must serve as a working platform to support construction equipment and as a foundation for the pavement structure that supports and distributes traffic loads. Thus, it is essential to evaluate the strength of the subgrade before beginning the structural design of the pavement. Figure 3-1 shows the spread of wheel load through the pavement structure and on to the subgrade.

If sufficient pavement thickness is not provided, the applied loads could cause greater stresses on the subgrade than it can resist. This may result in deflection of the pavement and ultimately in its failure.

In street and highway construction, the subgrade provides the foundation for the pavement. Different types of soils have different abilities to provide support. A sandy soil, for example, will support greater loads without deformation than a silty clay soil. Thus, for any given traffic volume and weight of vehicles using the roadway, a greater pavement thickness must be provided on clay soils than on sandy soils.

Figure 3-1. Spread of wheel-load through pavement structure.

Soil Classifications

Soil is classified for road and street construction in order to predict subgrade performance on the basis of a few simple tests. The American Association of State and Highway Transportation Officials (AASHTO) classification system for soils is commonly used as a test for subgrade-support value.

According to the AASHTO system, soils that have approximately the same general load-carrying capabilities are grouped in classifications of A-1 through A-7. (See Table 3-1.) In general the best highway subgrade soils are A-1, and the worst are A-7. The classification is based on the sieve analysis, plasticity index, and liquid limit of the soil being tested.
### Table 3-1. Classification of Soils and Soil-Aggregate Mixtures (With Suggested Subgroups)

<table>
<thead>
<tr>
<th>General Classification</th>
<th>Granular Materials (35% or Less of Total Sample Passing No. 200)</th>
<th>Silt-Clay Materials (More than 35% of Total Sample Passing No. 200)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A-1</td>
<td>A-2</td>
</tr>
<tr>
<td>Group Classification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sieve Analysis, percent passing:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 10</td>
<td>50 max</td>
<td>51 min</td>
</tr>
<tr>
<td>No. 40</td>
<td>30 max</td>
<td>25 max</td>
</tr>
<tr>
<td>No. 200</td>
<td>15 max</td>
<td>10 max</td>
</tr>
<tr>
<td>Characteristics of fraction passing No. 40:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid Limit</td>
<td>6 max</td>
<td>NP</td>
</tr>
<tr>
<td>Plasticity Index</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Usual Types of Significant Constituent Materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stone Fragments, Gravel &amp; Sand</td>
<td>Fine Sand</td>
<td>Silty or Clayey Gravel and Sand</td>
</tr>
<tr>
<td>General Rating As Subgrade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excellent to Good</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fair to Poor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The state of Iowa has been subdivided into surface soil areas that reflect their engineering soil classification. The accompanying figure provides a general soil classification map of Iowa. In addition, soil bulletins with more complete and detailed descriptions of soil types are available for each Iowa county. Note that these maps provide only a general grouping of a range of soils. Local spots may vary considerably.

![Figure 3-2. General Soil Classification Areas](image)
Subgrade Strength

Because thickness calculations depend on the strength of the finished subgrade, the soil must be tested for this information. Tests are based on bearing capacity related to the moisture and density of the soil. The California Bearing Ratio (CBR) is one of the most widely used methods of designing pavement structure. Once the CBR value is determined, the soil classification can be identified. Or, when the soil classification is known, a relative CBR value can also be identified.

The lower the CBR value of a particular soil, the less strength it has to support the pavement. This means that a thicker pavement structure is needed on a soil with a low CBR rating than on a soil with a high CBR rating. Generally, clays have a CBR classification of 6. Silty loam and sandy loam soils are next with CBR values of 6 to 8. The best soils for road building purposes are sands and gravels whose CBR ratings normally exceed 10.

The change in pavement thickness needed to carry a given traffic load is not directly proportional to the change in CBR value of the subgrade soil. For example, a one-unit change in CBR from 5 to 4 requires a greater increase in pavement thickness than does a one-unit CBR change from 10 to 9.

A number of soil classification-strength systems are currently in use for roads and airports. A correlation chart follows for a general soil overview.
CORRELATION CHART SOIL CLASSIFICATION-STRENGTH

California Bearing Ratio (CBR) – ASTM D1883

UNIFIED ASTM D2487

AASHTO M 145

A-1-b, A-1-a
A-2-6, A-2-7
A-2-4, A-2-5

Federal Aviation Agency

E-12, E-11
E-10

Resistance Value – R
20 30 40 50 55 60 70 80 85

AASHTO TRIAXIAL CLASSIFICATION (STD T 212-65)

Modulus of Subgrade Reaction – k, psi per in.
100 150 200 250 300 400 500 600 700 800

Bearing Value, psi (30-in. diameter plate, 0.1-in. deflection)
10 20 30 40 60 70

California Bearing Ratio – CBR

2 3 4 5 6 7 8 9 10 15 20 25 30 40 50 60 70 80 90 100
Soil Testing
A qualified laboratory can conduct tests to provide soil classification and subgrade strength information (such as the CBR). Such testing is necessary to ensure a proper structural design and is part of all major projects. However, such soil testing is relatively expensive, especially for small projects, and may not be available for all projects.

Subgrade Classes
For the designs recommended in this manual, all soils have been divided into three classes: good (G), Moderate (M), and poor (P). CBR design values are assigned to these different subgrade classes.

Good
Good subgrade soils retain a substantial amount of their load-supporting capacity when wet. Included are the clean sands, sand-gravels, and those free of detrimental amounts of plastic materials. Excellent subgrade soils are relatively unaffected by moisture or frost and contain less than 15 percent passing a No. 200 mesh sieve. A soil classified as good will have a CBR value of 9 or greater.

Moderate
Moderate subgrade soils are those that retain a moderate degree of firmness under adverse moisture conditions. Included are such soils as loams, silty sands, and sand gravels containing moderate amounts of clays and fine silts. When this soil becomes a cohesive material, it should have a minimum proctor density of 110 pounds per square inch. A soil classified as moderate will have a CBR value of 6 to 8.

Poor
Poor subgrade soils are those that become quite soft and plastic when wet. Included are those soils having appreciable amounts of clay and fine silt (50 percent or more) passing a No. 200 sieve. The coarse silts and sandy loams may also exhibit poor bearing properties in areas where deep-frost penetration into the subgrade is encountered for any appreciable periods of time. This also is true where the water table rises close to the surface during certain periods of the year. A soil classified as poor will have a CBR value of 3 to 5.

Very poor soils (those with a CBR of 3 or lower) often perform poorly as pavement subgrades. However, to improve their performance, these soils can be stabilized with granular material or a geotextile. Lime, fly-ash, asphalt cement, portland cement, and combinations of cement stabilizers also can be added to improve the subgrade support. The selection of a stabilizing agent, the amount to use, and the application procedure depend on the soil classification and the subgrade-support value desired. These should be determined through appropriate laboratory testing.
DRAINAGE

General Considerations

Highway engineers recognize the importance of good drainage in the design, construction, and maintenance of any pavement. Probably no other single factor plays such an important role in determining the ability of a pavement to provide trouble-free service throughout long periods of time.

The accumulation of water in the subgrade, or in an untreated aggregate base course, usually creates problems. When the soil is saturated, application of dynamic wheel loads induces pore pressures and lowers the resistance to shear. Some soils have a high volume change (when water is added), which causes differential heaving. The subsequent weakening of the pavement structure causes it to lose stability and its capability to support traffic loads.

The combination of water in the pavement’s asphalt layers and dynamic, repeated traffic loading can strip or separate the asphalt film from the aggregate. This reduces the load-carrying capacity of the mixture.

When developing the features of a highway drainage system, it is important to consider the system’s principal purposes: (1) to collect and drain away both surface water and subsurface water; (2) to lower the groundwater table, if necessary; (3) to intercept water from surrounding areas and carry it away from the roadway; and (4) to prevent or retard erosion.

There are two basic categories of drainage – surface and subsurface. Surface drainage includes the disposal of all water present on the pavement surface, shoulder surface, and the adjacent ground when sloped toward the pavement. Subsurface drainage deals with water in the subbase, the surrounding soil, and in the several pavement courses. Inadequate attention to either of these two drainage conditions can lead to premature pavement failure.

Surface Drainage

In surface drainage conditions, the pavement and shoulders must be crowned or cross-sloped to facilitate the flow of water off of the roadway. Normally, the cross-slope moves the water to a curbed or inverted-shaped gutter and then off of the pavement into a storm sewer or flume to a ditch.

On parking areas or playgrounds, the cross-slope or crown may be inverted toward a center swale with a grated inlet for drainage interception.

Shoulders can best be drained if the entire shoulder width has an asphalt-paved surface. If the shoulder is not asphalt, its cross-slope should be steeper in order to minimize seepage through the aggregate or grass shoulder.

Surface drainage from the pavement and from the adjacent land areas must be intercepted and disposed of. If a curbed section is provided, drainage is accumulated in the gutter area and periodically discharged into either a pavement inlet or a ditch through a flume. The determination of inlet locations requires technical calculations and studies to maintain a tolerable spread of water on the pavement.

Drainage ditches are constructed along the edges of non-curbed roadway sections. Water flowing from the pavement and shoulder surfaces moves down the roadway foreslope into a rounded ditch area. A backslope leads from the bottom of the ditch up to intercept the adjacent land. The adjacent land is frequently sloped toward the ditch and can contribute to a sizable portion of the drainage flow.
Good design practices will provide cross-slopes both on the surface and in the underlying pavement courses and subgrade. In this way, water will not accumulate but will flow laterally to the sides.

**Subsurface Drainage**

Subsurface water is free water that percolates through, or is contained in, the soil beneath the surface. When it emerges or escapes from the soil, it is referred to as seepage water. The point of emergence is called a seepage area or a spring.

Pavement subsurface water usually is present as free water that flows under the force of gravity or as capillary water that moves under capillary action in the soil.

Water will rise from the underlying soil through the subgrade and into an untreated aggregate pavement course. This free water will move readily into an untreated aggregate base to a low point on the profile. If steep grades are present, and the subsurface water flowing in an untreated aggregate base to the low spot is not intercepted, a hydrostatic head may result. This lifting force will cause a failure of the pavement structure. Water in the pavement courses also may contribute to the stripping of asphalt films from the aggregate particles.

**Subdrains**

When water collects in the structural elements of the pavement, subdrains are required. Identification of these areas and determination of drain locations require the technical expertise and insight of an engineer. The choice of drain filter material and the design of the drainage system must be given careful attention by experts. Perforated and slotted pipe usually serve to move the free water from the trouble spot to a drainage area.

**Check Drainage During Construction**

Regardless of the care used in the preliminary investigation, the soil survey, and in the pavement structure’s design, it is usually not possible to determine from borings the exact elevation of water-bearing strata or the rate of flow that will develop. For this reason, it is essential that the engineer reevaluate the conditions and check the need for, and the adequacy of, any subsurface drainage indicated on the plans.

Soil conditions should be observed during the grading and subgrade preparation work. Any wet, soft, or spongy areas encountered at grade should be investigated and provisions made for their proper drainage. Even a minor rate of seepage may build up to a large quantity of water over a period of time if a means of escape is not provided. Such a soft spot usually forewarns of a structural failure at a later date—even shortly after traffic has used the new facility. After the pavement is in place, corrective measures are costly, create traffic problems, and can cause poor public relations.
DESIGN TYPES

In general, the design of a new asphalt pavement structure involves two basic pavement types: (1) full-depth pavements, and (2) pavements with an untreated aggregate base course.

Full-depth, Asphalt Concrete paving is one in which asphalt mixtures are used for all courses above the subgrade. Such pavements are less affected by subgrade moisture and are more conducive to staged construction. Full-depth asphalt pavement is used in all types of highway construction and where high volumes of traffic and trucks are anticipated.

Untreated aggregate base pavements may be used where local aggregates and subsurface drainage conditions are suitable and where traffic loadings are minimal. The untreated aggregate base is placed and compacted on the prepared subgrade. In general, an asphalt binder and surface course are used to complete the pavement structure. Although the initial cost for untreated aggregate base asphalt pavements may be lower than the cost for full-depth, hot mix types, the former type should be used with caution. Moisture in the base may cause pavement failure.

Figure 3-4

Figure 3-5
ASPHALT CONCRETE SPECIFICATIONS

It is recommended that specifications for Asphalt Concrete follow Iowa Department of Transportation Standard Specifications for the particular class and mixture size required. This will result in uniformity and economy because most APAI-member contractors may have job mixes on several mixtures already prepared for state and local agency use. In the absence of a previously prepared job mix, the contractor or private testing should develop a job mix formula for the desired project, and intended use.

The following gradations are suggested guidelines for the class and mixture size specified. The asphalt cement content is a guide only and may need to be adjusted to meet local aggregate conditions and intended use.

Quality of aggregates (according to factors such as freeze and thaw, abrasion, plasticity index, etc.) for the various mixes can be obtained from the Iowa DOT Standard Specifications in the 3 sections listed in the following tables.

Salvaged and Reclaimed Material
Recycling of reclaimed asphalt pavement (RAP) material into new asphalt concrete has become a routine and accepted process for use of the salvaged product. The contractor substitutes reclaimed aggregate and binder for virgin materials at varying ratios from 10-50% by weight. The salvaged material may be taken from the project or a stockpile provided by the contractor. Control of the use and quality of the recycled mix shall be through the job mix formula process. Salvaged material may be used in the base, binder, and surface courses of type A or B mixes for which it qualifies. Historical test results from milled material taken from Iowa DOT projects indicate that millings are falling within the following limits.

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>%Passing Rang</th>
<th>%Passing AVERAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot;</td>
<td>98-100</td>
<td>100</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>94-100</td>
<td>98</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>84-98</td>
<td>93</td>
</tr>
<tr>
<td>No. 4</td>
<td>65-88</td>
<td>77</td>
</tr>
<tr>
<td>No. 8</td>
<td>51-74</td>
<td>62</td>
</tr>
<tr>
<td>No. 16</td>
<td>36-57</td>
<td>49</td>
</tr>
<tr>
<td>No. 30</td>
<td>28-42</td>
<td>36</td>
</tr>
<tr>
<td>No. 50</td>
<td>17-30</td>
<td>24</td>
</tr>
<tr>
<td>No. 100</td>
<td>11-26</td>
<td>18</td>
</tr>
<tr>
<td>No. 200</td>
<td>9-22</td>
<td>14</td>
</tr>
</tbody>
</table>

Salvaged materials, whether previously processes or not, shall be sized for the intended mix use. Final gradation of the recycled mix shall meet the requirements for the specified mix size and type.
Aggregate for Type B. Asphalt Concrete

Aggregate for Type B asphalt concrete shall meet the requirements as specified in Section 4126, Iowa DOT Standard Specifications.

Gradation: The job mix formula for the mixture size specified, when tested by means of laboratory sieves, shall meet the following requirements:

Table 3-3. Gradation of Job Mix: Type B Asphalt Concrete

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>1 inch</th>
<th>3/4 inch</th>
<th>1/2 inch</th>
<th>3/8 inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2 inch</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 inch</td>
<td>92-100</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/4 inch</td>
<td>77-92</td>
<td>98-100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1/2 inch</td>
<td>60-80</td>
<td>76-95</td>
<td>92-100</td>
<td>100</td>
</tr>
<tr>
<td>3/8 inch</td>
<td>—</td>
<td>60-88</td>
<td>70-94</td>
<td>98-100</td>
</tr>
<tr>
<td>No. 4</td>
<td>34-55</td>
<td>42-70</td>
<td>50-75</td>
<td>63-89</td>
</tr>
<tr>
<td>No. 8</td>
<td>20-38</td>
<td>30-56</td>
<td>36-60</td>
<td>44-68</td>
</tr>
<tr>
<td>No. 30</td>
<td>7-20</td>
<td>14-32</td>
<td>16-34</td>
<td>20-37</td>
</tr>
<tr>
<td>No. 200</td>
<td>2-7</td>
<td>3-7</td>
<td>3-7</td>
<td>3-7</td>
</tr>
</tbody>
</table>

Asphalt Cement Content: 5-7%

AC-5 grade recommended for Type B Base
AC-10 grade recommended for Type B Surface
*Class 1 - 30 percent crushed particles (minimum)
*Class 2 - no minimum percentage of crushed particles
50 - Blow Marshall mix criteria normally specified

Aggregate for Type A Asphalt Concrete

Aggregate for Type A asphalt concrete shall meet the requirements as specified in Section 4127, Iowa DOT Standard Specifications.

Gradation: The job mix formula for the mixture size specified, when tested by means of laboratory sieves, shall meet the following requirements:

Table 3-4. Gradation of Job Mix: Type A Asphalt Concrete

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>1 inch</th>
<th>3/4 inch</th>
<th>1/2 inch</th>
<th>3/8 inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 1/2 inch</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 inch</td>
<td>92-100</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/4 inch</td>
<td>77-92</td>
<td>98-100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1/2 inch</td>
<td>60-80</td>
<td>76-95</td>
<td>92-100</td>
<td>100</td>
</tr>
<tr>
<td>3/8 inch</td>
<td>—</td>
<td>60-88</td>
<td>70-94</td>
<td>98-100</td>
</tr>
<tr>
<td>No. 4</td>
<td>34-55</td>
<td>42-70</td>
<td>50-75</td>
<td>63-89</td>
</tr>
<tr>
<td>No. 8</td>
<td>20-38</td>
<td>30-56</td>
<td>36-60</td>
<td>44-68</td>
</tr>
<tr>
<td>No. 30</td>
<td>7-20</td>
<td>14-32</td>
<td>16-34</td>
<td>20-37</td>
</tr>
<tr>
<td>No. 200</td>
<td>2-7</td>
<td>3-7</td>
<td>3-7</td>
<td>3-7</td>
</tr>
</tbody>
</table>

Asphalt Cement Content: 5-7%

AC-10 grade recommended for Type A Concrete
*60 percent crushed particles (minimum)
50 - Blow Marshall mix criteria normally specified
Standard Mix Descriptions

It is recommended that designs and specifications for Asphalt Concrete follow the Iowa Department of Transportation standards for the specific type and mix design required. Instructional Memorandum on Field Inspection manuals published by the Central Office of Materials, are available from the DOT storeroom. Designated mix descriptions follow.

Recycled Asphalt Concrete

Recycled asphalt concrete mixtures are composed of a combination of virgin gravel, crushed stone, sand and salvaged/reclaimed asphalt paving (RAP) materials. The combined aggregates are mixed with asphalt cement through a hot mix plant mix process to produce a recycled mix.

Job mix formulas are required by the specifications to determine the target percent asphalt binder for a specified mix type and gradation. Recycled materials are routinely used in base, binder, and surface courses. These mixtures may be designed as type A or B asphalt concrete with the same quality requirements, therefore requiring no name change or designation.

Type B Asphalt Concrete

Type B Asphalt Concrete base, binder, leveling, strengthening, and surface course mixtures are composed of gravel, crushed stone; or combinations of gravel, stone, and sand, produced from approved sources and formulated to provide service for roads carrying low to moderate traffic. The formulation procedure results in a job mix formula for each aggregate combination along with a recommended percentage of asphalt cement.

Type B Asphalt Concrete may be placed as a base, binder, or surface course depending upon mix class and size. Type B specifications are used in secondary road systems, municipal streets, parking lots, and other areas. To meet all appropriate requirements, and because several options are available, care must be exercised in selecting the mix class, lift thickness, and mix size during the various stages of design and construction.

