01203477 Pavement Structure
Introduction

Assistant Professor Dr.Weerakaset Suanpaga (D.Eng)
Department of civil engineering
KASETSART UNIVERSITY

Contents

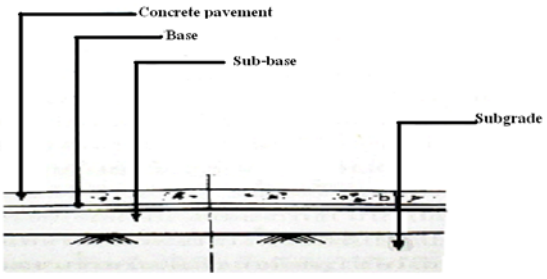
1.Pavement Types

-*Flexible pavements.* Those which are surfaced with bituminous (or asphalt) materials. These types of pavements are called "flexible" since the total pavement structure "bends" or "deflects" due to traffic loads. A flexible pavement structure is generally composed of several layers of materials which can accommodate this "flexing".

-*Rigid pavements*. Those which are surfaced with portland cement concrete (PCC). These types of pavements are called "rigid" because they are substantially stiffer than flexible pavements due to PCC's high stiffness

Figure 1: Rigid and Flexible Pavement Load Distribution

1.1Rigid pavement



Cross section of concrete pavement

1.2 Cross Section of Basic Structural Elements

-Flexible Pavements

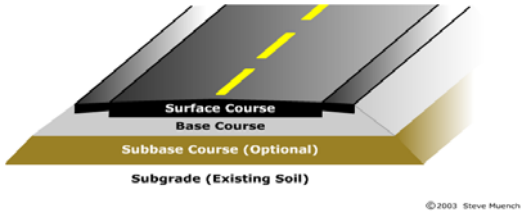


Figure 1.: Basic Flexible Pavement Structure

Flexible Pavements Structure

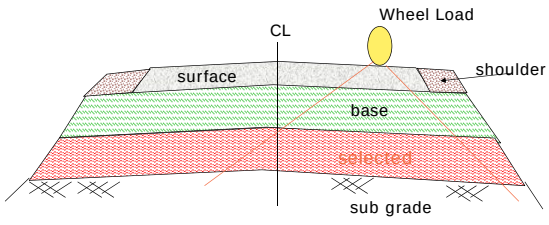


Figure 2. Flexible pavement structure and wheel load distribution

1.3.Pavements Structure
1.3.1 Subgrade Course

- sub grade is a original soil
- to make a standard, it require soil improvement by soil compaction if it is a Soft-spot soil =>should to remove (Excavation)
- Stiff soil ok ➔ could distribute load or high baring/stress capability

1.3.2.Selected Materials

- we will use selected material in case of the original Subgrade's quality very bad eq. CBR ≤ 2%
- so many selected materials such as Soil Aggregates Or Sand

1.3.3.Subbase Course

The subbase course is between the base course and the subgrade. It functions primarily as structural support but it can also:

1.Minimize the intrusion of fines from the subgrade into the pavement structure.
2.Improve drainage.
3.Minimize frost action damage.
4.Provide a working platform for construction.

The subbase generally consists of lower quality materials than the base course but better than the subgrade soils. A subbase course is not always needed or used. For example, a pavement constructed over a high quality, stiff subgrade may not need the additional features offered by a subbase course so it may be omitted from design. However, a pavement constructed over a low quality soil such as a swelling clay may require the additional load distribution characteristic that a subbase course can offer. In this scenario the subbase course may consist of high quality fill used to replace poor quality subgrade (over excavation)

1.3.3. Subbase Course-cont'

- Materials : Soil Aggregate that has the well graded (dense grade) =>low percent of air void after compaction and high density
- Materials in group of soil aggregate are
  - -Laterite or lateritic soils
  - -gravel mixed sand
  - -soil mixed sand
  - -soil+sand that are stabilized by Cement or Asphalt

1.3.4.Base Course

- Base courses are most typically constructed from durable aggregates. The Material in this base course are crushed *igneous rock* (granite, marble etc), limestone, soil aggregate
- Use the High quality of Materials because this base course are received by the high density of stresses.