Job mix formulas are required by the specifications for all aggregate combinations. The formulas are comprised of the aggregate percentages, percent asphalt, and gradation as limited by the specification requirements.

Type A Asphalt Concrete

Type A Asphalt Concrete binder, leveling, strengthening, and surface course mixtures are composed of combinations of high-quality gravel, crushed stone, and sand produced from approved sources and formulated for service on road surfaces carrying a high volume of traffic; and as surface courses with lower-quality base courses for other uses. Because four mix sizes are available, care must be exercised in selecting the lift thickness and mix sizes during the various stages of design and construction so that appropriate requirements are met.

Job mix formulas are required by the specifications for all aggregate combinations. The formulas are comprised of the aggregate percentages, percent asphalt, and gradation as limited by specified tolerances for each controlling sieve size.
CONSTRUCTION OF ASPHALT PAVEMENTS

Construction Equipment
It is the responsibility of the contractor to provide equipment that will produce results in compliance with the plans and specifications of the contract. The following section contains information on the basic equipment used to produce and construct Asphalt Concrete pavements.

Asphalt Mixing Facilities
The mixing facility produces the Asphalt Concrete mixture placed as pavement. The facility should be designed and coordinated to produce mixtures within specified job mix tolerances.

Asphalt storage tanks must have a device for the controlled heating of material to temperature requirements as specified. Heating should be accomplished so that no flame will come in contact with the tank. The circulating system should be large enough to ensure proper and continuous circulation of asphalt between storage tank and mixer during the entire operating period. While the pump is in operation, the discharge end of the circulating pipeline should be kept below the surface of the asphalt in the tank.

The facility should have an accurate means for feeding the aggregate into the dryer to ensure uniform production and a constant temperature. The facility should contain a rotary drum dryer that will continuously agitate the aggregates during the heating, drying, and mixing processes.

For batch mixing processes, screens may be positioned over the hot aggregate storage bins to separate all aggregates to sizes required for proportioning to meet the job mix formulae. Where no such screens are used, proportioning must be handled as part of the cold-feed system.

If drum mixers or continuous mixing plants are used in the production of mixes, approved materials must be fed into the cold-feed system in the proper proportions to meet the job mix formulae.

The facility must have the means to obtain the required percentage of asphalt in the mix within the tolerance specified. This can be accomplished by weighing, metering, or measuring volumetrically. Steam jacketing or other insulation should maintain the specified temperature of asphalt in pipelines, meters, buckets, spray bars, flow lines, and other containers.

A thermometer ranging from 200°F to 400°F should be placed in the asphalt feed line or tank.

The facility should have a dust collector, a mixer cover, and whatever additional housing necessary to ensure proper dust control.

Adequate and safe stairways to the mixer platform and guarded ladders to other units of the facility should be provided. All gears, pulleys, chains, sprockets, and other dangerous moving parts should be well guarded and protected. A platform for sampling and inspection of the mix should be located near the facility.
The use of surge or storage bins is permitted for storing asphalt pavement materials.

**Hauling Equipment**

Haul trucks are used to bring the Asphalt Concrete from the asphalt mixing facility to the paving site. Equipment used in hauling bituminous mixtures should be clean and have tight bodies to prevent material loss. These units can be equipped with suitable covers to protect the mixture in transit during unfavorable weather conditions.

**Compaction Equipment**

Compaction equipment is used to compact the Asphalt Concrete to attain density after placement. The compaction equipment should be of the type or types that will produce the required density and pavement smoothness. Steel-wheeled rollers are of four types—three-wheeled, two-axle tandem, three-axle tandem, and vibratory. These rollers should be equipped with power units. Rollers should be in good working condition and equipped with a reversing clutch. Rollers should have adjustable scrapers to keep the wheel surfaces clean and an efficient means of keeping them wet to prevent mixes from sticking. These surfaces should have no flat areas, openings, or projections that will mar the surface of the pavement.

Pneumatic-tired rollers should be self-propelled. The rollers should be equipped with pneumatic tires of equal size and diameter that are capable of exerting average contact pressure.

**Spreading Equipment**

Spreading equipment is used to place the Asphalt Concrete as pavement. Where feasible, the Asphalt Concrete should be placed and spread by a mechanical spreader. Mechanical, self-powered pavers should be capable of spreading the mix within the specified tolerances and true to the line, grade, and crown indicated on the plans. A motor patrol may be used for the leveling course.

Pavers should be equipped with efficient steering devices and should be capable of traveling both forward and in reverse. They should be equipped with hoppers and distributing screws that place the mix in front of screeds. The screed unit should be adjustable in height and crown and equipped with a controlled heating device for use when required. The screed must strike off the mix to the depth and crown section specified without the aid of manual adjustment during operation. Pavers should be capable of spreading mixes without segregation or tearing and producing a finished surface of even and uniform texture.
The wheels of the roller should be spaced so that one pass will accomplish one complete coverage equal to the rolling width of the machine. There should be a minimum of 1/4 inch-overlap of the tracking wheels. The roller should be constructed so that the contact pressure will be uniform for all wheels and the tire pressure of the tires will not vary more than 5 pounds per square inch. The rollers should be constructed with enough ballast space to provide uniform wheel loading as may be required. The operating weight and tire pressure of the roller may be varied to obtain contact pressures that will result in the density.

Cold Milling
Cold milling is the most common pavement scarification method for salvaging material. This method uses a self-propelled milling machine with a rotating drum containing special teeth that cut the pavement to a predetermined depth and reduce the size of the salvaged material. Single-pass cutting widths of up to 12 feet and depths of 4 inches have been attained with this type of machine. The drums are hydraulically controlled and are capable of maintaining road profile and depth of cut to 1/8 inch. Milled material is usually suitable for hot or cold recycling with little additional breakdown.

Construction Practices
Preparation of Subgrade
Remove all large rock, debris, and topsoil from the area to be paved. All vegetation, including root systems, should be removed. To prevent future growth, the subgrade should be treated with an approved herbicide. Install all drainage and utility facilities and then properly backfill and compact.

The subgrade must be properly shaped to meet true lines and elevations and compacted to not less than 95 percent of maximum laboratory density. The surface of the compacted subgrade should not vary more than 3/4 inch from the established grade.

Areas showing pronounced deflection under construction traffic indicate instability in the subgrade. If the situation is not corrected by reworking and additional rolling, the areas must be removed and replaced with suitable material and compacted or stabilized using a geotextile. The use of Asphalt Concrete base or course granular material is recommended.

Constructing Asphalt Concrete Base
The Asphalt Concrete base may consist of one or more courses placed on a prepared subgrade. It must have a total compacted thickness as indicated on the plans or as specified. In general, a base with total thickness of 4 inches or less should be placed in one lift. A base with a total thickness of more than 4 inches may be placed in two or more lifts with the bottom lift having a minimum of 3 inches.

Untreated Aggregate Base
The crushed aggregate base course may consist of one or more layers placed directly on the prepared subgrade. The material must be spread and compacted to the required thickness, grades, and dimensions indicated in the plans or as specified. The minimum compacted thickness of each lift should be no less than two times the size of the largest aggregate particle, or 4 inches, whichever is greater. The maximum compacted lift thickness should be 6 inches.

Binder and Surface Courses
The upper lifts of the pavement may consist of one or more courses of Asphalt Concrete placed on the previously constructed Asphalt Concrete base. In general, the top or wearing course must not be constructed to a depth greater than 3 inches. Where a thickness greater than 3 inches is indicated, it should be placed in two courses consisting of a binder and a surface or wearing course. The minimum lift thickness must be 1 inch, but this thickness should never be less than two times the maximum particle size.
**Tack Coat**

A tack or bond coat of CSS-1, SS-1, MC-70 or an approved alternate should be applied between each course at an undiluted rate of 0.02 to 0.05 gallons per square yard. The surface must be cleaned of all dust, dirt, or other loose material before the bond coat is applied. If emulsion is used, it should be diluted with equal parts of water or as specified in the proposal.

All pavement markings on public highways must comply with the Manual on Uniform Traffic Control Devices (MUTCD). Standards for color, materials, width, shape, and concept are set forth in the MUTCD.

The most frequently used pavement markings are longitudinal markings. The basic concept is to use yellow lines to delineate the separation of traffic flows in opposing directions or to mark the left edge of pavement of divided highways and one-way roads. Solid yellow lines are also used to mark no passing zones. White lines are used to separate traffic lanes flowing in the same direction or to mark the outside edge of pavements.

**Minimum Grade**

It is recommended that the minimum pavement grade be not less than 2 percent (approximately 1/4 inch per foot) to ensure proper surface drainage.

**Pavement Markings**

Pavement markings have an important function in traffic control. They convey certain regulations and warnings in a clearly understandable manner without diverting the driver’s attention from the roadway. An asphalt pavement clearly has an advantage in providing highly visible, attention-attracting markings – even under adverse weather conditions. White- and yellow-painted markings or thermo markings stand out on the black background.

The patterns and width of longitudinal lines vary with use. A broken line is formed by segments and gaps, usually in the ratio of 1:3. On rural highways, a recommended standard is 10-foot segments and 30-foot gaps. A normal line is 4 to 6 inches wide.
Flaggers may be needed for safety. It is important that they be properly dressed and instructed in flagging standards. Flagging procedures are set forth in Part XI of the MUTCD, and the Iowa DOT provides supplemental information and training booklets.

Figure 3-7. Use of hand devices by flagger.
Barricades are portable devices used to control traffic by closing, restricting, or delineating construction areas. The MUTCD specifies the type of barricade to use for a specific situation and describes barricade characteristics. The diagonal stripes slope downward either left or right from the upper to lower panel and should “slope downward in the direction toward which traffic must turn in detouring.”

When a road or a site normally used by traffic is closed, it should be barricaded and signed in accordance with the MUTCD.

Figure 3-8. Channelizing devices.
TESTING AND INSPECTION

Inspection and testing of the production and placement of Asphalt Concrete – or of any material – is necessary to ensure a quality product. Plant and field inspections include: (1) the preparation of the aggregate; (2) the Asphalt Concrete plant setup and operation; (3) the control of the Asphalt Concrete mixture; (4) the delivery and placement; and (5) the final finishing and compaction.

It is beyond the scope of this Design Guide to do more than emphasize the importance of a quality testing and inspection program. The Iowa DOT publishes manuals on asphalt plant inspection and field testing that are available through the DOT Storeroom. Training courses on this subject are offered by APAI and other agencies.
III.

DESIGN CONSIDERATIONS
Chapter 4
Thickmess Design

GENERAL CONSIDERATIONS

Several procedures can be used to calculate the thickness of the proposed asphalt pavement. All are based on the volume and weight of the traffic that will use the facility and on the load-supporting capability of the underlying soil.

The AASHTO Road Test and other studies have indicated that heavy-vehicle wheel loads cause much greater damage to roads than do light loads. Thus, where large volumes of traffic with heavily loaded trucks are anticipated, an in-depth analysis of the pavement thickness is important. Because all of the higher functional classifications have the potential for heavy loadings, a traffic analysis is an important part of the preparation for thickness computations. Similarly, a knowledge of the load-bearing capability of the soil is an important aspect of the structural design process. The lack of a soil study with appropriate corrective action could significantly shorten the life of a poorly drained pavement.

All of the design procedures available for a structural thickness analysis cannot be included here. Additional information is included in The Asphalt Institute’s Thickness Design Manual (MS 1) and their Simplified and Abridged Version published in Information Series No. 18 (IS-181). Another reference is The AASHTO Guide for Design of Pavement Structures, 1986. These guides are based on mechanistic/empirical design models, and they use Nomographs to attain pavement thickness. Several computer programs for designing pavements (including Asphalt Institute and AASHTO programs) are also available. The APAI or your contractor can help you with design questions.
PAVEMENT THICKNESS DESIGN TABLES

Future traffic assignments can be rather nebulous and are subject to many external influences. Some areas see no growth over a design period. Therefore, common practice is to group categories of traffic into classes. Similarly, it has been found that, based on a local knowledge, soil-supporting values can be grouped into classifications of poor, moderate, and good. These classifications (see Chapter 3) provide an opportunity to use pavement thickness design tables rather than more detailed formula procedures. These tables have been prepared by experts in the industry to simplify the process for engineers, technicians, and architects who prepare a pavement design.

Design Procedure

Tables 4-1 through 4-5 can be used directly to select design thicknesses from the design input factors. In order to use the tables, appropriate traffic and subgrade classes must be selected as follows.

Traffic

The design procedure separates traffic into six classes (I through VI). Each class is defined by the number of autos per day, the average daily number of heavy trucks expected on the facility during the design period, and the type of street or highway. Traffic classifications are presented in Chapter 3. The pavement thicknesses given in the tables of this and the following chapter are based on the average daily traffic (ADT) values over a 20-year design period. Heavy trucks are described as two-axle, six-tire vehicles or larger.

Soils

It is desirable to have laboratory tests on the subgrade soil. However, if tests are not available, a design may be based on careful field examinations by an engineer. Soils may be classified as good, moderate, or poor or by a CBR value. Soil classifications are presented in Chapter 3. If a soil CBR value lies between those given in the classifications, the lower classification is used.

Design Steps

The following steps can be used to determine a pavement thickness.

1. From the known average daily traffic, determine the total number of trucks over the design period. Using this information, select the traffic classifications (Class I through VI) from Chapter 3.

2. Select a subgrade class (good, moderate, or poor) from Chapter 3 using soil data from the project. If no soil information is known, use the poor classification for the subgrade.

3. Select a design thickness from Tables 4-1 through 4-5 using the selected traffic class and subgrade class.

Design Example

- A collector street is estimated to carry 500 vehicles and 20 trucks a day. Traffic class III is selected using Chapter 3.

- No soil data is known, so the engineer selects the poor soil classification.

- The total design thickness selected from Table 4-2 is 7-1/2 inches. The base course is 6 inches, and the surface course is 1-1/2 inches.
Residential Streets

The primary function of residential streets is to provide access to abutting property. This classification consists of the largest portion of the street and road network and provides the linkage to connect to higher types of facilities. Motorists’ speeds may be low, or higher, depending on the standards to which the specific facility is designed.

Most trips on residential streets are short, and traffic volumes are low. Truck traffic is usually limited to vehicles that provide residential services such as trash pickup, moving vans, heating oil delivery, etc.

Table 4-1. Thickness Design: Residential Streets

<table>
<thead>
<tr>
<th>A. For Asphalt Concrete Base Pavements</th>
<th>Thickness in Inches</th>
<th>Traffic Class (ADT)</th>
<th>Subgrade CBR</th>
<th>Base</th>
<th>Surface</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Criteria*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>9</td>
<td>4.0</td>
<td>1.0</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>6</td>
<td>5.0</td>
<td>1.0</td>
<td>6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>3</td>
<td>5.5</td>
<td>1.5</td>
<td>7.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III (201-700 ADT)</td>
<td>Good</td>
<td>9</td>
<td>4.0</td>
<td>1.5</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>6</td>
<td>5.0</td>
<td>1.5</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>3</td>
<td>6.0</td>
<td>1.5</td>
<td>7.5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B. For Untreated Aggregate Base Pavements</th>
<th>Thickness in Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Criteria*</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>9</td>
</tr>
<tr>
<td>Moderate</td>
<td>6</td>
</tr>
<tr>
<td>Poor</td>
<td>3</td>
</tr>
<tr>
<td>Untreated Aggregate Base</td>
<td>Asphalt Concrete Base</td>
</tr>
<tr>
<td>II (50-200 ADT)</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>8.0</td>
</tr>
<tr>
<td>III (201-700 ADT)</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>8.0</td>
</tr>
</tbody>
</table>

*See chapter 3 for traffic and soil class details
Collector Streets
Collector or feeder streets connect the residential street system with arterial routes. This classification of street serves dual functions of both land access and through-traffic movement. The mileage of collectors in any one jurisdiction may be very small. Generally, collectors have moderate amounts of low-to-intermediate-speed traffic, including some bus traffic, and heavy trucks.

Table 4-2. Thickness Design: Collector Streets

<table>
<thead>
<tr>
<th>A. For Asphalt Concrete Base Pavements</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traffic Class (ADT)</strong></td>
<td><strong>Subgrade</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Class</strong></td>
</tr>
<tr>
<td>II (50-200 ADT)</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
</tr>
<tr>
<td>III (201-700 ADT)</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
</tr>
<tr>
<td>IV (1,501-4,500 ADT)</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B. For Untreated Aggregate Base Pavements</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traffic Class (ADT)</strong></td>
<td><strong>Subgrade</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Class</strong></td>
</tr>
<tr>
<td>II (50-200 ADT)</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
</tr>
<tr>
<td>III (201-700 ADT)</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
</tr>
<tr>
<td>IV (1,500-4,500 ADT)</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
</tr>
</tbody>
</table>

*See chapter 3 for traffic and soil class details
**Arterial Streets**

Arterial streets provide the highest operating speeds and the highest levels of traffic service. They serve the major corridors of traffic and are usually multiple lane in urban areas. They are typically high-volume facilities that connect major activity centers.

As with the design of residential and collector facilities, many localities have adopted standards for the design and construction of arterials. All applicable local and state codes, standards, and specifications should be complied with when designing and constructing these facilities. The information contained in this Design Guide should augment local guidelines in assuring the proper planning and design of arterials.

Although arterials frequently carry very large traffic volumes and heavy truck traffic, pavement designs recommended herein are applicable only to facilities having a low percentage of truck traffic. Design of Asphalt Concrete pavements for trucking highways requires considerable expertise and detailed analysis.

**Table 4-3. Thickness Design: Arterial Streets**

<table>
<thead>
<tr>
<th>Traffic Class (ADT)</th>
<th>Subgrade Class</th>
<th>Thickness in Inches</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Asphalt Concrete</strong></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Good</td>
<td>5.5</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>6.5</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>7.5</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Good</td>
<td>7.5</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>8.0</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>9.0</td>
<td>3.0</td>
</tr>
<tr>
<td>VI</td>
<td>Good</td>
<td>Special design consideration needed. Refer to a more complete design procedure.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*See chapter 3 for traffic and soil class details*
Low-Volume Secondary and Rural Roads

Low-volume rural roads consist of local roads and collectors whose primary function is to provide access to abutting property and from there to arterial routes. Motorists’ speeds may be low, or higher depending on the standards to which the specific facility is designed.

Truck traffic is usually low, consisting of some bus traffic and heavy trucks. Most traffic consists of vehicles providing local service such as heating oil and gasoline, local farm traffic, and farm vehicles.

<table>
<thead>
<tr>
<th>Traffic Class (ADT)</th>
<th>Subgrade</th>
<th>Design Criteria*</th>
<th>Thickness in Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Class</td>
<td>CBR</td>
</tr>
<tr>
<td>II (50-200 ADT)</td>
<td>Good</td>
<td>9</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>6</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>3</td>
<td>5.5</td>
</tr>
<tr>
<td>III (201-700 ADT)</td>
<td>Good</td>
<td>9</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>6</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>3</td>
<td>6.0</td>
</tr>
<tr>
<td>IV (1,501-4,500 ADT)</td>
<td>Good</td>
<td>9</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>6</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>3</td>
<td>7.5</td>
</tr>
</tbody>
</table>

*See chapter 3 for traffic and soil class details
High-Volume Secondary and Rural Roads

High-volume rural roads consist of arterial roads and the highway system. They provide the highest operation speeds and highest level of traffic service. These roads serve as the major corridors of traffic and frequently have multiple lanes.

These roads frequently carry large traffic volumes and heavy truck traffic. The information contained within this guide should augment local guidelines in assuring proper planning and design of high-volume roads. The values found here are only applicable to low truck volumes. Design of Asphalt Concrete pavements for trucking highways requires considerable expertise and detailed analysis.

Table 4-5. Thickness Design: High Volume Secondary and Rural Roads

<table>
<thead>
<tr>
<th>Traffic Class (ADT)</th>
<th>Subgrade Class</th>
<th>Design Criteria*</th>
<th>Thickness in Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Asphalt Concrete</td>
<td>Base</td>
</tr>
<tr>
<td>III (201-700 ADT)</td>
<td>Good</td>
<td>9</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>6</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>3</td>
<td>6.0</td>
</tr>
<tr>
<td>IV (1,501-4,500 ADT)</td>
<td>Good</td>
<td>9</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>6</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>3</td>
<td>7.5</td>
</tr>
<tr>
<td>V (6,001-9,500 ADT)</td>
<td>Good</td>
<td>9</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>6</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>3</td>
<td>9.0</td>
</tr>
<tr>
<td>VI (9,501 &amp; Above ADT)</td>
<td>Good</td>
<td>9</td>
<td>Special design consideration needed. Refer to a more complete design procedure.</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

*See chapter 3 for traffic and soil class details
V.

PARKING LOT DESIGN
Chapter 5
Parking Lot Design

GENERAL CONSIDERATIONS

The parking lot is the first - and the last - part of a building complex to be viewed by the user. It is the gateway through which all customers, visitors, and employees pass. This first impression is very important to the overall feeling and atmosphere conveyed to the user.

Developers want their new facilities to be attractive, well designed, and functional. Though many hours are spent on producing aesthetically pleasing building designs, the same design consideration for the parking area is often overlooked. Pavements in parking areas that are initially under-designed can experience excessive maintenance problems and a shortened service life.

When properly designed and constructed, parking areas can be an attractive part of the facility that is also safe, and most important, usable to the maximum degree. In addition, parking areas should be designed for low maintenance costs and easy modification for changes in use patterns.
The information in this chapter will provide a general guide to proper parking area design, construction, and facility layout. Minimum pavement thickness designs are given for various size parking lots, heavily-loaded areas, and industrial parking lots. In addition, this chapter gives comparable designs for both full depth asphalt pavements and asphalt over untreated aggregate base.

**General Planning**

In developing the parking area plan, several important details should be considered. First and foremost in the mind of the developer may be providing the maximum parking capacity in the available space while ensuring convenience and safety.

Rules have been developed for optimizing parking area space. Among them are the following:

1. Use rectangular areas where possible.
2. Make the long sides of the parking areas parallel.
3. Design so that parking stalls are located along the lot’s perimeter.
4. Use traffic lanes that serve two rows of stalls.

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Spaces/Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td></td>
</tr>
<tr>
<td>Single-Family</td>
<td>2.0/Dwelling</td>
</tr>
<tr>
<td>Multifamily</td>
<td></td>
</tr>
<tr>
<td>Efficiency</td>
<td>1.0/Dwelling</td>
</tr>
<tr>
<td>1 - 2 Bedroom</td>
<td>1.5/Dwelling</td>
</tr>
<tr>
<td>Larger</td>
<td>2.0/Dwelling</td>
</tr>
<tr>
<td>Hospital</td>
<td>1.2/Bed</td>
</tr>
<tr>
<td>Auditorium/Theater/Stadium</td>
<td>0.3/Seat</td>
</tr>
<tr>
<td>Restaurant</td>
<td>0.3/Seat</td>
</tr>
<tr>
<td>Industrial</td>
<td>0.6/Employee</td>
</tr>
<tr>
<td>Church</td>
<td>0.3/Seat</td>
</tr>
<tr>
<td>College/University</td>
<td>0.5/Student</td>
</tr>
<tr>
<td>Retail</td>
<td>4.0/1000 GFA</td>
</tr>
<tr>
<td>Office</td>
<td>3.3/1000 GFA</td>
</tr>
<tr>
<td>Shopping Center</td>
<td>5.5/1000 GLA</td>
</tr>
<tr>
<td>Hotels/Motel</td>
<td>1.0/Room</td>
</tr>
<tr>
<td>Senior High Schools</td>
<td>0.2/Student</td>
</tr>
<tr>
<td></td>
<td>1.0/Staff</td>
</tr>
<tr>
<td>Other Schools</td>
<td>1.0/Classroom</td>
</tr>
</tbody>
</table>

GFA, sq. ft. of gross floor area
GLA, sq. ft. of gross leasable area
Special attention should be given to the flow of traffic in and out of the lot as well as circulating routes inside the lot. Keep entrances far away from busy street intersections and from lines of vehicles stopped at a signal or stop sign. Be sure that the entering vehicles can move into the lot on an internal aisle, thereby avoiding entering congestion caused by involvement with turning vehicles. A pedestrian traffic-flow study is important to provide information about both safety and convenience.

The 90° parking angle provides the most parking spaces for a given area. The high degree of difficulty for entering and leaving these parking stalls makes this type of parking more suited to all-day parking, such as employee parking. This angle is generally not preferred for “in and out” lots such as those of fast food restaurants and banks.

**Parking Angle**

The most popular angles for parking stalls are 60°, 45°, and 90°. The most common angle for parking is the 60° angle because of the ease of operation it provides. This angle permits reasonable traffic lane widths and eases entry and exit of the parking stall.

Where lot size restricts the dimensions available for aisles and stalls, a 45° angle may be used. The smaller change of direction required to enter and back-out of the stall space permits use of narrower aisles. The 45° angle reduces the total number of parking spaces for a given area but is the only acceptable angle for a herringbone parking lot pattern.

**Parking Space Dimensions**

Typical parking stall dimensions vary with the angle at which the stall is arranged in relation to the aisle. Stall widths (measured perpendicular to the vehicle when parked) range from 8-1/2 to 9-1/2 feet. The minimum width for public use parking spaces is 9 feet by 19 feet. Recommended stall dimensions for compacts and similar-sized vehicles are 7-1/2 feet by 15 feet. If a number of such spaces are to be provided, they should be grouped together in a prime area to promote their use. Stall widths for parking lots where shoppers generally have large packages, such as supermarkets and other similar parking facilities, should be 9-1/2 feet or even 10 feet wide.
Figure 5-2.

Table 5-2. Parking layout dimensions (ft) for 9 ft stalls at various angles.

<table>
<thead>
<tr>
<th>Stall Layout Elements</th>
<th>Dimension</th>
<th>On Diagram</th>
<th>45°</th>
<th>60°</th>
<th>75°</th>
<th>90°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stall width parallel to aisle</td>
<td>A</td>
<td>12.7 10.4 9.3 9.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stall length of line</td>
<td>B</td>
<td>25.0 22.0 20.0 18.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stall depth to wall</td>
<td>C</td>
<td>17.5 19.0 19.5 18.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aisle width between stall lines</td>
<td>D</td>
<td>12.0 16.0 23.0 26.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stall depth, interlock</td>
<td>E</td>
<td>15.3 17.5 18.8 18.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module, wall to interlock</td>
<td>F</td>
<td>44.8 52.5 61.3 63.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module, interlocking</td>
<td>G</td>
<td>42.6 51.0 61.0 63.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module, interlock to curb face</td>
<td>H</td>
<td>42.8 50.2 58.8 60.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bumper overhang (typical)</td>
<td>I</td>
<td>2.0 2.3 2.5 2.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offset</td>
<td>J</td>
<td>6.3 2.7 0.5 0.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Setback</td>
<td>K</td>
<td>11.0 8.3 5.0 0.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross aisle, one-way</td>
<td>L</td>
<td>14.0 14.0 14.0 14.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross aisle, two-way</td>
<td>M</td>
<td>24.0 24.0 24.0 24.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Parking Lot Markings

Markings are a very important element of a good parking lot. The parking area should be clearly marked to designate parking spaces and to direct traffic flow. As specified in the Manual on Uniform Traffic Control Devices (MUTCD), parking on public streets should be marked out by using white traffic paint, except for dangerous areas, which should be marked in yellow.

However, yellow lines are commonly used in off-street parking lots. All pavement striping should be 4 inches in width.

New asphalt surfaces can be marked with either traffic paint or cold-applied marking tape. For best results with paint application, allow the Asphalt Concrete to cure for several days.

Construction Practices

Drainage Provisions

Drainage problems are frequently a major cause of parking area pavement failures. It is critical to keep water away from the subgrade soil. If the subgrade becomes saturated, it will lose strength and stability, making the overlying pavement structure susceptible to breakup under imposed loads.

Drainage provisions must be carefully designed and should be installed early in the construction process. Parking area surfaces should have a minimum slope of 2 percent or 1/4 inch per foot. They should be constructed so water does not accumulate at the pavement edge. Areas of high natural permeability may require an underdrain system to carry water away from the pavement substructure. Any soft or spongy area encountered during construction should be immediately evaluated for underdrain installation or for removal and replacement with suitable materials.
The use of Asphalt Concrete base (compared to use of untreated aggregate base) will greatly reduce the potential for problems related to water strength and stability.

Subgrade Preparations
All underground utilities should be protected or relocated before grading. All topsoil should be removed. Low-quality soil may be improved by adding granular materials, lime, asphalt, or other mixtures. Laboratory tests are recommended to evaluate the load-supporting characteristics of the subgrade soil. However, designs are frequently selected after careful field evaluations based on experience and knowledge of local soil conditions.

The area to be paved should have all rock, debris, and vegetation removed. The area should be treated with a soil sterilant to inhibit future flora growth. Grading and compaction of the area should be completed so as to eliminate yielding or pumping of the soil.

The subgrade should be compacted to a uniform density of 95 percent of the maximum density. This should be determined in accordance with Standard Proctor density (Test Method 103). The compaction requirement may substitute a specified number of diskings and roller coverages of each lift. When finished, the graded subgrade should not deviate from the required grade and cross section by more than 1/2 inch in 10 feet.

Prime Coat
An application of a low-viscosity liquid asphalt may be required over untreated aggregate base before placing the Asphalt Concrete surface course. A prime coat and its benefits differ with each application, and its use often can be eliminated. Discuss requirements with the paving contractor.
Asphalt Base Construction
The asphalt base course material should be placed directly on the prepared subgrade in one or more lifts. It should be spread and compacted to the thickness indicated on the plans. Compaction of this asphalt base is one of the most important construction operations contributing to the proper performance of the completed pavement. This is why it is so important to have a properly prepared and unyielding subgrade against which to compact. The asphalt base material should meet the specifications for the mix type specified.

Untreated Aggregate Base Construction
The untreated aggregate base course should consist of one or more layers placed directly on the prepared subgrade. It should be spread and compacted to the uniform thickness and density as required on the plans. The minimum thickness of untreated aggregate is 4 inches. The aggregate material should be of a type approved and suitable for this kind of application.

It should be noted that an untreated aggregate base is sensitive to water in the subgrade. The pavement failures associated with water in the subgrade are accelerated if an untreated base allows water to enter the pavement structure.

Tack Coat
Before placing successive pavement layers, the previous course should be cleaned and a tack coat of diluted emulsified asphalt should be applied if needed. The tack coat may be eliminated if the previous course is freshly placed and thoroughly clean.

Asphalt Concrete Surface Course
Material for the surface course should be an Asphalt Concrete mix placed in one or more lifts to the true lines and grade as shown on the plans. The plant mix material should conform to specifications for Asphalt Concrete.

The asphalt surface should not vary from established grade by more than 1/4 inch in 10 feet when measured in any direction. Any irregularities in the surface of the pavement course should be corrected directly behind the paver. As soon as the material can be compacted without displacement, rolling and compaction should start and should continue until the surface is thoroughly compacted and all roller marks disappear.
THICKNESS DESIGN FOR PARKING LOTS

Design thicknesses given in this section are minimum values calculated on the volume and type of traffic that will use the facility and on the load-supporting capability of the underlying soils. For additional soil class information, refer to Chapter 3.

Special truck lanes are sometimes required to expedite traffic to loading areas, trash dumpster sites, and equipment areas. Design thicknesses for these lanes or pavement areas should be increased. Drainage problems are also a major cause of pavement failures. Their significance warrants a special section on drainage that should be reviewed before selecting a pavement design either from this guide or from any other source.

Design Procedure
Tables 5-3 through 5-6 can be used directly to select design thicknesses for a number of design input factors. To use the tables, appropriate traffic and subgrade classes must be selected as follows.

Design Steps
The following steps can be used to determine a pavement thickness.

1. Using the number of parking spaces to be marked, select the traffic class (less than 50 spaces, 50 to 500, more than 500, or industrial) to be used. Determine if any areas will receive heavy truck traffic.

2. Using soil data from the project, select a subgrade class (good, moderate, or poor) from Chapter 3. If no soil information is known, use the poor classification for the subgrade. (If the CBR value for the soil lies between the values given, use the lower classification.)

3. Using the selected traffic class and subgrade class, select a design thickness from Tables 5-3, 5-4, or 5-6. Use Table 5-5 to design heavily-loaded areas.

Design Example
- A new department store wishes to place a 350-car parking lot in front. A truck loading zone and dumpster site will be placed in back. From Chapter 3, traffic class II is selected.
- No soil data are known, so the engineer selects the poor soil classification.
- The total full-depth asphalt design thickness selected from Table 5-4 for the parking lot is 6-1/2 inches; the base course is 5 inches, and the surface course is 1-1/2 inch. The total full-depth asphalt design thickness selected from Table 5-5 for the truck loading zone and approaches is 8 inches; the base course is 6 inches and the surface course is 2 inches.
Pavement Thickness Tables

The pavement thickness for parking lots should be in accordance with the following tables:

Table 5-3. Thickness Chart: Parking Lots with Less Than 50 Spaces

<table>
<thead>
<tr>
<th>A. For Asphalt Concrete Base Pavements</th>
<th>Thickness in Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design Criteria*</td>
</tr>
<tr>
<td>Traffic Class (Spaces)</td>
<td>Subgrade Class CBR</td>
</tr>
<tr>
<td>I (&lt;50 spaces)</td>
<td>Good 9</td>
</tr>
<tr>
<td></td>
<td>Moderate 6</td>
</tr>
<tr>
<td></td>
<td>Poor 3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B. For Untreated Aggregate Base Pavements</th>
<th>Thickness in Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design Criteria*</td>
</tr>
<tr>
<td>Traffic Class (Spaces)</td>
<td>Subgrade Class CBR</td>
</tr>
<tr>
<td>I (&lt;50 spaces)</td>
<td>Untreated Aggregate Base</td>
</tr>
<tr>
<td>Good 9</td>
<td>4.0</td>
</tr>
<tr>
<td>Moderate 6</td>
<td>4.0</td>
</tr>
<tr>
<td>Poor 3</td>
<td>6.0</td>
</tr>
</tbody>
</table>

*See chapter 3 for traffic and soil class details
### Table 5-4. Thickness Chart: Parking Lots with More Than 50 Spaces

#### A. For Asphalt Concrete Base Pavements

<table>
<thead>
<tr>
<th>Traffic Class (Spaces)</th>
<th>Subgrade Class</th>
<th>Design Criteria*</th>
<th>Thickness in Inches Hot Mix Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Base</td>
</tr>
<tr>
<td>II  (50-500 spaces)</td>
<td>Good</td>
<td>9</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>6</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>3</td>
<td>4.5</td>
</tr>
<tr>
<td>III (500 &amp; Above spaces)</td>
<td>Good</td>
<td>9</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>6</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>3</td>
<td>5.5</td>
</tr>
</tbody>
</table>

#### B. For Untreated Aggregate Base Pavements

<table>
<thead>
<tr>
<th>Traffic Class (Spaces)</th>
<th>Subgrade Class</th>
<th>Design Criteria*</th>
<th>Thickness in Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Untreated Aggregate Base</td>
</tr>
<tr>
<td>II  (50-500 spaces)</td>
<td>Good</td>
<td>9</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>6</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>3</td>
<td>8.0</td>
</tr>
<tr>
<td>III (500 &amp; Above spaces)</td>
<td>Good</td>
<td>9</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>6</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>3</td>
<td>8.0</td>
</tr>
</tbody>
</table>

*See chapter 3 for traffic and soil class details*
**Heavily-Loaded Areas**

The pavement for entrances, frontage roads, trash dumpster sites, and delivery truck parking, as well as the approach areas to these spaces, **must be** increased in thickness to prevent pavement failure caused by the weight and dynamic loading. These areas should be constructed with full-depth asphalt in a thickness that will support this special type of pavement loading. Failure to provide this strengthening can result in severe pavement failure. The pavement thickness for these areas should be in accordance with the following table:

**Table 5.5. Thickness Chart: Heavily-Loaded Areas in Parking Lots**

<table>
<thead>
<tr>
<th>Design Criteria*</th>
<th>Thickness in Inches</th>
<th>Subgrade</th>
<th>CBR</th>
<th>Base</th>
<th>Surface</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Class</td>
<td>Asphalt Concrete</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subgrade Class</td>
<td>CBR</td>
<td>Base</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good (Up to 20 heavy trucks per day)</td>
<td>9</td>
<td>4.0</td>
<td>2.0</td>
<td>6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>6</td>
<td>5.0</td>
<td>2.0</td>
<td>7.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>3</td>
<td>6.0</td>
<td>2.0</td>
<td>8.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*See chapter 3 for traffic and soil class details

Note: Untreated aggregate base courses are not recommended for industrial parking lots or for parking areas for heavy trucks.

**Industrial Parking Lots**

Industrial parking lots and those designed primarily for trucks require a thicker design than the other lots described in this chapter. Because of heavy loads associated with trucks, it is not recommended that untreated aggregate base courses be used. The pavement thickness for truck lots should be in accordance with the following table:

**Table 5.6. Thickness Chart: Heavily-Loaded Areas in Parking Lots**

<table>
<thead>
<tr>
<th>Design Criteria*</th>
<th>Thickness in Inches</th>
<th>Subgrade</th>
<th>CBR</th>
<th>Base</th>
<th>Surface</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Class (ADT)</td>
<td>Asphalt Concrete</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(20 to 200 trucks per day)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Good</td>
<td>9</td>
<td>5.5</td>
<td>2.0</td>
<td>7.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>6</td>
<td>6.5</td>
<td>2.0</td>
<td>8.5</td>
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<td></td>
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<tr>
<td>Poor</td>
<td>3</td>
<td>6.5</td>
<td>3.0</td>
<td>9.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*See chapter 3 for traffic and soil class details
PLANNED STAGE CONSTRUCTION

Planned stage construction is a means of providing fully adequate pavements with the effective use of funds, materials, and energy. As defined, it is the construction of an Asphalt Concrete parking lot or roadway in two or more stages, separated by a predetermined interval of time. In many situations, building pavements by stages makes good economical sense. It is a technique long used by city and highway engineers.

Stage Construction is not maintenance. It is the placement of a minimum depth of pavement during initial construction, and a final surface course placed at a planned future date. Asphalt Concrete lends itself to this kind of construction.