In certain situations where high base stiffness is desired, base courses can be constructed using a variety of HMA mixes

Type of Base
1. Hot-rolled Asphalt
2. Water bound Macadam
3. Soil Stabilization
4. Base course or Soil Aggregate*

*in most case we use in Thailand

Figure 3: Limerock Base Course Undergoing Final Grading

1.3.5.Surface Course

- Type of surface pavement
  1. surface made from soil or crushed rock
  2. Asphalt concretes
  3. Cement concrete

2.Definition/glossary

- nominal maximum aggregate size
- Maximum Size
- Nominal maximum size
- Gradation

2.1nominal maximum aggregate size

Aggregates can be classified by
-mineral,
-chemical
-physical properties.=>pavement typically relies on physical properties for performance characterization

2.2 Maximum Size

=> The smallest sieve through which 100 percent of the aggregate sample particles pass

2.3 Nominal maximum size

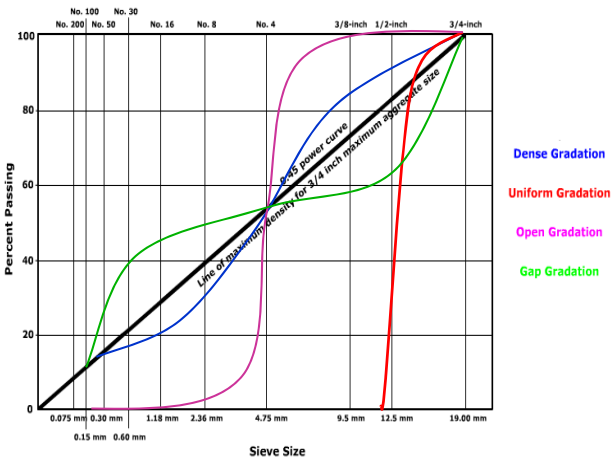
=>The largest sieve that retains some of the aggregate particles but generally not more than 10 percent by weight

2.4 Gradation

- is aggregate's particle size distribution, or gradation
- In HMA, gradation helps determine almost every important property including stiffness, stability, durability, permeability, workability, fatigue resistance, frictional resistance and resistance to moisture damage (Roberts et al., 1996)
- measured by a sieve analysis

2.5 Typical Gradations

- Dense or well-graded. Refers to a gradation that is near maximum density
- Gap graded. Refers to a gradation that contains only a small percentage of aggregate particles in the mid-size range
  =>curve is flat in the mid-size range
- Open graded. Refers to a gradation that contains only a small percentage of aggregate particles in the small range
  => more air voids (not enough small particles to fill in the voids between the larger particles).
  =>curve is flat and near-zero in the small-size range.
- Uniformly graded. Refers to a gradation that contains most of the particles in a very narrow size range
  => contains most of the particles in a very narrow size range (all the particles are the same size)
  => The curve is steep and only occupies the narrow size range specified.



3 HMA Mix Types

Hot mix asphalt is known by many different names such as hot mix, asphalt concrete (AC or ACP), asphalt, blacktop or bitumen

HMA is distinguished by its design and production methods and includes traditional dense-graded mixes as well as stone matrix asphalt (SMA) and various open-graded HMAs.

3 HMA Mix Types-cont'

- Typically agencies consider other types of asphalt-based pavement surfaces such as fog seals, slurry seals and BSTs to be maintenance treatments and are therefore covered in the Maintenance & Rehabilitation section. Reclaimed asphalt pavement (RAP) is generally considered a material within HMA, while forms of in-place recycling are considered separately

4.Flexible pavements type

There are many different types of flexible pavements. This section covers three of the more common types of HMA mix types used in the U.S.

- *Dense-graded HMA*. Flexible pavement information in this Guide is generally concerned with dense-graded HMA. Dense-graded HMA is a versatile, all-around mix making it the most common and well-understood mix type in the U.S.
- *Stone matrix asphalt (SMA)*. SMA, although relatively new in the U.S., has been used in Europe as a surface course for years to support heavy traffic loads and resist studded tire wear.
- *Open-graded HMA*. This includes both open-graded friction course (OGFC) and asphalt treated permeable materials (ATPM). Open-graded mixes are typically used as wearing courses (OGFC) or underlying drainage layers (ATPM) because of the special advantages offered by their porosity.