As an example, the owner of a new department store with a 350-car parking lot, for financial reasons, decides to stage construct the 6-1/2" full-depth asphalt parking lot. Stage 1 is constructed at the time the store is built. A total depth of 5" of asphalt concrete is placed. Stage 2, consisting of the final surface course of 1-1/2", will be placed at a set time in the future. The truck loading zone and dumpster site are paved the full depth during initial construction.

Stage construction has the advantage of providing a thoroughly adequate, all-weather pavement for the initial development of an area. Any damage to the Stage 1 pavement caused by traffic, settlements, or utility tearups can be repaired prior to placement of the final surface. With a proper asphalt tack coat, where needed, the Stage 2 pavement bonds to the old surface and becomes an integral part of the entire pavement structure.

Asphalt Concrete Curb

Asphalt curbs have become increasingly popular as accessories to paving because they are: (1) economical and easy to construct; (2) can be built much faster than other types; (3) are not affected by ice- and snow-melting chemicals; and (4) can be laid on an existing pavement using a slip form paver.

Many parking facilities have some form of curbing around the perimeter for both functional and aesthetic reasons. The curbs control drainage, delineate the pavement edge, prevent vehicular encroachment on adjacent areas, and enhance the parking lot.

Curb Mixture

The method of mixing the Asphalt Concrete and the composition of the mixture must conform with IDOT Specification 2303, 2304, or an approved commercial mix. The bitumen content should be modified as necessary to produce a suitable mixture for Asphalt Concrete curb construction. Curb mixes that are proportioned using the mixture sizes of 3/8- or 1/2-inch have proven to be most satisfactory and are recommended for curb construction in Iowa.
The addition of 10 to 25 pounds of powdered asphalt per ton of mix will produce an exceptionally tough and durable curb. The asphalt cement used in the mix should be reduced on a pound-for-pound basis when powdered asphalt is added to the mixture. The temperature of the mixture at the time of mixing and laying should range from 250°F to a maximum of 300°F.

Curb Construction

Before curb construction begins, the placement area must be cleaned thoroughly. A tack coat must be applied to the pavement surface at a maximum rate of 0.10 gallons per square yard.

The Asphalt Concrete curb must be laid true to the specified line, profile, and cross section with an approved self-propelled curb-laying machine. The mixture must be fed to the hopper of the machine directly from the truck with a chute or conveyor, or it should be shoveled by hand into the hopper.

Asphalt Concrete curbs should be backed with earth fill or by constructing a double line of curb and filling the median with compacted asphalt mix.

The following illustrates two basic types of systems – Asphalt Concrete curbs and Portland Cement Concrete curb and gutter.

**Figure 5-3.** Details of 6" Extruded Curb (A. C. Concrete)

**Figure 5-4.** Typical curb sections
Site paving is the recommended first step in many types of building construction projects. It offers several advantages as a working mat or platform before building construction begins for shopping centers, schools, manufacturing concerns, warehouses, and similar facilities.

In this technique, an Asphalt Concrete base course is constructed on a prepared subgrade over the entire area that will become parking areas, service roadways, and buildings. When building construction is completed, a final Asphalt Concrete surface course is placed on the asphalt base.

**Advantages**

Paving a building site before construction is completed has several benefits. These include the following:

1. It ensures constant accessibility and provides a firm platform upon which people and machines can operate efficiently, speeding construction.

2. It provides a dry, mud-free area for construction offices, materials storage, and worker parking, eliminating dust control expenditures.

3. It eliminates the need for costly select material—the asphalt subfloor ensures a floor slab that is dry and waterproof.

4. Steel-erection costs can be reduced because a smooth, unyielding surface results in greater mobility for cranes and hoists.
5. The engineer can set nails in the asphalt pavement as vertical- and horizontal-control points, effectively avoiding the risk of loss or disturbance of this necessary survey work.

6. Excavation for footings and foundations and trenching for grade beams can be accomplished without regard for the asphalt base.

**Construction Practices**

**Subgrade Preparation**

All vegetation (including root systems), rocks, debris, and topsoil should be removed from the area to be paved. To prevent future growth, the subgrade should be treated with an approved soil sterilant. Install drainage and utility facilities; backfill and compact. Adjustments in utilities or underground facilities can be readily accomplished through the asphalt base should changes occur.

The subgrade must be properly shaped to meet true lines and elevations. It must be compacted to not less than 95 percent of maximum laboratory density. The surface of the compacted subgrade must not deviate by more than 3/4 inch from the established grade. A minimum slope of about 2 percent or 1/4 inch per foot should be maintained to provide adequate drainage of surface water from the finished pavement.

Areas that show pronounced deflection under construction traffic indicate instability in the subgrade. If reworking and additional rolling do not correct the situation, the area soil must be removed, replaced with suitable material, and compacted. The use of asphalt-treated base or coarse granular material is recommended.

**Base-Platform Construction**

Asphalt Concrete Base Material must be placed on the prepared subgrade. A base of 4 inches or less in depth should be placed in one lift. A base of a total thickness of more than 4 inches may be placed in two or more lifts with the bottom lift being a minimum of 3 inches. The material must be spread and compacted to the required thickness and density as specified and in the grades and dimensions shown on the plans.

The surface of the base must not deviate more than 1/2 inch when measured with a 10-foot straight edge.

**Surface Course Construction**

After building construction is essentially completed, and all building materials and offices have been removed from the previously paved base, preparation for placement of the final surface course of Asphalt Concrete can begin. Should building operations or winter weather delay placement of the final surface, the Asphalt Concrete base will adequately serve traffic needs during the interim.

Preparation for the surface course requires thorough cleaning and sometimes washing of the asphalt base to remove tracked-on dirt and foreign particles. After cleaning, any cracked or broken areas in the base should be removed, replaced with bituminous mix, and thoroughly compacted. All manholes, valve boxes, and other pavement fixtures should be brought to finished grade.

The hot mix asphalt surface course consists of one or more layers placed on the previously constructed Asphalt Concrete base course. The material must be spread and compacted to the required thickness and in the grades and dimensions shown on the plans.

The finished surface must not deviate more than 1/4 inch when measured with a 10-foot straight edge.

**Tack Coat**

Before placing the surface course, the base course should be cleaned thoroughly. If needed, a tack coat of diluted emulsified asphalt may be applied for bonding.
VI.

DESIGNS FOR RECREATIONAL USES
Chapter 6
Designs for Recreational Uses

ASPHALT PAVEMENTS FOR NON-VEHICULAR USE

In addition to highways, streets, and parking lots that carry autos and trucks, many other applications for asphalt pavements exist. Sidewalks, bicycle and golf cart paths, playground areas, tennis courts, and site paving are some common applications.

Because of the unique nature of these asphalt pavement applications, a more detailed approach to their design is presented here. In many cases, the primary design consideration is a pavement structure capable of supporting occasional maintenance and emergency vehicles and resisting freeze/thaw cycles. Therefore, a minimum thickness to accommodate these loads may be the basis of the thickness design.
BIKEWAYS, GOLF CART PATHS, RECREATIONAL TRAILS, AND WALKWAYS

It is desirable to blend this type of pathway into the contours of the existing ground to preserve aesthetics and to reduce the impact on the natural environment. Surface drainage should flow away from these pathways wherever possible.

Because of the variety of designs and applications, individual pathway widths are not listed here. For bikeway and golf cart paths in particular, the size and availability of conventional road construction and maintenance equipment may determine width. Generally, a minimum width of 8 feet is recommended; a 12-foot width may be more cost effective. As a safety measure, additional widening on sharp curves is recommended.

Recreation trails and walkways are usually paved to an 8-foot width to accommodate construction and maintenance operations and to provide access for emergency vehicles. It may be desirable to pave a walkway in an urban environment only 4-feet wide (or wider if significant numbers of pedestrians are present). These pavements usually are not designed to withstand repeated loads from maintenance or emergency vehicles, but an occasional heavy-load application can be made without damage.
Construction Practices

Drainage

It is very important to keep water away from the subgrade soil. If the soil becomes saturated, it will lose strength and stability, making the overlying pavement structure susceptible to breakup under imposed loads. Both surface and subsurface drainage must be considered. All drainage must be carefully designed and should be installed as early in the construction process as practical.

Bicycle and golf cart paths should have a minimum slope of 2 percent or 1/4 inch per foot. They should be constructed in such a way that water will not collect at the pavement edge. Areas of very high natural permeability may require an underdrain system to carry water away from the pavement structure.

Subgrade Preparation

Because the subgrade must serve both as the working platform to support construction equipment and as the foundation for the pavement structure, it is vital to ensure that the subgrade is properly compacted and graded. All underground utilities should be protected or relocated before grading. All drainage structures should be completed with the grading. Remove all topsoil, debris, and rocks from the areas to be paved and treat with a soil sterilant to inhibit future flora growth. The subgrade should be shaped properly to meet true alignment and elevation. It should be compacted to not less than 95 percent of maximum laboratory density. The surface should not vary more than 3/4 inch from the established grade.

Areas that show a pronounced deflection under heavy construction traffic indicate instability in the subgrade. Such areas probably require removal of the material and replacement with suitable subgrade soil material such as compacted, crushed stone or compacted, bituminous-concrete base. If a water seepage area is encountered, the subgrade should be drained.

Asphalt Concrete Pavements

Bicycle, golf cart paths, recreational trails, and sidewalks may be constructed in one course or with a separate base and surface course.

The Asphalt Concrete base course should be placed directly on the prepared subgrade in one lift in a thickness of 4 inches or less, and spread and compacted. Compaction is one of the most important construction operations in terms of its contribution to the performance of the completed pavement.

If a compacted aggregate base is proposed, place it on the prepared subgrade and compact it to ensure a hard, uniform, well-compacted surface.

The surface course, or the full-depth Asphalt Concrete base course, should be placed to the true line and grade. Any irregularities in the surface of this course should be corrected directly behind the paver. As soon as the material can be compacted without displacement, rolling and compaction should be started and should continue until the surface is thoroughly compacted and all roller marks have disappeared.

Before placing successive layers, the previous course should be clean. If necessary, a tack coat of diluted emulsified asphalt may be applied.
Pavement Markings
Pavement markings for bicycle paths are covered in the MUTCD under Part XI. Markings are especially important when the designated bicycle lane is to be accommodated on the roadway and shared with motorists.

Figure 6-1.

Pavement Thickness
The pavement thickness for bikeways, golf cart paths, recreational trails, and walkways should be in accordance with the following table:

Table 6-1. Thickness Chart: Bikeways, Paths, Trails, and Walkways

<table>
<thead>
<tr>
<th>A. For Asphalt Concrete Base Pavements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Criteria*</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Traffic Class (ADT)</td>
</tr>
<tr>
<td>Good</td>
</tr>
<tr>
<td>Moderate</td>
</tr>
<tr>
<td>Poor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B. For Untreated Aggregate Base Pavements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Criteria*</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Traffic Class (ADT)</td>
</tr>
<tr>
<td>Good</td>
</tr>
<tr>
<td>Moderate</td>
</tr>
<tr>
<td>Poor</td>
</tr>
</tbody>
</table>

*See chapter 3 for soil class details
RECREATIONAL AREAS

The following information and design guidance cover the basic components of building durable, economical asphalt playgrounds. Because individual designs are based on intended uses and available funds, dimensions and suggested layouts are not included here.

Basketball Courts

A common section of the playground or recreational area is the basketball court. The following information and design guidance cover the basic components of building basketball courts. General guidelines for court layout and dimensions are included.

Court Layout

The basic layout and dimensions of a basketball court and backboard are illustrated in the following figure (6-2).

Court dimensions are:

• Professional: 94 feet long by 50 feet wide.
• High school: 84 feet long by 50 feet wide.

Backboard dimensions are:

• Rectangular backboard: 74 inches wide by 48 inches high.
• Fan backboard: 54 inches wide by 35 inches high.

An unobstructed space of at least 3 feet outside the end lines and sidelines is required. This space would preferably be 10 feet wide. All end lines, sidelines, and other court line markings, except neutral zone markers, must be a minimum of 2 inches wide.

These pavements usually are not designed to withstand repeated loads from heavy maintenance or emergency vehicles, but an occasional load application can be made without damage.
**Designs for Recreational Use**

**Figure 6-2**

**Construction Practices**

**Drainage**

Both surface and subsurface drainage should be investigated. If excessive moisture is allowed to accumulate under the pavement, the life of the playground surface may be shortened. If necessary, a system of subsurface drainage must be constructed.

Surface drainage on the playground should be directed to the pavement edges and carried away in suitable channels or drainage facilities. It is recommended that the minimum pavement cross-slope be 2 percent or 1/4 inch per foot to preclude standing water and ensure rapid drainage.

**Subgrade Preparation**

Because the subgrade must serve as both the working platform to support construction equipment and as the foundation for the pavement structure, it is critical that the subgrade be properly compacted and graded. All drainage structures should be completed with the grading.

Remove all topsoil, debris, and rocks from the areas to be paved and treat with a soil sterilant to inhibit future flora growth. The subgrade should be properly shaped to meet true alignment and elevation. It should be compacted to not less than 95 percent of maximum laboratory density. The surface should not vary more than 3/4 inch from the established grade.

Areas that show a pronounced deflection under heavy construction traffic indicate instability in the subgrade. Such areas probably require removal of the material and replacement with suitable subgrade soil material such as compacted, crushed stone or compacted, bituminous-concrete base.
**Base Construction**

Asphalt Concrete base material should be placed on the prepared subgrade in one lift in a thickness of 4 inches or less. The material must be spread and compacted to the required thickness and density as specified and in the grades and dimensions shown on the plans.

The surface of the completed base must not deviate more than 1/2 inch when measured with a 10-foot straight edge.

**Tack Coat**

Before placing successive courses, the previous course should be clean. If needed, a tack coat of diluted emulsified asphalt may be applied as a bond coat.

**Surface Course Construction**

A surface course of Asphalt Concrete may be placed on the previously constructed Asphalt Concrete base. It must be spread and compacted to the required thickness and density as specified and in the grades and dimensions shown on the plans.

The finished surface must not deviate more than 1/4 inch when measured with a 10-foot straight edge.

**Pavement Thickness**

The pavement thickness for playgrounds should be in accordance with the following table:

---

**Table 6-2. Thickness Chart: Playgrounds**

<table>
<thead>
<tr>
<th>A. For Asphalt Concrete Base Pavements</th>
<th>Thickness in Inches</th>
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<tr>
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<td><strong>Design Criteria</strong></td>
<td><strong>Base</strong></td>
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<tr>
<td>Traffic Class (ADT)</td>
<td>Subgrade Class CBR</td>
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<td></td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>B. For Untreated Aggregate Base Pavements</th>
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</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Design Criteria</strong></td>
</tr>
<tr>
<td>Traffic Class (ADT)</td>
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<td></td>
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<td></td>
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<td></td>
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</tbody>
</table>

*See chapter 3 for soil class details*
TENNIS COURTS

The following information and design guidance cover the basic components of building durable, economical asphalt pavements for tennis courts. General guidelines for the layout and dimensions are included. These pavements usually are not designed to withstand repeated loads from heavy maintenance or emergency vehicles, but an occasional load application can be made without damage.

Court Layout

The basic layout and dimensions of a tennis court are illustrated in the following figure.

- Post foundations should be:
  - 24 inches in diameter at the top,
  - 30 inches in diameter at the bottom, and
  - not less than 36 inches in depth.

- The dimension between posts is:
  - 33 feet on single courts and
  - 42 feet on double courts.

- New posts are galvanized, 2-7/8 inches in diameter, and equipped with a net-tightening device.

- The standard net is:
  - 42 feet in length and
  - 3 feet-3 inches wide.

- An edging of brick, concrete, steel, or treated wood should be installed around the entire perimeter of the court area. Top elevation of the edging should be 1/2 inch below the finished grade level, and the court’s surface should be tapered from 6 inches from the edge to meet it.
Construction Practices

Drainage and Surface Slope

Both surface and subsurface drainage must be thoroughly investigated. Proper drainage is vital to ensure a non-cracked, smooth playing surface for many years. If subsurface drainage conditions are not satisfactory, a perimeter drain is recommended. An Asphalt Concrete base on a suitable type of subgrade soil may not require underdrainage.

In order to drain properly, the finished court surfaces should have a minimum slope of 1 inch per 10 feet on a true plane from side to side, end to end, or corner to corner. The surface should not slope away in two directions from the net.

Subgrade Preparation

Remove all rock, vegetation (including root systems), debris, and unsuitable topsoil from the area to be paved. To prevent future growth, treat the subgrade with an approved soil sterilant. Install all drainage facilities and adjust or relocate utilities.

The subgrade must be shaped to meet true lines and elevations and compacted to not less than 95 percent of maximum laboratory density. The surface of the compacted subgrade must not vary more than 3/4 inch from the established grade. Good compaction is particularly important in tennis court construction, because subsequent settlement of the subgrade may cause cracking in the court surface. In some cases this can render the court unusable.

Base Construction

Asphalt Concrete base material must be placed on the prepared subgrade in one lift in a thickness of 4 inches or less. The material must be spread and compacted to the required thickness and density as specified and in the grades and dimensions shown on the plans.

The surface of the completed base must not deviate more than 3/8 inch when measured with a 10-foot straight edge but must slope 1 inch per each 10 feet on a true plane from side to side, end to end, or corner to corner as indicated on the plans.

Tack Coat

Before placing successive courses, the previous course should be clean. If needed, a tack coat of diluted emulsified asphalt may be applied for bonding.

Surface Course Construction

A surface course of Asphalt Concrete must be placed on the previously constructed Asphalt Concrete base, spread and compacted to the required thickness and density as specified and in the grades and dimensions shown on the plans.

The finished surface shall not deviate more than 1/8 inch when measured with a 10-foot straight edge but must slope 1 inch per each 10 feet on a true plane from side to side, end to end, or corner to corner as indicated on the plans.

Color Finish Course (If Specified)

Before applying the color finish course, the court should be given a water check to determine if there are any depressions (birdbaths). This is done by flooding the surface with water and allowing it to drain. Depressions of sizable dimensions – greater than 1/8 inch – should be patched and leveled with the material recommended by the color finish manufacturer.

The color finish material may be one of several proprietary products and must be applied according to manufacturer’s directions.

Playing Lines

Following construction, it is recommended that a minimum of 15 days elapse before applying the playing lines. A latex striping-paint should be used. It should be placed no
thicker than necessary for delineation. Base lines should not be more than 4 inches wide, and playing lines should not be more than 2 inches wide. Base and playing lines must be accurately located and marked in accordance with the rules of the United States Lawn Tennis Association.

If a color finish has been applied, the striping paint should be from a manufacturer and of a type recommended by the surface coating manufacturer. It should be painted in accordance with the paint manufacturer’s standard specifications. Traffic, oil, alkyd, or solvent vehicle-type paints should not be used.

**Tennis Court Overlays**

There are many reasons for overlaying an existing tennis court. For example, it may have a badly oxidized or aged surface, poor drainage, or a poorly constructed base. Each of these conditions and their severity should be considered in determining the required overlay pavement thickness.

Many items should be considered when determining the most sound and economical procedures to follow in resurfacing a tennis court. Therefore, it is strongly recommended that a qualified asphalt paving contractor, one experienced in tennis court construction, be consulted.

**Pavement Thickness**

The pavement thickness for tennis courts should be in accordance with the following table:

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**Table 6-3. Thickness Chart: Tennis Courts**

<table>
<thead>
<tr>
<th>Traffic Class (ADT)</th>
<th>Subgrade Class</th>
<th>CBR</th>
<th>Base</th>
<th>Surface</th>
<th>Total</th>
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</thead>
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<td>1.0</td>
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<td>3.5</td>
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<tr>
<td></td>
<td>Poor</td>
<td>3</td>
<td>4.0</td>
<td>1.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Traffic Class (ADT)</th>
<th>Subgrade Class</th>
<th>CBR</th>
<th>Untreated Aggregate Base</th>
<th>Asphalt Concrete Surface</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Good</td>
<td>9</td>
<td>4.0</td>
<td>2.5</td>
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<td></td>
<td>Poor</td>
<td>3</td>
<td>6.0</td>
<td>3.0</td>
<td>9.0</td>
</tr>
</tbody>
</table>

*See chapter 3 for soil class details*
ASPHALT-RUBBER RUNNING TRACKS

High schools and colleges are increasing the demand for outdoor and indoor asphalt-rubber running tracks and runways for long jump, high jump, and pole vault. For information on track size, number of lanes, and other features, refer to the Amateur Athletic Union or other official specifications.

Construction Practices

Subgrade Preparation
Remove all large rocks, debris, and topsoil from the area to be paved. All vegetation, including root systems, should be removed. To prevent future growth, treat the subgrade with an approved herbicide. Install all drainage and utility facilities, and properly backfill and compact the subgrade.

The subgrade must be properly shaped to meet true lines and elevations. It must be compacted to not less than 95 percent of maximum laboratory density. The surface of the compacted subgrade must not vary more than 3/4 inch from the established grade.

Areas that show pronounced deflection under construction traffic indicate instability in the subgrade. If reworking and additional rolling do not correct the situation, the areas must be removed, replaced with suitable material, and compacted. The use of Asphalt Concrete base or coarse granular material is recommended.

Base Construction
Asphalt Concrete base material must be placed on the prepared subgrade. The material must be spread and compacted to the required
thickness and density as specified and in the grades and dimensions shown on the plans.

A minimum thickness of 4 inches is recommended. In general, a total base thickness of 4 inches or less should be placed in one lift.

The surface of the completed base must not deviate more than 1/2 inch when measured with a 10-foot straight edge.

Asphalt-Rubber Surface Construction

Several manufacturers supply rubber material for use in asphalt-rubber surface mixes. Obtaining advice from these companies is suggested. Because many members of the APAI are familiar with various mixes, information may also be obtained by contacting members in your area.

If an asphalt-rubber mix proves to be uneconomical or impractical, an alternative recommendation would be to specify an asphalt sand mix.

The surface course material must be placed on the previously constructed Asphalt Concrete base, spread, and compacted to the required thickness and density as specified and in the grades and dimensions shown on the plans. A minimum thickness of 1 inch is recommended.

The finished surface must not deviate more than 1/4 inch when measured with a 10-foot straight edge.

Tack Coat

A tack or bond coat of CSS-1, SS-1, MC-70, or an approved alternative must be applied at the rate of 0.02 to 0.05 gallons per square yard between each course. The surface must be cleaned of all dust, dirt, or other loose material before the bond coat is applied. If emulsion is used, it must be diluted with equal parts of water or as specified in the proposal.
VII.

PAVEMENT MANAGEMENT
Chapter 7
Pavement Management

PAVEMENT MANAGEMENT CONCEPTS

Historically, small agencies have developed an informal process for managing pavement. Pavements are examined periodically and the worst ones are repaired, rehabilitated, or reconstructed. At times, individuals with clout bring pressure to bear to repair a particular street or road. Through the years, this informal process has worked because the knowledge, experience, and common sense of those in decision making positions led to logical street and highway programs.

Today, however, as traffic volumes and vehicle loadings increasingly burden pavements, local governments’ maintenance budgets have not kept pace with the rising costs of labor, materials, and equipment. Because local agencies today are faced with increasing economic demands, a more systematic process is needed to justify and account for pavement maintenance expenditures.

More and more agencies are adopting a pavement management program that will answer the following questions:

1. How does one determine what pavement is “worst”?
2. When is the best time to schedule repair, rescaling, or resurfacing?
3. What is the savings or cost of deferring repairs?
4. What is the most cost-effective action to take in repair or restoration?

Pavement management can be defined as an orderly process for providing, operating, maintaining, repairing, and restoring a network of pavements.

The decision to repair or rehabilitate is complicated because of the variety of types of pavement distress — some serious and others relatively minor. If pavements with some serious levels of distress are not rehabilitated in an expedient manner, their ultimate repair may be significantly more expensive. An overlay made at the proper time in the life of a pavement, for example, may extend the life for many years. If not overlayed, the same pavement may require complete reconstruction.

Carrying out a pavement management program involves the development of a recordkeeping strategy with the appropriate forms. The procedures can be relatively simple or very complex depending on the size of the agency. Complex and costly computer operations are used in large jurisdictions. In the case of a smaller street or road network, there are a number of microcomputer programs available from consultants, or through public agencies. Iowa State University Extension’s Local Transportation Information Center offers workshops on the subject.
The Asphalt Institute has developed A Pavement Rating System for Low-Volume Asphalt Roads. Information about its system is contained in Information Series No. 169 (IS-169). The subject also is covered in some detail in The Asphalt Handbook manual series No. 4 (MS-4).

Rating a Road

The Asphalt Institute’s publication provides a system for any individual or agency to inspect a road, rate it, and interpret the results. All that is needed is an individual or individuals with maintenance knowledge - such as a superintendent or foreman - to walk the road and assign a numerical value to each type of pavement defect. The type of distress, the extent of the distress, and its relative seriousness must be recorded.

In this procedure, lower values are assigned to less serious problems and higher values to more serious problems. A rating of zero indicates that the pavement is relatively free of defects. A rating of 5 or 10 would indicate serious distress. After each defect has been rated, the individual ratings are added. The sum is then subtracted from 100 and the result is a condition rating for that particular piece of road.

It is important that pavements are evaluated in a consistent manner. Those conducting a condition rating survey must have knowledge of the various types of defects, their cause, and the remedial action required. A guide for identifying and correcting pavement failures is included in Appendix A of this Design Guide. Additional detailed information on this subject is available in The Asphalt Institute’s publications (MS-16), (MS-17), (MS-4), and others.

Interpretation of a Condition Rating

The absolute value assigned by the condition rating provides an indicator of the type and degree of repair work necessary. As a general rule, if the condition rating is between 80 and 100, normal maintenance operations (crackfilling, pothole repair, or seal coat) are all that are required. If the condition falls below 80, it is likely that an overlay will be necessary. If the condition rating is below 30, major reconstruction may be necessary.

Figure 7-2.

Figure 7-3
Another valuable use for the condition rating is to provide a rational method for ranking roads and streets according to their condition. A priority ranking should be the basis for programming and budgeting maintenance, rehabilitation, and reconstruction.

**Figure 7-4. Asphalt pavement rating form**

<table>
<thead>
<tr>
<th>DEFECTS</th>
<th>RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse Cracks</td>
<td>0-5</td>
</tr>
<tr>
<td>Longitudinal Cracks</td>
<td>0-5</td>
</tr>
<tr>
<td>Alligator Cracks</td>
<td>0-10</td>
</tr>
<tr>
<td>Shrinkage Cracks</td>
<td>0-5</td>
</tr>
<tr>
<td>Rutting</td>
<td>0-10</td>
</tr>
<tr>
<td>Corrugations</td>
<td>0-5</td>
</tr>
<tr>
<td>Raveling</td>
<td>0-5</td>
</tr>
<tr>
<td>Shoving or Pushing</td>
<td>0-10</td>
</tr>
<tr>
<td>Pot Holes</td>
<td>0-10</td>
</tr>
<tr>
<td>Excess Asphalt</td>
<td>0-10</td>
</tr>
<tr>
<td>Polished Aggregate</td>
<td>0-5</td>
</tr>
<tr>
<td>Deficient Drainage</td>
<td>0-10</td>
</tr>
<tr>
<td>Overall Riding Quality (0 is excellent; 10 is very poor)</td>
<td>0-10</td>
</tr>
</tbody>
</table>

Sum of Defects ______

Condition Rating = 100 - Sum of Defects

= 100 - ______

Condition Rating = ______
PAVEMENT MAINTENANCE

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. Because destructive environmental and traffic forces are constantly at work, all pavements require maintenance. Cracks, holes, depressions, and other types of distress are the visible evidence of pavement wear. In urban areas, utility cuts and repairs are major contributors to the need for pavement maintenance.

Taking care of pavement deterioration at the proper time and in the proper manner can significantly increase the life of the 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 soon repaired. Open joints and cracks allow water to enter the subgrade and lead to pumping and faulting with resultant structural failure. It has been estimated that on rural pavements in Iowa, 70 percent of the
subgrade moisture originates at the edge of the pavements.

Pavement maintenance involves the identification of pavement distress types and the determination of appropriate maintenance activities. The following sections provide information on full-depth patching, thin overlays, and overlays. In addition, a section on identifying and correcting pavement failures is included in Appendix A.

Full-Depth Asphalt Patching

The full-depth asphalt patch is an important maintenance technique for protecting and preserving the sizable investment in roads. It is used to repair all types of localized pavement distress that extend below the roadway surface. Examples include potholes, alligator cracking, upheaval, and shoving.

Simply stated, the procedure is to remove the failed area and replace it with fresh asphalt mix. Although the operation is not difficult, some of the necessary fine points are frequently not given sufficient attention. Yet these details often determine whether the completed patch will be a temporary expedient or an integral part of a functional pavement system.

The following illustration outlines the correct procedure for constructing a full-depth patch:

1. Untreated pothole.
2. Surface and base removed to firm support.
3. Tack coat applied.
4. Full-depth asphalt mixture placed and being compacted.
5. Finished patch compacted to level of surrounding pavement.

Figure 7-5.
Constructing the Patch

- With a pavement saw or pneumatic hammer, cut the outline of the patch, extending at least 1 foot outside of the distressed area. The outline should be square or rectangular with two of the sides at right angles to the direction of traffic.

- Excavate as much pavement as necessary to reach firm support. If a patch is to be an integral part of the pavement, its foundation must be as strong or stronger than that of the original roadway. This may mean that some of the subgrade will also have to be removed. The faces of the excavation should be straight and vertical.

- Trim and compact the subgrade.

- Apply a tack coat to the vertical faces of the excavation. Emulsified asphalts or liquid asphalt are all suitable.

- Backfill with the asphalt mixture. Shovel the mixture directly from the truck into the prepared excavation. Place the mixture against the edges of the hole first (rather than in the center and then raking to the edges). The maximum lift thickness largely depends upon the type of asphalt mixture and the available compaction equipment. Hot mix asphalt can and should be placed in deep lifts, because the greater heat retention of the thicker layers facilitates compaction. From a compaction standpoint, patches using hot mix asphalt can be backfilled in one lift. However, when placing a patch that is deeper than 5 inches, it is often useful to leave the first lift 1 to 2 inches below the finished grade, making it easier to judge the total quantity of mixture required for the patch.
- Spread carefully to avoid segregation of the mixture. Avoid pulling the material from the center of the patch to the edges. If more material is needed at the edge, it should be deposited there and the excess raked away. The amount of mixture used should be sufficient to ensure that after compaction, the patch surface will not be below that of the adjacent pavement. On the other hand, if too much material is used, a hump will result.

- Compact each lift of the patch thoroughly. Use equipment that is suited for the size of the job. A vibratory plate compactor is excellent for small jobs, while a vibratory roller is likely to be more effective for larger areas.

- When compacting the final lift (which may be the only lift), overlap the first pass and return of the vibratory roller or plate compactor no more than 6 inches on the patch on one side. Then move to the opposite side and repeat the process. Once this is accomplished, proceed at right angles to the compacted edges with each pass and return, overlapping a few inches on the uncompacted mix. If there is a grade, compaction should proceed from the low side to the high side to minimize possible shoving of the mix.

- When adequate compaction equipment is used, the surface of the patch should be at the same elevation as the surrounding pavement. However, if hand tamping or other light compaction methods are used, the surface of the completed patch should be slightly higher than the adjacent pavement because the patch is likely to be further compressed by traffic.

- Check the vertical alignment and smoothness of the patch with a straight edge or stringline.
Thin Surface Treatments

Asphalt surface treatment is a broad term embracing several types of asphalt and asphalt aggregate applications, which are usually less than 1 inch thick and can be applied to any kind of road surface. The road surface may be a primed granular base or similar surface, or it may be an existing pavement. Surface treatments applied to an existing pavement surface often are called seal coats.

This chapter covers surface treatments consisting of asphalt emulsion-aggregate applications only. Because surface treatments and seal coats differ in name only for this type of construction, they are treated as a single subject.

A single surface treatment involves spraying asphalt emulsion, which is immediately followed by application of a thin aggregate cover that is rolled as soon as possible. For multiple surface treatments, the aggregate cover process is repeated two or even three times, with the aggregate size becoming smaller with each application. The maximum size aggregate for each successive application is about one-half that of the previous one. The total thickness of the treatment is about the same as the maximum size aggregate particles of the first course.

Properly constructed, asphalt surface treatments are economical, easy to place, and effective. They seal and add life to road surfaces. However, each type has one or more special purposes. A surface treatment is not actually pavement. Rather, it resists traffic abrasion and provides a waterproof cover over the underlying structure. It adds little load-carrying strength and therefore is not normally taken into account when computing the load limit of a pavement. While a surface treatment can provide an excellent surface if used for the correct purpose, it is not a cure-all for all paving problems. A clear understanding of the advantage and limitations of asphalt-emulsion surface treatments is essential to ensure best results. It is vital to make a careful study of traffic requirements and an evaluation of the condition of existing materials and pavement layers.

Single Surface Treatment

A single surface treatment, often called a “seal coat,” involves spraying asphalt emulsion followed at once by a thin aggregate cover. This cover is rolled as soon as possible after laying.

When the aggregate is compacted to its densest position, the voids between aggregates are filled about two-thirds to three-fourths full with asphalt. A typical design will call for 70 percent of the voids to be filled. A full outline of materials and procedures can be found in Section 2307 of the IHD Standard Specifications. Application rates are given in Table 7-1.

Table 7-1. Surface Treatment Application Rates

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Spreading Rate</th>
<th>Basic Rate</th>
<th>Aggregate Spreading Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>0.15-0.20</td>
<td>0.15</td>
<td>10-15</td>
</tr>
<tr>
<td>3/8 inch</td>
<td>0.25-0.35</td>
<td>0.30</td>
<td>20-25</td>
</tr>
<tr>
<td>1/2 inch</td>
<td>0.35-0.45</td>
<td>0.40</td>
<td>25-30</td>
</tr>
</tbody>
</table>

A single surface treatment or seal coat may be used for one of several reasons:

1. As an interim measure pending application of a higher pavement type.
2. To correct surface raveling and oxidation of old pavements.
3. To provide a waterproof cover over an existing pavement structure.
4. To correct excessive traffic wear beyond that presumed in the original design.
The single treatment approach is especially well-suited for light-duty traffic and as an interim maintenance procedure. It also may be used following crack sealing operations. The surface treatment is applied to resist the abrasive forces of the traffic.

Problems that can be associated with a treatment of this type include:

1. Construction during cool weather. It usually requires about one month of warm weather following construction for the aggregate particles to become reoriented and properly embedded in the asphalt membrane.

2. Possible loss of cover aggregate may occur because of the relatively thin layer and the time required for embedding and bonding to develop. In single treatments the larger aggregate particles are more prone to be lost.

**Multiple Surface Treatment**

A multiple surface treatment can produce a pavement thickness in the range of 1/2 to 3/4 inch. Some extra reinforcement may be added with this type of treatment. If properly designed and constructed, double surface treatments give about three times the service life of a single surface treatment for about one and one-half times the construction cost. Because the cover stone for the second layer is smaller, loss of particles from a graded cover aggregate is greatly minimized.

In a double surface treatment, the largest size of stone in the first course determines the surface layer thickness. The second course serves to fill the voids in the mat of the first course aggregate. The extent to which these voids are filled determines the texture and riding quality of the surface treatment.

**Sand Seal**

Sand seal is defined as a spray application of asphalt emulsion followed by a light covering of fine aggregate, such as clean sand or screenings. Although this is a rather simple operation, it can be useful in correcting a number of pavement flaws. The procedure involves an emulsion spray application. Usually emulsion grades RS-1, CRS-1, or HFMS-1 are used at a rate of about 0.15 to 0.20 gallons per square yard. This is followed by about 10 to 15 gallons per square yard of sand or screenings cover.

The sand seal is used primarily for the following purposes:

- To enrich a dry, weathered, or oxidized surface. The sand seal will help prevent loss of material from the old surface by traffic abrasion.

- To prevent the intrusion of moisture and air. When an existing pavement surface begins to crack, moisture and air pass into the underlying pavement structure, reducing its load-carrying ability. A sand seal can provide a barrier to prevent this intrusion.

- To develop a skid-resistant surface texture. By selecting a sharp, angular, fine aggregate, a highly skid-resistant surface can be provided. The sand may also be used to “soak up” spots of asphalt that have appeared on the surface because of an overly rich condition.

**Slurry Seal**

A slurry seal is a mixture of well-graded fine aggregate, mineral filler (if needed), emulsified asphalt, and water applied to a pavement as a surface treatment. It is used in both the preventive and corrective maintenance of asphalt pavement surfaces. It does not, nor is it intended to, increase the structural strength of a pavement section. Any pavement that is
structurally weak in localized areas should be repaired before applying the slurry seal. All ruts, humps, low pavement edges, crown deficiencies, waves, or other surface irregularities that diminish the riding quality should be corrected before placing the slurry seal.

When applied to the surface of an older pavement, slurry seal can be used quite effectively. It will seal the surface cracks, stop raveling and loss of matrix, make open surfaces impermeable to air and water, and improve skid resistance. Its timely application will help reduce surface distress caused by oxidation of the asphalt and embrittlement of the paving mixture.

Slurry seal offers the following advantages:

- Rapid application.
- No loose cover aggregate.
- Excellent surface texture for paint striping.
- Ability to correct minor surface irregularities.
- Minimum loss of curb height.
- No need for manhole and other structural adjustments.
- In many cases, the relatively low cost of the treatment makes it practical to import aggregates for special effects, such as high-skid resistance, color contrast, and noise reduction.
- Resists degrading effect of oil and gasoline dripped from cars.

**ASPHALT CONCRETE OVERLAYS**

Asphalt Concrete is an excellent resurfacing material that is equally effective for overlaying asphalt/aggregate surfaces, existing Asphalt Concrete pavements, or Portland cement pavements. Asphalt overlays add strength to an old pavement structure, extend service life, and provide a smooth, skid-resistant pavement. They improve riding quality and 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.

**Advantages**

A Asphalt Concrete overlay offers the following advantages:

1. **Convenience.** The pavement may remain in use while it is being upgraded.

2. **Economy.** An old pavement frequently may be improved and returned to service more quickly and for less cost than a new road can be constructed.

3. **Durability.** Well-designed, well-constructed improvements provide a pavement that is stronger than new, which reduces maintenance requirements.
Design Considerations

Before constructing a Asphalt Concrete overlay, careful and correct preparation of the existing pavement is essential for maximum pavement performance. Each resurfacing project must be designed on an individual basis.