4.1 Dense-Graded Mixes

- is a well-graded HMA
- If properly designed and constructed. called=>relatively impermeable
- generally referred to by their nominal maximum aggregate size (fine-graded or coarse-graded)
- Fine-graded mixes have more fine and sand sized particles than coarse-graded mixes.

4.1 Dense-Graded Mixes cont'

·**Figure 4: Dense-Graded HMA** **Figure 5: Dense-Graded Cores**

- **Purpose:** Suitable for all pavement layers and for all traffic conditions. They work well for structural, friction, leveling and patching needs.
- **Materials:** Well-graded aggregate, asphalt binder (with or without modifiers)

4.1 Dense-Graded Mixes cont'

·**Purpose:** Dense-graded mixes are suitable for all pavement layers and for all traffic conditions. They work well for structural, friction, leveling and patching needs

·**Materials:** Well-graded aggregate, asphalt binder (with or without modifiers), RAP

·**Mix Design:** Superpave, Marshall or Hveem procedures.

Table 2.1: Fine- and Course-Graded Definitions for Dense-Graded HMA (from NAPA, 2001)

Mixture Nominal Maximum Aggregate Size	Coarse-Graded Mix	Fine-Graded Mix
37.5 mm (1.5 inches)	< 35 % passing the 4.75 mm (No. 4 Sieve)	> 35 % passing the 4.75 mm (No. 4 Sieve)
25.0 mm (1.0 inch)	< 40 % passing the 4.75 mm (No. 4 Sieve)	> 40 % passing the 4.75 mm (No. 4 Sieve)
19.0 mm (0.75 inches)	< 35 % passing the 2.36 mm (No. 8 Sieve)	> 35 % passing the 2.36 mm (No. 8 Sieve)
12.5 mm (0.5 inches)	< 40 % passing the 2.36 mm (No. 8 Sieve)	> 40 % passing the 2.36 mm (No. 8 Sieve)
9.5 mm (0.375 inches)	< 45 % passing the 2.36 mm (No. 8 Sieve)	> 45 % passing the 2.36 mm (No. 8 Sieve)

4.2 Stone Matrix Asphalt (SMA)1

⇒sometimes called stone mastic asphalt

⇒ is a gap-graded HMA originally developed in Europe to maximize rutting resistance and durability.

·SMA, has been used in the U.S. since about 1990, although it has only begun to be used in Washington State recently on several pilot projects

- The mix goal is to create stone-on-stone contact. Since aggregates do not deform as much as asphalt binder under load, this stone-on-stone contact greatly reduces rutting.
- SMA is generally more expensive than a typical dense-graded HMA because it requires more durable aggregates, higher asphalt content, modified asphalt binder and fibers.
- In the right situations it should be cost-effective because of its increased rut resistance and improved durability.

4.2 Stone Matrix Asphalt (SMA) cont'

Figure 5: SMA Surface

Figure 6: SMA Lab Sample

- **Purpose:**
  - Improved rut resistance and durability. SMA is almost exclusively used for surface courses on high volume interstates and U.S. roads.
- **Materials:**
  - Gap-graded aggregate, modified asphalt binder, fiber filler
- **Other Info:**
  - SMA benefits include wet weather friction (due to a coarser surface texture),
  - lower tire noise (due to a coarser surface texture) and less severe reflective cracking.
  - Mineral fillers and additives are used to minimize asphalt binder drain-down during construction,
  - increase the amount of asphalt binder used in the mix and to improve mix durability.

4.2 Stone Matrix Asphalt (SMA) cont'

- **Purpose:** Improved rut resistance and durability. Therefore, SMA is almost exclusively used for surface courses on high volume interstates and U.S. roads.
- **Materials:** Gap-graded aggregate (usually from coarse aggregate, manufactured sands and mineral filler all combined into a final gradation), asphalt binder (typically with a modifier)
- **Mix Design:** Superpave or Marshall procedures with modifications. Refer to NAPA's *Designing and Constructing SMA Mixtures: State-of-the-Practice*, QIP 122 (1999) publication or NCHRP Report 425: *Designing Stone Matrix Asphalt Mixtures for Rut-Resistant Pavements*

4.2 Stone Matrix Asphalt (SMA) cont'

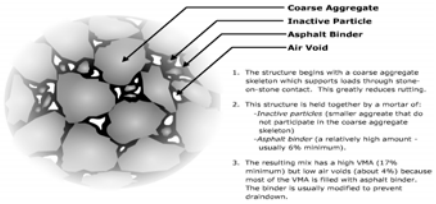


Figure 2.12: SMA Pavement Surface

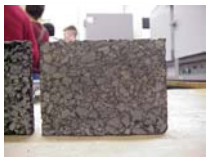


Figure 2.9: SMA Aggregate Structure. Notice the stone-on-stone contact of the larger aggregate particles.