Local Repairs

All weak areas should be repaired. Structural patches should be designed and constructed with full-depth Asphalt Concrete to ensure strength equal to or exceeding that of the surrounding pavement. Carefully placed and adequately compacted patches will produce uniform support for the overlay and ensure good performance.

Structural Deficiencies

Pavement deficiencies that do not affect structural adequacy are usually corrected by thin resurfacings using thicknesses selected from experience.

Weakened pavement structures call for overlays of designed thicknesses that will sufficiently strengthen the pavement structure to accommodate the traffic expected to use it.

Drainage

Older pavements may show signs of fatigue because of intrusion of groundwater from below or from surface water entering along the edge between pavement and shoulder. This water should be removed by underdrains or by other means several weeks before constructing the asphalt overlay.

Leveling

When the surface is distorted, the construction of leveling courses or wedges is required to restore proper line and cross section.

Overlay Thickness

Asphalt Concrete overlays may be used to correct both surface and structural deficiencies. Present pavement condition and estimates of future traffic influence appropriate thicknesses of these overlays. A 1-inch average depth of Asphalt Concrete surface should be the minimum thickness. As a standard rule, the lift thickness should be at least twice the maximum aggregate size in the mixture.

Overlay Thickness Calculations

How thick should the overlay be? Two publications available from The Asphalt Institute can aid in the calculations. The first, for roads and streets carrying up to 100 heavy trucks per day, is *A Simplified Method for The Design of Asphalt Overlays for Light to Medium Traffic Pavements* (IS-139).

The second procedure, for overlays on roads and streets carrying more than 100 heavy trucks per day, is detailed in The Asphalt Institute’s manual, *Asphalt Overlays for Highway and Street Rehabilitation* (MS17).

When the majority of the heavy trucks have a gross weight of more than 60,000 pounds, these simplified overlay design methods should not be used.

The following steps and tables may be used to determine overlay thickness needs.

- Using the estimated average number of heavy trucks per day, and the assigned subgrade category, determine the required thickness of full-depth asphalt pavement required using the appropriate table.

- Also, determine the effective thickness of the existing pavement as if it were converted to full-depth Asphalt Concrete. Each individual
course of the existing pavement is evaluated, using the appropriate table, to determine its equivalent thickness of Asphalt Concrete pavement; the sum is the effective thickness.

- The thickness of the Asphalt Concrete overlay required is equal to the required thickness determined in Step 1 minus the effective thickness of the existing pavement determined in Step 2.

**Table 7-2**

<table>
<thead>
<tr>
<th>Pavement Course</th>
<th>Minimum Requirements</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASPHALT CONCRETE</td>
<td>Stable, generally uncrracked with little or no deformation in the wheel paths</td>
<td>0.9 - 1.0</td>
</tr>
<tr>
<td></td>
<td>Stable, some fine cracking or slight deformation in the wheel paths</td>
<td>0.7 - 0.9</td>
</tr>
<tr>
<td></td>
<td>Appreciable cracking and crack patterns, or appreciable deformation in the wheel paths</td>
<td>0.5 - 0.7</td>
</tr>
<tr>
<td></td>
<td>Stable, generally uncrracked and exhibiting little deformation in the wheel paths</td>
<td>0.7 - 0.9</td>
</tr>
<tr>
<td></td>
<td>Stable, some fine cracking, some raveling or aggregate degradation, and slight deformation in the wheel paths</td>
<td>0.5 - 0.7</td>
</tr>
<tr>
<td></td>
<td>Extensive cracking, considerable raveling or aggregate degradation, appreciable deformation in the wheel paths and lack of stability</td>
<td>0.3 - 0.5</td>
</tr>
</tbody>
</table>

**PORTLAND CEMENT CONCRETE**

- Stable, undersealed and generally uncracked
- Stable, undersealed, some cracks but no pieces smaller than about one square metre (yard)
- Appreciably cracked and faulted, cannot be undersealed. Slab fragments, ranging in size from approximately one to four square metres (yards) have been well-seated on the subgrade by heavy pneumatic rolling
- Pavement broken into small pieces, 0.6m (2 ft) or less in maximum dimension. Use upper part of range when subbase is present; lower part of range when slab is on subgrade

**AGGREGATE**

- Granular subbase or base – reasonably well-graded, hard aggregates with some plastic fines and CBR not less than 20. Use upper part of range if P.I. is 6 or less; lower part of range if P.I. is more than 6

**SOIL**

- Improved subgrade or native subgrade, in all cases

**Table 7-3. Typical Thickness of Full-Depth Asphalt Concrete For Light to Moderate Traffic Roads**

<table>
<thead>
<tr>
<th>Traffic Class</th>
<th>Subgrade Class (CBR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Poor (3)</td>
</tr>
<tr>
<td>I</td>
<td>6.0</td>
</tr>
<tr>
<td>II</td>
<td>7.0</td>
</tr>
<tr>
<td>III</td>
<td>7.5</td>
</tr>
<tr>
<td>IV</td>
<td>9.5</td>
</tr>
<tr>
<td>V</td>
<td>12.0</td>
</tr>
</tbody>
</table>
Adequate preparation of the existing pavement prior to an asphalt overlay is important. When repairs are completed, the surface to be overlaid must be thoroughly cleaned. Then a tack coat of asphalt must be applied to ensure uniform and complete adherence of the overlay.

As discussed earlier under pavement management concepts, the condition rating provides a rational method for evaluating the need for an overlay. If the condition rating falls below 80, it probably calls for an overlay. Deferring the overlay allows further deterioration of the pavement. At some point in time, the life of the pavement is severely affected, which will increase costs significantly.

The predictive capabilities of a pavement management system allow an agency to analyze alternative programs and select a maintenance strategy that is cost effective. Deferred maintenance is more costly in the long run as illustrated by the quality of deterioration over time example.

**Figure 7-7.**

![Graph showing quality of condition over time](image)

**Table 7-4. Typical Overlay Thickness (Inches) For Local Roads, Residential Streets, and Collectors**

<table>
<thead>
<tr>
<th>Subgrade Type</th>
<th>Condition Rating Local and Residential Streets</th>
<th>Condition Rating Collector Roads and Streets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;25 25-50</td>
<td>&lt;25 25-50</td>
</tr>
<tr>
<td>Local Roads and Residential Streets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>1 1.5</td>
<td>1.5 1</td>
</tr>
<tr>
<td>Medium</td>
<td>1.5 1</td>
<td>2 1.5</td>
</tr>
<tr>
<td>Poor</td>
<td>2 1</td>
<td>2.5 1</td>
</tr>
<tr>
<td>Collector Roads and Streets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>2 1.5</td>
<td>2.5 2</td>
</tr>
<tr>
<td>Medium</td>
<td>2.5 2</td>
<td>3 3</td>
</tr>
<tr>
<td>Poor</td>
<td>3 2.5</td>
<td>3.5 3</td>
</tr>
</tbody>
</table>

For a discussion on the condition rating procedure for this particular table see the Pavement Management section.
VIII.

REHABILITATION
Chapter 8
Rehabilitation

RECYCLING ASPHALT PAVEMENTS

As natural resources become more scarce and more costly to obtain, their rehabilitation and re-use, or recycling, becomes more important. Asphalt cement and aggregates used in roadway construction constitute a sizable public investment. They are two very important natural resources whose value as construction materials are recoverable. This ability to recycle has enormous implications not only for the conservation of valuable resources but also for energy savings and total economic benefits.

Reprocessing the salvaged materials, plus the addition of virgin asphalt and new aggregates, can be accomplished through three different processes. In a hot mix process, a special drum for mixing is used to comply with environmental pollution requirements and the mixture produced is a fully recycled product containing 15-50% RAP. A cold, in-place recycling process normally involves processing a 2”-4” depth followed by an Asphalt Concrete overlay. A third process, termed surface recycling involves heater scarification of the top 1” of pavement followed by an asphalt concrete overlay.
**Hot Mix Recycling Advantages**

1. Significant structural improvements can be obtained with little or no change in thickness.
2. Additional right-of-way is not needed.
3. Frost susceptibility may be reduced.
4. Surface and base distortion problems may be corrected.
5. Base preparation and shoulder work are reduced.

**Cold Mix Recycling Advantages**

1. Can correct many types of pavement distress that involve both surface and base courses.
2. Reduces the need for new materials and overall cost.
3. Hauling costs may be decreased if in-place method is used.
4. Increases structural strength without adding to pavement thickness.
5. Drainage problems are avoided.
6. Adding asphalt waterproofs the base and renders it less susceptible to frost action and moisture change.

**Surface Recycling Advantages**

1. Provides a very low-cost maintenance strategy.
2. Restores flexibility of aged and brittle asphalt.
3. Cracks are interrupted and filled.
4. Surface distortion, removed and leveled, drainage and crowns are re-established.
5. Improves skid resistance.
6. Eliminates the need for surface repairs.
BREAKING AND SEATING

A Portland Cement Concrete (PCC) pavement that has good drainage and is still relatively sound can be salvaged through breaking and seating and a hot mix Asphalt Concrete overlay. This option for rehabilitation is designed to reduce the opportunity for reflective cracking by decreasing the slab size of the PCC. Proper breaking and seating will virtually eliminate reflective cracking. If reflective cracks should appear, they usually will be small, tight cracks that can be maintained easily.

With this method of rehabilitation, the PCC is cracked at 24- to 30-inch intervals with heavy drop hammer equipment to create a more uniform pattern of cracking. Next, the cracked PCC pavement is seated with a rubber-tired roller of at least 35 tons. This seating action by the roller pushes down any pieces of PCC that might be over a void in the subbase. After the breaking and seating steps are completed, a 3-to 5-inch asphalt overlay is placed directly on the prepared old pavement.

This method offers the following benefits:

1. Prevents/delays reflective cracking.
2. Extends pavement service life.
3. Reduces maintenance costs.
4. Improves riding smoothness.

The procedural steps of the breaking and seating process are:

1. Crack the PCC slabs.
2. Seat cracked pieces.
3. Remove and patch soft areas.
4. Sweep clean.
5. Apply tack coat.
6. Place asphalt leveling course/overlay.

This method of recycling has been used for more than 30 years in many states.
RUBBLIZING

The rubblizing of Portland Cement Concrete pavements before an Asphalt Concrete overlay means the complete destruction of the concrete slab and of all concrete slab action. With this technique, the concrete-to-steel bond is broken on jointed-reinforced concrete pavements and on continuously-reinforced concrete pavements. The rubblizing process effectively reduces the existing slab to an in-place crushed aggregate base.

The procedural steps in the rubblizing process are:

1. Install necessary drainage.
2. Remove any existing overlay.
3. Sawcut the full thickness of the pavement adjacent to remaining sections.
4. Pulverize the PCC pavement.
5. Cut off the exposed steel reinforcement.
6. Compact the pulverized PCC pavement.
7. Apply a prime coat.
8. Place the Asphalt Concrete leveling course and overlay.

The benefits of this method are:

1. Prevents reflective cracking.
2. Provides a sound base for the overlay.
3. Extends service of the pavement.
4. Provides a maintainable surface.
PAVING FABRICS

In recent years, paving fabrics, or geomembranes, have been used to reduce reflective cracking from the underlying pavement joints or cracks. A membrane is established through the application of liquid asphalt cement, fabric, and an Asphalt Concrete overlay. Fabric has been shown to be effective in developing a waterproof layer to minimize surface water intrusion.

An example of a possible use would be as a spot application on asphalt pavement sections that show signs of alligator cracking related to a weakened subgrade condition. Fabric would be placed just before the asphalt concrete overlay. Strip application of fabrics will be more effective if the crack or joint is a non-working joint, such as a longitudinal joint in a PCC pavement.

Experimental studies of fabric applications in Iowa have not been conclusive. Early reflective cracking may be delayed through the use of fabric in many cases, especially over a nonworking joint. Also, where water in the pavement structure is a potential problem, fabric can aid in the development of a waterproof membrane.

For additional assistance on specific applications of paving fabrics, contact the APAI.
SAWCUT AND SEALING JOINTS

On PCC rehabilitation projects, sawing and sealing the Asphalt Concrete overlay over the underlying PCC joints may extend the overlay’s service life. Unless special procedures, such as crack and seat, are used to prepare the existing PCC pavement, the joints may eventually reflect through the asphalt overlay. These cracks can occur within a short time, depending on factors such as the thickness of the overlay, traffic, and environmental conditions. Reflective cracking is caused by the underlying joints moving because of temperature and moisture changes, warping of the slab, and loading conditions that result in tensile, shear, and flexural forces greater than the strength of the pavement. This results in a crack in the overlay approximately above the underlying joint.

Reference marks, which will not be obliterated during the overlay operation, must be established at the underlying joint. The underlying joint must also be thoroughly cleaned and sealed with an approved sealer before overlaying.

Benefits

Sawcut and sealing of the asphalt overlay is an effective technique to reduce the detrimental effect of uncontrolled reflective cracking over the underlying PCC joints. The sawcut and seal technique establishes a weakened plane joint in the overlay directly above the joint, and it can then be effectively sealed and maintained.

The technique of sawcut and sealing joints offers the following benefits:

1. Controls reflective cracking.
2. Provides maintainable joints.
3. Extends service life.
4. Controls maintenance costs.
5. Adjoining surface will be stronger than at the natural crack.
7. Smoother riding pavement.

The procedural steps in the process are:

1. Locate and reference existing joints in the underlying slab.
2. Thoroughly clean and seal joints.
3. Place overlay.
4. Sawcut directly over the referenced joint.
5. Clean and dry the sawcut.
6. Seal the sawcut.

After placement of a backer rope or tape, the width-to-depth ratio on saw and seal joints should be 1:1. The initial cut should be narrower than the final width and almost twice the depth. This is with the use of hot-type sealers.

Primary candidates for sawing and sealing of overlays over joints in the underlying PCC pavements are those overlays that have not lost structural integrity at the joints. Examples are overlays that are intended to increase structural capacity, correct skid resistance, prevent further scaling, or reduce noise.

To be effective, the sawcut in the overlay should be directly over the underlying joint. A maximum tolerance of 1 inch is required.
APPENDICES

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Appendix A

Pavement Failure Identification

IDENTIFYING AND CORRECTING PAVEMENT FAILURES

The key to proper maintenance of asphalt pavements is to understand the causes of failures and the action(s) needed for correction before any repair work is done. To make the most of maintenance budgets, proven methods must be used to correct failures and to prevent their recurrence.

The following section provides basic information on the most common types of pavement failures, including their probable cause and the measures recommended for their correction. Personnel involved in asphalt maintenance operations must be well advised, trained, and properly equipped. With diligent application, the following section can assist in helping them achieve an efficient, effective, and consistent asphalt pavement maintenance system.

Types of Pavement Failures

The following photographs illustrate the types of pavement failures most commonly encountered in asphalt pavements. Next to each photograph is a description of the failure type, probable cause of the failure, and recommended correction.

Bleeding or Flushing

This distress is caused by excess asphalt in the surface layer. Contributing factors include insufficient or excess covering stone, lack of proper rolling during placement, or failure to protect a newly constructed surface from traffic until the asphalt has cured sufficiently.

Minor bleeding can often be corrected by applying coarse sand or stone screenings to blot up excess asphalt.

Major bleeding can be corrected by cutting off excess asphalt with a motor grader or removing it with a “heater planer.” If the resulting surface is excessively rough, resurfacing may be necessary.

Corrugations and Shoving

Corrugations and shoving are caused by instability in the asphalt layers caused by a mixture that is too rich in asphalt, has too high of a proportion of fine aggregate, has coarse or fine aggregate that is too rounded or too smooth-textured, or has asphalt cement that is too soft. Corrugations and shoving may also be caused by excessive moisture, contamination caused by oil spillage, or lack of curing time between placing seal treatments. This type of distress frequently occurs at grade intersections as a result of braking forces imposed by stopping vehicles.
To repair corrugations in an aggregate base overlain with a thin surface treatment, scarify the pavement, add aggregate as needed, mix well, re-compact, prime, and then resurface. Where the surface has 2 inches or more of asphalt plant mix, corrugations can be removed with a “heater planer.” After removal of corrugations, cover with a new surface treatment or new asphalt overlay. To repair shoved areas, remove surface and base as necessary and replace with a more stable material to prevent a recurrence. For out-of-season inclement weather repairs, smooth shoved areas with patching if the surface unevenness is hazardous to traffic.

Cracking, Alligator

Interconnected cracks forming a series of small polygons resembling an alligator’s skin are called alligator cracks. There are numerous kinds of alligator cracks, some of which are illustrated and discussed below.

In situ investigations must be performed to determine the most probable of several causes of alligator cracking. If poor drainage is implicated, corrections should be made as quickly as possible. Should the pavement be properly drained, then the base is probably inadequate, and the pavement will require reconstruction or a heavy resurfacing. Major resurfacing will also be required if cracking results from the fatigue effect of repetitive heavy truck loads. If the cause of distress cannot be corrected soon (rebuilding of the pavement may be several years in the future), temporary repairs may be required.

Alligator Cracking without Surface Distortion

Skin patching should be applied when weather permits. This is often a temporary measure and should not be considered a permanent correction of a major problem. Alligator cracking generally requires removal of the cracked pavement and an asphalt patch of at least 4 inches in depth.

Alligator Cracking with Distortion of Intact Surfaces

Where distortion is 1 inch or less and the existing surface is intact, a skin patch should be applied. Where distortion is more than 1 inch and the existing surface is intact, a tack coat should be applied followed by an Asphalt Concrete overlay.
**Alligator Cracking with Broken Surfaces**

Where the existing surface is badly cracked and loose (regardless of amount of distortion), remove old surface, tack area, and repair using Asphalt Concrete. Sound judgment should be used to determine when the existing surface is considered firm and should remain in place or when it is considered loose and should be removed before placing the Asphalt Concrete overlay.

**Alligator Cracking with Surface Distortion and Pumping**

There are several causes of this type of distress. Often poor drainage resulting in a wet base and/or subgrade is responsible. If the pavement is properly drained, then water is getting to the base and/or subgrade from cracks or holes in the surface or from moisture coming up through the subgrade.

This distress should be repaired as follows:

1. Cut out pavement and wet material.
2. If the base or surface is wet from underneath, install necessary underdrains to prevent future saturation.
3. Prime area.
4. Replace with a minimum of 4 inches of Asphalt Concrete.
5. Compact Asphalt Concrete.

For out-of-season inclement weather repair, keep the area filled with either cold patch material or treated aggregate base.

Note: If you follow the photographs on random surface cracks and alligator cracking, you can see how surface distress can progress from undesirable to intolerable because of lack of proper drainage. This is not to imply that poor drainage is the only cause of surface cracking. However, it is often a major contributor.

**Cracking, Edge**

The following items discussing edge cracks concern those pavement surfaces underlain by base material and not areas where the surface has been gradually widened over the years until its edge is inadequately supported by a base layer.

Cracking without surface distortion is usually caused by lack of shoulder (lateral) support. When the surface is distorted, possible causes are more diverse. In some cases, the base layer may be of insufficient quality or thickness to support the traffic loads. Poor drainage is also a frequent cause. Is water getting in from the top, sides, or bottom? Is base failure causing distortion and allowing water to wet the base and/or subgrade? Is a clogged ditch line causing water to seep through porous shoulder material and saturate the base and subgrade? Corrective measures should be undertaken as soon as possible.
Edge Cracks without Surface Distortion

The first step is to correct the problem of lack of lateral support if necessary. For cracks less than 1/4 inch in width, no maintenance is required. A skin patch is sufficient for larger cracks.

Edge Cracks with Distortion of Intact Surfaces

Where distortion is 1 inch or less and the existing surface is intact, a skin patch should be applied. Where distortion is more than 1 inch and existing surface is intact, tack area and build up with Asphalt Concrete.

Edge Cracks with Broken Surfaces

Where the existing surface is badly cracked and loose, regardless of distortion, the old surface must be removed. Prior to replacing the surface, consideration should be given to the necessity of first replacing the base material if it has been pushed up and out into the shoulder. This action will have reduced the amount of base material that remains in place and thus will have reduced the strength of the pavement. If this condition exists, it should be corrected by either replacing the base material or by building up the depressed area with Asphalt Concrete.

Sound judgment should be used to determine whether the existing surface is considered firm and should remain in place or if it is considered loose and should be removed and replaced. When Asphalt Concrete is used to replace the base material, it should be of equal or greater strength than the material it replaces.
Edge Cracks with Surface Distortion and Pumping

This distress is caused by wetting or drying action beneath the shoulder surface caused by conditions that trap water and allow it to stand along and seep through the joint between the shoulder and the mainline surface.

If the cracking is less than \(1/4\) inch in width, no maintenance is required. Otherwise, a crack should be filled with a cutback or emulsified asphalt.

Joint Crack at Lane Joints

Distress is caused by a weak seam between adjoining spreads in the courses of the pavement.

If the cracking is less than \(1/4\) inch in width, no maintenance is required. Otherwise, the crack should be filled with a cutback or emulsified asphalt.

Cracking, Random

The causes of random cracking are numerous and, in its early stages, difficult to determine. Consequences range from severe, such as deep foundation settlement, to slight, such as a construction error or mishap.

Joint Crack at Pavement Edge

To repair such distress, take the following steps:

1. Remove unsuitable material.
2. Install any necessary underdrains.
3. Replace base with a well-graded aggregate.
4. Compact aggregate.
5. Prime area.
6. Replace surface using Asphalt Concrete.

When inclement weather prohibits proper repair, try to keep the distressed area filled with cold patch material.

Cracking, Joint

Joint cracks occur where the shoulder or paved wedge separates from the mainline pavement or along weak seams of adjoining pavement spreads in the surface layers.
Narrow Cracks

For cracking less than 1/4 inch in width, take no action. If associated distress of another type exists, the cracking will progress, and remedial action will ultimately be required.

Wide Cracks

When random cracks reach 1/4 inch or more in width, remedial action is often required. However, the appropriate action may be difficult to determine. On some pavements, cracking will not progress significantly from year to year. Previous experience and/or the traffic volume and type of pavement may indicate that it is not necessary to take immediate action. Sound judgment should be used when deciding if action should be taken in this case. In most cases, the crack should either be covered with a skin patch or be filled with a cutback or emulsified asphalt and covered with sand.

Note: Both methods are acceptable, and good judgment should be used to determine which method is best according to the particular distress, materials available, and previous experience.

Cracking, Reflection

Reflection cracking is caused by vertical and horizontal movements in the pavement beneath overlays that result from expansion and contraction with temperature or moisture changes. Reflection cracking is very apparent where plant mix has been placed over Portland Cement Concrete pavement or where old alligator cracks have propagated up through an overlay or patch.

If reflection cracks are no more than 1/4 inch in width, no maintenance is required. Larger cracks should be filled with a cutback or an emulsified asphalt and covered with sand.

Such treatment is seldom permanent when applied to overlays over old Portland Cement Concrete pavement. Continual expansion and contraction of the concrete causes conventionally repaired cracks to reappear quickly. A single course surface treatment over the existing pavement immediately preceding the overlay is a good crack relief measure that minimizes reflective cracking.
Cracking, Shrinkage

Shrinkage cracking appears on the pavement surface as interconnected cracks forming a series of polygons, usually having sharp angles at the corners. Unlike alligator cracking, which is associated primarily with traffic loading, shrinkage cracking is caused by volume change within the Asphalt Concrete, the aggregate base, and/or the subgrade layers.

If the shrinkage cracking is severe and has seriously weakened the pavement structure, a structural overlay will be necessary to restore it. Most likely, however, the cracking will not be progressive, and a surface treatment – preceded by filling the larger cracks with a cutback or emulsified asphalt – will suffice for surface restoration.

Cracking, Slippage

Slippage cracks are crescent-shaped cracks that usually point in the direction of traffic movement. They result from insufficient bond between the surface and underlaying courses, caused by dust, oil, rubber, dirt, water, or no tack coat between the two courses.

To repair slippage cracks, neatly remove the unbounded section of the surface, apply a suitable tack, and replace the surface with a high quality Asphalt Concrete. During inclement weather, keep the exposed area filled with cold mix material if it is likely to be a traffic hazard.

Cracking, Transverse

A transverse crack follows a course approximately at right angles to the pavement center line, usually extending across the full pavement width. In Iowa, transverse cracks are most often the result of reflection cracking. However, they can also result from stresses induced by low-temperature contraction of the pavement, especially if the asphalt is hard and brittle.

Repair procedures for transverse cracking are similar to those for reflection cracking.

Polished Aggregate

Although uncrushed gravels often have surfaces that are initially smooth and potentially hazardous, crushed rock initially has a rough, skid-resistant texture. Under the action of traffic, however, some aggregates – including many limestones – become polished and slick, especially when wet. The likelihood of aggregate becoming polished increases with the volume of traffic. Because polished aggregate results in a loss of skid resistance, it is potentially hazardous. The most economical repair is to apply a skid-resistant surface treatment.

Potholes

Potholes occur most frequently during the winter months when it is difficult to make the most desirable repairs. Consequently, it is often necessary to repair potholes in ways that are less than permanent. General patching should not be done during inclement weather except to correct hazardous conditions. Sound judgment must be exercised when making repairs during poor weather conditions.

Potholes are caused by water penetrating the surface and causing the base and/or subgrade to become wet and unstable. They also may be caused by a surface that is too thin or that lacks
sufficient asphalt content, lacks sufficient base, or has too many or too few fines. Did you and/or your personnel fail to perform maintenance that would have prevented pothole formation? If water is the culprit, it is caused by a cracked surface, high shoulders or pavement depressions ponding water on the pavement, porous or open surface, or clogged side ditches? Correct the cause of the problem as soon as possible.

**Potholes in Surface Treatments over Aggregate Base**

To repair potholes in Asphalt Concrete, take the following actions:

1. Clean out hole.
2. Remove any wet base.
3. Square up pothole so that it has neat lines both perpendicular and parallel to the center line and has vertical sides.
4. Prime the pothole.
5. Fill the pothole with Asphalt Concrete.

**Raveling**

Raveling is caused by a dry brittle surface; dirty, dusty, or soft aggregate; patching beyond base material; lack of compaction of surface during construction; too little asphalt in mix; or excessive heating during mixing.

To repair potholes in surface treatments, take the following actions:

1. Clean out hole.
2. Remove any wet base.
3. Shape hole so that it has vertical sides.
4. Prime hole.
5. Fill hole with Asphalt Concrete.

**Potholes in Asphalt Concrete**

When a small percentage of the pavement is raveling, repair with a skin patch (this includes edge raveling). When a large percentage of the pavement shows raveling, the pavement should be resurfaced.

Note: If the raveling is not a part of the paved surface, no action should be taken. In other words, don’t patch beyond the edge of the pavement.

**Channels or Rutting**

Channels are caused by heavy loads and high tire pressures, subgrade settlement caused by saturation, poor construction methods, or asphalt mixtures of inadequate strength.
Intact Surface

Where the depression is 1 inch or less and the surface is cracked but still largely intact, skin patch the area. Where the depression is more than 1 inch and the surface is cracked but still largely intact, repair with asphalt concrete.

Disintegrated Surface

Where the surface is badly cracked and loose (regardless of amount of depression), remove the old surface. If the area shows signs of mud being pumped to the surface, remove all wet material, replace base material, compact, prime, and build up with Asphalt Concrete.

Upheaval or Frost Boil

Upheaval is caused by expansion of freezing moisture in the lower courses of the pavement or subgrade or by the swelling effect of moisture in expansive soils.

When this distress occurs, repair by installing combination drains as necessary and replacing base and surface.
Appendix B
Glossary

A

AASHTO – The American Association of State Highway and Transportation Officials. An organization of highway engineers from the 50 states that develops guides and standards.

AGGREGATE – Any hard, inert, mineral material used for mixing in graduated fragments. It includes sand, gravel, crushed stone, or slag.

ASPHALT – A dark brown to black cementitious material that can be solid, semi-solid, or liquid in consistency, in which the predominant constituents are bitumens that occur in nature as such or are obtained as residue in refining petroleum. Asphalt is a constituent in varying proportions of most crude petroleum.

ASPHALT BASE COURSE – A foundation course consisting of mineral aggregate, bound together with asphaltic material.

ASPHALT BINDER COURSE – An intermediate course between a base course and an asphalt surface course. The binder course is usually a coarse-graded aggregate Asphalt Concrete containing little or no mineral matter passing through a No. 200 sieve.

ASPHALT CEMENT (AC) – Asphalt that is refined to meet specifications for paving, industrial, and special purposes. Its penetration is usually between 40 and 300.

ASPHALT CONCRETE – High quality, thoroughly controlled hot mixture of asphalt cement and well-graded, high quality aggregate, thoroughly compacted into a uniform dense mass typified by the Missouri Department of Transportation Type B and C and Superpave mixes.

ASPHALT INTERMEDIATE COURSE – A course between a base course and asphalt surface course. Sometimes called binder course.

ASPHALT JOINT FILLER – An asphaltic product used for filling cracks and joints in pavement and other structures.

ASPHALT OVERLAY – One or more courses of asphalt construction on an existing pavement. The overlay generally includes a leveling course to correct the contour of the old pavement, followed by a uniform course or courses to provide needed thickness.

ASPHALT PAVEMENTS – Pavements consisting of a surface course of mineral aggregate coated and cemented together with asphalt cement on supporting courses such as asphalt bases; crushed stone, slag, or gravel.


ASPHALT SOIL STABILIZATION (Soil treatment) – Treatment of naturally occurring nonplastic or moderately plastic soils with liquid asphalt at normal temperatures. After mixing, aeration and compaction provide water resistant base and subbase courses with improved load-bearing qualities.

ASPHALT SURFACE TREATMENTS – Applications of asphaltic materials to any type of road or pavement surface, with or without a cover of mineral aggregate that produces an increase in thickness of less than 1 inch.
B

BASE COURSE – The layer of material immediately beneath the surface or intermediate course. It may be composed of crushed stone; crushed slag; crushed or uncrushed gravel and sand; or combinations of these materials. It also may be bound with asphalt (asphalt base course).

BINDER COURSE – A transitional layer of bituminous paving between the base and the surface course.

BORROW – Suitable material from sources outside the roadway prism used primarily for embankments.

BITUMINOUS CONCRETE – A designed combination of graded crushed stone, filler, and bituminous cement mixed in a central plant, laid and compacted while hot.

CBR (California Bearing Ratio) – A measurement of the strength and support value of a crushed stone base or subgrade soil.

CAPILLARY ACTION – The rise or movement of water in the voids of a soil caused by capillary forces.

CEMENT-TREATED BASE – Cement-treated base consists of specified soil aggregates and Portland Cement Concrete mixed in a pug mill and deposited on the subgrade to the specified thickness.

COARSE AGGREGATE – Aggregate particles retained on a No. 8 sieve.

COARSE GRADED AGGREGATE – An aggregate having a continuous grading in size of particles from coarse through fine with a predominance of coarse sizes.

COMPACTION – The densification of crushed stone base, subgrade soil, or bituminous material by means of vibration or rolling.

CONTRACT – The written agreement executed between the contractor and other parties, setting forth the obligations of the parties thereunder; including, but not limited to the performance of the work, the furnishing of labor and materials, and a basis of payment.

CONTRACTOR – The individual, partnership, corporation, or joint venture contracting for performance of prescribed work.

CRUSHED STONE – The product resulting from the artificial crushing of rocks, boulders, or large cobblestones with the particles resulting from the crushing operation having all faces fractured.

CRUSHER RUN – Aggregates that have received little or no screening after initial crushing operations. Crusher run aggregates are generally more economical than screened aggregates.

CUL-DE-SAC – An area at the terminus of a dead-end street or road constructed for the purpose of allowing a vehicle to turn around.

CULVERT – Any structure that is not classified as a bridge and that provides an opening under any roadway.

CUT – The portion of the roadway formed by excavation below the surface of the earth.
CUTBACK ASPHALT – Asphalt cement that has been liquified by blending with petroleum solvents. Upon exposure to atmospheric conditions, the solvents evaporate, leaving the asphalt cement to perform its function.

DEEP LIFT ASPHALT PAVEMENT – A pavement in which the asphalt base course is placed in one or more lifts of 4 or more inches compacted thickness.

DESIGN THICKNESS – The total pavement structure thickness above the subgrade.

DENSE GRADED AGGREGATE – A mineral aggregate uniformly graded from the maximum size down to and including sufficient mineral dust to reduce the void space in the compacted aggregate to exceedingly small dimensions approximating the size of voids in the dust itself.

DRAINAGE – Structures and facilities for collecting and carrying away water.

EMULSIFIED ASPHALT – An emulsion of asphalt cement and water that contains a small amount of an emulsifying agent, a heterogeneous system containing two normally immiscible phases (asphalt and water), in which the water forms the continuous phase of the emulsion and minute globules of asphalt form the discontinuous phase. Emulsified asphalts may be either anionic, electro-negatively-charged asphalt globules or cationic, electro-positively-charged asphalt globules, depending upon the emulsifying agent.

EQUIPMENT – All machinery, tools, and other apparatus, together with the necessary supplies for upkeep and maintenance, needed for the proper construction and acceptable completion of the work.

EROSION – Removal and transportation of soil by the action of water or wind.

FINE AGGREGATE – Aggregate particles passing a No. 8 sieve.

FINE GRADED AGGREGATE – An aggregate having a continuous grading in sizes of particles from coarse through fine with predominance of fine sizes.

FLEXIBLE PAVEMENT – A pavement structure that maintains intimate contact with and distributes loads to the subgrade and depends on aggregate interlock, particle friction, and cohesion for stability. Asphalt or bituminous concrete pavements are flexible pavements; concrete is not.
FOG SEAL – A light application of liquid asphalt without mineral aggregate cover. Slow-setting asphalt emulsion diluted with water is the preferred type.

FREE WATER (GROUNDWATER) – Water that is free to move through a soil mass under the influence of gravity.

FRENCH DRAIN – A trench loosely backfilled with stones, the largest being placed on the bottom with the size decreasing toward the top.

FULL-DEPTH ASPHALT PAVEMENT – An asphalt pavement in which asphalt mixtures are employed for all courses above the subgrade or improved subgrade. A full-depth asphalt pavement is laid directly on the prepared subgrade.

GRAVEL – A coarse granular material (usually larger than 1/4 inch in diameter) resulting from the natural erosion and disintegration of rock. Crushed gravel is the result of artificial crushing with most fragments having at least one face resulting from fracture.

HYDROSTATIC PRESSURE – The pressure in a liquid under static conditions; the product of the unit weight of the liquid and the difference in elevation between the given points and the free water elevation.

IMPROVED SUBGRADE – Any course or courses of select or improved material between the foundation soil and the subbase is usually referred to as the improved subgrade. The improved subgrade can be made up of two or more courses of different quality materials.

LEVELING COURSE – An asphalt/aggregate mixture of variable thickness used to eliminate irregularities in the contour of an existing surface before superimposed treatment or construction.

LIQUID ASPHALT – An asphalt material having a soft or fluid consistency that is beyond the range of measurement by the normal penetration test, the limit of which is 300 maximum. Liquid asphalts include cutback asphalt and emulsified asphalts.

MATERIALS – Any substances specified for use in the construction of the project and its appurtenances.

MEDIUM CURING ASPHALT (MC) – Liquid asphalt composed of asphalt cement and a kerosene-type diluent of medium volatility.

MINERAL DUST – The portion of the fine aggregate passing a No. 200 sieve.

MINERAL FILLER – A finely divided mineral product at least 65 percent of which will pass a No. 200 sieve. Pulverized limestone is the most common manufactured filler, although other stone dust, hydrated lime, Portland cement, and certain natural deposits of finely divided mineral matter are also used.
**N**

**NATURAL ASPHALT** – Asphalt occurring in nature that has been derived from petroleum by natural processes of evaporation of volatile fractions leaving the asphalt fractions. The native asphalts of most importance are found in the Trinidad and Bermudez Lake deposits. Asphalt from these sources is called Lake Asphalt.

**O**

**OPEN GRADED AGGREGATE** – An aggregate containing little or no mineral filler or in which the void spaces in the compacted aggregate are relatively large.

**P**

**PAVEMENT STRUCTURE (COMBINATION OR COMPOSITE)** – All courses of selected material placed on the foundation or subgrade soil, other than any layers or courses constructed in grading operations. When the asphalt pavement is on an old Portland Cement Concrete base or other rigid-type base, the pavement structure is referred to as a combination or composite-type pavement structure.

**PERCOLATION** – The movement of free water through soil.

**PERMEABILITY** – A measure of the rate or volume of flow of water through a soil.

**PETROLEUM ASPHALT** – Asphalt refined from crude petroleum.

**PLANS** – The standard drawings current on the date bids are received; and the official approved plans, profiles, typical cross sections, electronic computer output listings, working drawings and supplemental drawings, or exact reproductions thereof, current on the date bids are received; and all subsequent approved revisions thereto, which show the location character, dimensions, and details of the work to be done.

**PLANT MIX** – A mixture produced in an asphalt mixing plant, that consists of mineral aggregate uniformly coated with asphalt cement or liquid asphalt.

**PORTLAND CEMENT CONCRETE (PCC)** – A composite material that consists essentially of Portland cement and water as a binding medium in which is mixed coarse and fine particles of crushed stone.

**PRIME COAT** – An application of low-viscosity liquid asphalt to an absorbent surface. It is used to prepare an untreated base for an asphalt surface.

**PROPOSAL** – The offer of a bidder, submitted on the approved official form, to perform the work and to furnish the labor and material at prices set forth therein, valid only when properly signed and guaranteed.

**R**

**RAPID CURING ASPHALT (RC)** – Liquid asphalt composed of asphalt cement and a naphtha- or gasoline-type diluent of high volatility.

**REHABILITATION** – The renewal of an existing surface or pavement structure by repair, recycling, or overlay techniques.

**RECLAIMED ASPHALT PAVEMENT (RAP)** – Removed and/or reprocessed pavement materials containing asphalt and aggregates.
RESURFACING – Existing surfaces may be improved by resurfacing (or overlaying) with a plant mix asphalt mat of varying thicknesses. It may be considered in two categories: (1) overlays to provide smooth, skid- and water-resistant surfaces or to make improvements in grade and/or cross section; and (2) overlays to strengthen existing pavements to handle heavier loads or increased traffic. Sometimes called overlays.