4.3 Open-Graded Mixes

- an open-graded HMA mixture
  - is designed to be water permeable. Open-graded mixes use only crushed stone (or gravel) and a small percentage of manufactured sands. The two most typical open-graded mixes are:
- *Open-graded friction course (OGFC).*
  - Typically 15 percent air voids and no maximum air voids specified.
- *Asphalt treated permeable bases (ATPB).*
  - Less stringent specifications than OGFC since it is used only under dense-graded HMA, SMA or PCC for drainage.

4.3 Open-Graded Mixes cont'

Figure 7 OGFC Surface

Figure 8 OGFC Lab Samples

- **Purpose:** *OGFC*
  - Used for surface courses only.
  - reduce tire splash/spray in wet weather and typically result in smoother surfaces than dense-graded HMA.
  - high air voids reduce tire-road noise by up to 50-percent (10 dBA) (NAPA, 1995).

  ATPB - Used as a drainage layer below dense-graded HMA, SMA or PCC.
- **Materials:** Aggregate (crushed stone or gravel and manufactured sands), asphalt binder (with modifiers)
- **Other Info:** OGFC is more expensive per ton than dense-graded HMA, but the unit weight of the mix when in-place is lower, which partially offsets the higher per-ton cost. The open gradation creates pores in the mix, which are essential to the mix's proper function. Anything that tends to clog these pores, such as low-speed traffic, excessive dirt on the roadway or deicing sand, can degrade performance.

4.3 Open-Graded Mixes cont'

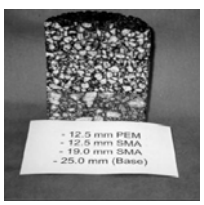


Figure 2.13: Core from a Pavement Using PEM as the Wearing Course (from NAPA, 2001)

Figure 2.14: Asphalt Treated Permeable Base

5 Mix Selection Guidance

- Based on the previous information, there are some general rules for HMA mix type use, which are summarized in Table 2.2.
- Notice that, as discussed, dense-graded HMA is generally appropriate for all uses, SMA and OGFC (and PEM) are typically used as surface courses on high volume roads and ATPB is usually used for base courses on high volume roads.
- Keep in mind that Table 2.2 is just a summary of general guidance and that there are, as always, case specific exceptions.

Table 2.2: General Appropriateness of Mix Types For Each HMA Layer (NAPA, 2001)

Course	Low Traffic (< 300,000 ESALs)				Medium Traffic (300,000 - 10 million ESALs)				High Traffic (> 10 million ESALs)			
	Dense	SMA	OGFC	ATPB	Dense	SMA	OGFC	ATPB	Dense	SMA	OGFC	ATPB
Surface	●				●	○	○		●	●	●	
Intermediate	●				●				●	○		
Base	●				●			○	●			●

● = Appropriate
○ = Moderately Appropriate
empty = Not Appropriate

Note: Before deciding to use ATPB, the Pavement Research Center's research results should be carefully considered.

6.Recycled HMA or Reclaimed Asphalt Pavement (RAP)1

- ***RAP is essentially old pavement that is reclaimed for use.***
- ***it is collected in loose granular form as a byproduct of pavement rehabilitation or reconstruction (see Figures 1 and 2).***
- ***RAP can be used in a variety of ways such as:***
  - ***As an addition to regular HMA.***
  - ***As an aggregate in cold-mix asphalt or asphalt emulsion***
  - ***As a granular base course when pulverized.***
  - ***As a fill or embankment material.***

Reclaimed Asphalt Pavement cont'

- Figure 9: RAP Pile in Eastern Washington Figure 10: RAP Up Close

7.Other Recycling Options

7.1 Hot in-place recycling (HIPR).

=> can only correct shallow surface distress problems (less than 2 inches).
=> can be done by heater scarification, repaving or remixing.