RIGID PAVEMENT – A pavement structure that distributes loads to the subgrade, having as one course a Portland Cement Concrete slab of relatively high bending resistance.

ROAD – A general term denoting a public way for purpose of vehicular travel, including the entire area within the right-of-way.

ROADBED – The graded portion of a highway within the top and side slopes, prepared as a foundation for the pavement structure and shoulders.

ROCK – From which crushed stone, sand, and gravel are made; the rock most suitable for making good aggregates.

SEAL COAT – A thin asphalt surface treatment used to waterproof and improve the texture of an asphalt wearing surface. Depending on the purpose, seal coats may or may not be covered with aggregate. The main types of seal coats are aggregate seals, fog seals, emulsion slurry seals, and sand seals.

SELECT MATERIAL – Suitable material obtained from roadway cuts, borrow areas, or commercial sources and designated or reserved for use as foundation for the subbase, for subbase material, shoulder surfacing, or other specific purposes.

SHOULDER – The portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use, and for lateral support of base and surface courses.

SLOW CURING ASPHALT (SC) – Liquid asphalt composed of asphalt cement and oils of low volatility.

SLAG – The air-cooled, non-metallic by-product of a blast furnace operation consisting essentially of silicates and alumino-silicates of lime and other bases that is developed simultaneously with iron in a blast furnace. Naturally it is only available in those localities where pig iron is produced. Crushed slag weighs about 80 pounds per cubic foot.

SLURRY SEAL – A mixture of slow-setting emulsified asphalt, fine aggregate, and mineral filler with water added to produce slurry consistency.

SOIL AGGREGATE – Natural or prepared mixtures consisting predominantly of hard, durable particles or fragments of stone, slag, gravel, or sand, that contain some soil-clay or stone dust conforming to specified requirements.

SOIL CEMENT BASE – Consists of a mixture of the natural subgrade material and Portland cement in the proper amounts. After thorough mixing, the proper amount of water is added, and the material is compacted to the required thickness.

SOIL SUPPORT – A term expressing the ability of the roadbed material, or subgrade soil, to support the traffic loads transmitted through a flexible pavement structure.
SPECIAL PROVISIONS – Special directions, provisions, or requirements peculiar to the project under consideration and not otherwise thoroughly or satisfactorily detailed or set forth in the specifications. Special provisions set forth the final contractual intent in the matter involved.

STAGE CONSTRUCTION – The construction of roads and streets by applying successive layers of Asphalt Concrete according to design and a predetermined time schedule.

STREET – A general term denoting a public way for purpose of vehicular travel, including the entire area within the right-of-way.

SUBBASE – The course in the asphalt pavement structure immediately below the base course is the subbase. If the subgrade soil is of adequate quality, it may serve as the subbase.

SUBCONTRACTOR – Any individual, partnership, or corporation to whom the contractor sublets part of the contract.

SUBDRAIN – A structure placed beneath the ground surface to collect and carry away underground water.

SUBGRADE – The uppermost material placed in embankments or unmoved from cuts in the normal grading of the roadbed. It is the foundation for the asphalt pavement structure. The subgrade soil sometimes is called basement soil or foundation soil.

SUBGRADE STABILIZATION – Modification of roadbed soils by admixing with stabilizing or chemical agents that will increase load-bearing capacity, firmness, and resistance to weathering or displacement.

SURFACE COURSE – One or more layers of a pavement structure designed to accommodate the traffic load, the top layer of which resists skidding, traffic abrasion, and the disintegrating effects of climate. The top layer is sometimes called the ‘wearing course.’

SUBSURFACE DRAINAGE – Removal of free water from various structural components of the pavement or the surrounding soil.

U

UNDERDRAIN – A perforated or porous-walled pipe placed with suitable pervious backfill beneath the ground surface to collect and carry away underground water.

V

VISCOSITY – This is a measure of the resistance to flow. The term is used as “high viscosity” or “low viscosity.” A high viscosity material refers to a heavy or still material that will not flow easily. A low viscosity material is the opposite. Viscosity is measured in absolute units called poises. It was formerly measured in empirical values of time, distance, and temperature. This method was called Saybolt Furol Viscosity.

W

WEARING COURSE – The top course of asphalt pavements, also called the surface course.
### TABLE C-1. Approximate Quantities of Asphalt Concrete per Square Yard

<table>
<thead>
<tr>
<th>Approximate Thickness</th>
<th>Gravel or Granite</th>
<th>Limestone or Trap Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Weight</td>
<td>Surface Weight</td>
</tr>
<tr>
<td>1&quot; 1/2&quot;</td>
<td>110</td>
<td>110</td>
</tr>
<tr>
<td>2&quot;</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>2 1/2&quot;</td>
<td>275</td>
<td>110</td>
</tr>
<tr>
<td>3&quot;</td>
<td>335</td>
<td>115</td>
</tr>
<tr>
<td>3 1/2&quot;</td>
<td>390</td>
<td>115</td>
</tr>
<tr>
<td>4&quot;</td>
<td>454</td>
<td>115</td>
</tr>
<tr>
<td>5&quot;</td>
<td>577</td>
<td>115</td>
</tr>
<tr>
<td>6&quot;</td>
<td>680</td>
<td>115</td>
</tr>
<tr>
<td>7&quot;</td>
<td>793</td>
<td>115</td>
</tr>
<tr>
<td>8 1/2&quot;</td>
<td>960</td>
<td>115</td>
</tr>
<tr>
<td>9&quot;</td>
<td>1018</td>
<td>173</td>
</tr>
</tbody>
</table>

### TABLE C-2. Gallons of Emulsified Asphalt Required Per 100 Linear Feet: Various Widths and Rates

| Width - Feet | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   | 15   | 16   | 17   | 18   | 19   | 20   | 21   | 22   | 23   | 24   |
|--------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 100W         |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Q (gallons)  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| R (gallons/sq. yd) |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| W (feet)    | 100  | 150  | 200  | 250  | 300  | 350  | 400  | 450  | 500  | 550  | 600  | 650  | 700  | 750  | 800  | 850  | 900  | 950  | 1000 | 1050 | 1100 | 1150 | 1200 | 1250 | 1300 | 1350 | 1400 | 1450 | 1500 |

**Note:** Formula used for calculation: 
\[
Q = \frac{11.11WR}{9} \\
R = 11.11W \\
W = \text{Width of application, in feet}
\]

**Where:**
- \( Q \) = Quantity of asphalt required, in gallons per 100 ft.
- \( R \) = Rate of application in gallons per sq. yd.
- \( W \) = Width of application, in feet

### Conversion Tables

**Appendix C**

**Conversion Tables**
### TABLE C-3. Tons of Material Required Per 100 Linear Feet for Various Widths and Pounds Per Square Yard

<table>
<thead>
<tr>
<th>lb/yd²</th>
<th>WIDTH - FEET</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20</th>
<th>22</th>
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<td>10</td>
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<td>0.17</td>
<td>0.22</td>
<td>0.28</td>
<td>0.33</td>
<td>0.39</td>
<td>0.44</td>
<td>0.50</td>
<td>0.56</td>
<td>1.11</td>
<td>1.67</td>
<td>2.22</td>
<td>2.78</td>
<td>3.33</td>
<td>4.44</td>
<td>5.56</td>
<td>6.67</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0.17</td>
<td>0.23</td>
<td>0.33</td>
<td>0.44</td>
<td>0.56</td>
<td>0.67</td>
<td>0.83</td>
<td>1.00</td>
<td>1.17</td>
<td>1.33</td>
<td>2.67</td>
<td>3.33</td>
<td>4.44</td>
<td>5.56</td>
<td>6.67</td>
<td>8.33</td>
<td>11.11</td>
<td>16.67</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>0.28</td>
<td>0.44</td>
<td>0.67</td>
<td>0.89</td>
<td>1.13</td>
<td>1.39</td>
<td>1.67</td>
<td>1.94</td>
<td>2.22</td>
<td>2.50</td>
<td>5.00</td>
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<td>11.11</td>
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<td>22.22</td>
<td>33.33</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>0.33</td>
<td>0.67</td>
<td>1.00</td>
<td>1.33</td>
<td>1.67</td>
<td>2.00</td>
<td>2.33</td>
<td>2.72</td>
<td>3.11</td>
<td>3.50</td>
<td>7.00</td>
<td>9.00</td>
<td>11.11</td>
<td>13.33</td>
<td>16.67</td>
<td>22.22</td>
<td>33.33</td>
<td>44.44</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>0.39</td>
<td>0.78</td>
<td>1.17</td>
<td>1.56</td>
<td>1.94</td>
<td>2.33</td>
<td>2.72</td>
<td>3.11</td>
<td>3.50</td>
<td>3.90</td>
<td>8.00</td>
<td>10.00</td>
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<td>26.67</td>
<td>35.00</td>
<td>44.44</td>
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<tr>
<td>60</td>
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<td>0.89</td>
<td>1.33</td>
<td>1.78</td>
<td>2.22</td>
<td>2.67</td>
<td>3.11</td>
<td>3.56</td>
<td>4.00</td>
<td>4.44</td>
<td>8.89</td>
<td>11.11</td>
<td>14.44</td>
<td>17.78</td>
<td>21.11</td>
<td>26.67</td>
<td>35.00</td>
<td>44.44</td>
<td></td>
</tr>
<tr>
<td>70</td>
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<td>1.50</td>
<td>2.00</td>
<td>2.50</td>
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<td>4.00</td>
<td>4.50</td>
<td>5.00</td>
<td>10.00</td>
<td>13.33</td>
<td>17.78</td>
<td>21.11</td>
<td>26.67</td>
<td>35.00</td>
<td>44.44</td>
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<td>2.78</td>
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<td>44.44</td>
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<td>1.85</td>
<td>2.47</td>
<td>3.09</td>
<td>3.70</td>
<td>4.32</td>
<td>4.94</td>
<td>5.56</td>
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<td>12.33</td>
<td>16.67</td>
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<td>60.00</td>
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</table>

**NOTE:** Formula used for calculation:

\[ w = \frac{W \times R}{100000} \]

Where:
- \( w \) = Weight of material in tons per 100 feet
- \( R \) = Rate of application, lb/yd²
- \( W \) = Width of application, feet

### TABLE C-4. Cubic Yards of Material per 100 Linear Feet: Various Widths and Depths

<table>
<thead>
<tr>
<th>Width, Feet</th>
<th>Depth - Inches</th>
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<th>9</th>
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<th>11</th>
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<td>3.70</td>
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<td>1.85</td>
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<td>4.63</td>
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<td>30.9</td>
<td>34.0</td>
<td>37.0</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** Formula used for calculation:

\[ q = \left( \frac{D \times W}{3} \right) \left( \frac{100}{3} \right) \]

Where:
- \( q \) = Quality of material, cubic yards
- \( D \) = Depth, inches
- \( W \) = Width, feet
- \( L \) = Length

**Per 100 Linear Feet:**

\[ q = \left( \frac{D \times W}{3} \right) \left( \frac{100}{3} \right) = 0.3086 DW \]

**Per Mile:**

\[ q = \left( \frac{D \times W}{3} \right) \left( \frac{15280}{3} \right) = 16.2963 DW \]
### TABLE C-5.

#### COMMON PREFIXES USED WITH METRIC UNITS

<table>
<thead>
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<th>Prefix</th>
<th>Symbol</th>
<th>Multiplication Factor</th>
</tr>
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<tr>
<td>mega</td>
<td>M</td>
<td>1,000,000</td>
</tr>
<tr>
<td>kilo</td>
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</tr>
<tr>
<td>hecto</td>
<td>h</td>
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<td>deka</td>
<td>da</td>
<td>10</td>
</tr>
<tr>
<td>base unit</td>
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<td>1</td>
</tr>
<tr>
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<td>d</td>
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</tr>
<tr>
<td>centi</td>
<td>c</td>
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</tr>
<tr>
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<td>m</td>
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</tr>
<tr>
<td>micro</td>
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#### METRIC UNITS AND SYMBOLS

**Length**
- kilometer: km
- meter: m
- centimeter: cm
- millimeter: mm
- micrometer: μm

**Area**
- hectare: ha
- square meter: m²
- square centimeter: cm²
- square millimeter: mm²

**Volume**
- cubic meter: m³
- cubic centimeter: cm³
- cubic millimeter: mm³
  - kiloliter: kL
  - liter: L
  - milliliter: mL

**Mass**
- megagram: Mg
- kilogram: kg
- gram: g

**Temp.**
- degrees Celsius: °C
  - °C = (°F-32)/1.8

**Pressure**
- pascal: Pa
- kilopascal: kPa
- megapascal: MPa

**Force**
- newton: N
- kilonewton: kN

---

### TABLE C-6.

#### ENGLISH (INCH-POUND UNITS)

#### METRIC (SI) CONVERSION

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<th>Multiply</th>
<th>To Find</th>
<th>By</th>
</tr>
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</tr>
<tr>
<td>yard</td>
<td>meter</td>
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</tr>
<tr>
<td>foot (U.S. Survey)</td>
<td></td>
<td>0.3048006</td>
</tr>
<tr>
<td>inch</td>
<td>millimeter</td>
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</tr>
<tr>
<td>Sta (English)</td>
<td>Sta (Metric)</td>
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</tr>
<tr>
<td>ton (2,000 lb.)</td>
<td>megagram</td>
<td>0.9071847</td>
</tr>
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</tr>
<tr>
<td>ounce</td>
<td>gram</td>
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</tr>
<tr>
<td>lbs./sq. in.</td>
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<tr>
<td>lbs./sq. ft.</td>
<td>pascals</td>
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<td>cubic yd.</td>
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<td>cubic meter</td>
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</tr>
<tr>
<td>cubic in.</td>
<td>cubic millimeter</td>
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<td>gallon</td>
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</tr>
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<td>fluid ounce</td>
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<td>sq. meter</td>
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<td>sq. mi.</td>
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PM 690 1st Edition 1-96
Based on ASTM E 380
APPENDIX D

PUBLICATIONS
Appendix D

Publications

NATIONAL ASPHALT PAVEMENT ASSOCIATION (NAPA)

The following publications are available from the National Asphalt Pavement Association (NAPA). A more complete listing of available publications and other material can be obtained by contacting either the APAI office or NAPA.

QIP-97 Quality Control for Hot Mix Asphalt Manufacturing Facilities and Paving Operations
QIP-108 Tender Mixes – Probable Causes, Possible Remedies
QIP-109 Asphalt Cement Content Diagnostic Approach for Hot Mix Asphalt (HMA) Facilities
QIP-110 Hot Mix Asphalt Segregation: Causes and Cures
QIP-111 The Design of Hot Mix Asphalt for Heavy Duty Pavements
QIP-112 Constructing Quality Hot Mix Asphalt Pavements – Trouble Shooting Guide
QIP-113 Improving Performance of Longitudinal Construction Joints in Hot Mix Asphalt Pavements
QIP-114A Using Additives and Modifiers in Hot Mix Asphalt - Part A
QIP-114B-E Using Additives and Modifiers in Hot Mix Asphalt – Parts B, C, D, & E
IS-69 Stockpiling and Cold Feed for Quality
IS-71 Hot Recycling in Hot Mix Batch Plants
IS-77 Are Hot Mix Tarps Effective?
IS-84 Development of Marshall Procedures for Designing Asphalt Paving Mixtures
IS-85 Selecting Proper Marshall Procedures for Optimum Asphalt Content of Dense Graded Paving Mixtures
IS-97 Blistering in Asphalt Pavements – Causes and Cures
IS-98 Cracking and Seating of PCC Pavements Prior to Overlaying with Hot Mix Asphalt
IS-101 Guidelines on the Use of Bag-house Fines
IS-107 Estimating User Costs of Asphalt and Concrete Pavement Rehabilitation
IS-109 Design of HMA Pavements for Commercial, Industrial & Residential Applications
IS-111 Pavement Smoothness
IS-117 Guidelines For Use of HMA Overlay to Rehabilitate PCC Pavement
IS-119 Hot Mix Asphalt for High Stress Applications
PS-12 Recreation Asphalt
PS-14 For Your Parking Area Asphalt is Just Better
PS-20 Pavement Life Cycle Costing
PS-21 Which of These Claims Being Made for Concrete Pavement Do You Find Believable?
THE ASPHALT INSTITUTE

The following publications are available from the Asphalt Institute (AI). A more complete listing of publications and other material can be obtained by contacting either the APAI office or the Asphalt Institute.

ES-2 Vibratory Compaction of Asphalt Paving Mixtures
ES-3 Design of Hot Asphalt Mixtures
ES-8 Paving Asphalt
ES-9 Factors Affecting Compaction
ES-10 Cause and Prevention of Stripping in Asphalt Pavements
ES-12 Asphalt Surface Treatments – Construction Techniques
IS-91 Full-Depth Asphalt Pavements for Parking Lots, Service Stations and Driveways
IS-96 How to Design Full-Depth Asphalt Pavements for Streets
IS-139 A Simplified Method for the Design of Asphalt Overlays for Light to Medium Traffic Pavements
IS-147 Athletics and Recreation on Asphalt
IS-154 Thickness Design – Asphalt Pavements for General Aviation
IS-168 Tender Mixes – The Causes and the Cures
IS-169 A Pavement Rating System for Low-Volume Asphalt Roads
IS-173 Energy Requirements for roadway Pavements
IS-178 Alternatives in Pavement Maintenance, Rehabilitation, and Restoration
IS-180 Safe Storage and Handling of Hot Asphalt
IS-181 Asphalt Pavement Thickness Design
MS-1 Thickness Design – Asphalt Pavements For Highways and Streets
MS-2 Mix Design Methods for Asphalt Concrete – And Other Hot-mix Types
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MS-8 Asphalt Paving Handbook
MS-10 Soils Manual – For the Design of Asphalt Pavement Structures
MS-14 Asphalt Cold Mix Manual
MS-15 Drainage of Asphalt Pavement Structures
MS-16 Asphalt in Pavement Maintenance
MS-17 Asphalt Overlays for Highway and Street Rehabilitation
MS-19 A Basic Asphalt Emulsion Manual
MS-20 Asphalt Hot-Mix Recycling
MS-21 Asphalt Cold-Mix Recycling
MS-22 Principles of Construction of Hot-Mix Asphalt Pavements
SP-1 Superpave PG Asphalt Binder Specification & Testing
SP-2 Superpave Level I Mix Design
AMERICAN ASSOCIATION OF STATE
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The following publications are available from the American Association of State Highway and Transportation Officials (AASHTO). A more complete listing of publications and other material can be attained by contacting AASHTO.

AASHTO  Guide for Design of Pavement Structures 1993

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The Asphalt Institute (AI)
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Lexington, Kentucky 40512-4052
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American Association of State Highway and Transportation Officials (AASHTO)
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Traffic Control Device Handbook, Stock No. 050-001-00270-1. Price is $20 per copy or $1,500 for 100 copies to a single address.
APPENDIX E

CREDITS

AND

REFERENCES
Appendix E
CREDITS

Special recognition is given to the following agencies or associations for their help in providing information and resources which contributed to the writing of this Design Guide.

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The Plantmix Asphalt Industry of Kentucky, Inc.
The Virginia Asphalt Associates, Inc.
The National Asphalt Pavement Association

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REFERENCES


APPENDIX F

MEMBER FIRMS