- *Heater scarification.* The pavement surface is heated with radiant heaters, scarified using a bank of nonrotating teeth, rejuvenated using an additive to improve the recycled asphalt binder viscosity, mixed and leveled, then compacted using conventional compaction equipment. Heater scarification is limited in its ability to repair severely rutted pavements, which are more easily rehabilitated with a conventional HMA overlay.
- *Repaving.* This method is similar to heater scarification, only the top layer is completely removed (rather than left in place) and then placed in either one or two lifts.
- *Remixing.* This method is used when additional aggregate is required to improve the strength or stability. Remixing is similar to repaving but adds new virgin aggregate or new HMA to the recycled material before it is leveled.

7.Other Recycling Options

7.2 Cold in-place recycling (CIPR).

=>essentially pulverizes the existing pavement structure to a predetermined depth, adds a binding agent (such as an emulsion or foamed asphalt), then lays and compacts the resulting product for use as a stabilized base course. This base course is then paved over with an HMA surface course

7.3 Asphalt Treated Base (ATB)

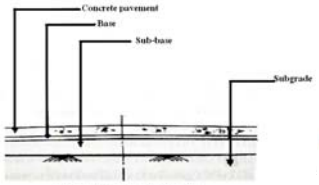
- is a dense-graded HMA with a wide gradation band and lower asphalt content (2.5 - 4.5 percent by weight of aggregate) intended for use as a base course.
- ATB costs less than typical HMA mixes because it can be produced with less expensive aggregates and lower percentages of asphalt binder.
- In addition to the site paving benefits, ATB can be advantageous because it can provide:

7.3 Asphalt Treated Base (ATB) advantageous

- *A waterproof barrier to prevent fines infiltration into the subgrade and pavement structure.* If water accumulates in the subgrade, the repetition of pavement loading can cause subgrade fines to migrate into the base and pavement structure. This can clog the base layer, which impedes drainage and create voids in the subgrade into which the pavement may settle.
- *An alternative to untreated base material.* Structurally, **ATB is about three times as strong as an untreated granular base** (such as crushed surface base or top course). Therefore, it is possible to use thinner layers for the same structural support, which can save on excavation costs. In some cases a layer of aggregate base is still needed to provide material to fine grade and to provide a smooth surface on which to pave
- **Other ATB Information**
  - Compacted Density ≈ 1.85 tons/yd3
  - Layer coefficient ("a") for use in the 1993 AASHTO Empirical Structural Design ≈ 0.35

8. Rigid pavement

Rigid pavements are so named because the pavement structure deflects very little under loading due to the high modulus of elasticity of their surface course. A rigid pavement structure is typically composed of a PCC surface course built on top of either (1) the subgrade or (2) an underlying base course. Because of its relative rigidity, the pavement structure distributes loads over a wide area with only one, or at most two, structural layers



Cross section of concrete pavement

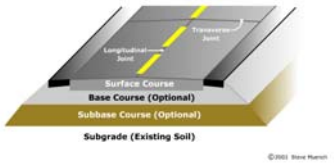


Figure 2.20: Basic Rigid Pavement Structure

8.1Surface Course

The surface course is the layer in contact with traffic loads and is made of PCC. It provides characteristics such as friction (see Figure 2.21), smoothness, noise control and drainage. In addition, it serves as a waterproofing layer to the underlying base, subbase and subgrade. The surface course can vary in thickness but is usually between 150 mm (6 inches) (for light loading) and 300 mm (12 inches) (for heavy loads and high traffic). Figure 2.22 shows a 300 mm (12 inch) surface course.


Figure 2.21: PCC Surface


Figure 2.22: Rigid Pavement Slab (Surface Course) Thickness

8.2 Base Course

- The base course is immediately beneath the surface course. It provides (1) additional load distribution, (2) contributes to drainage and frost resistance, (3) uniform support to the pavement and (4) a stable platform for construction equipment (ACPA, 2001). Bases also help prevent subgrade soil movement due to slab pumping. Base courses are usually constructed out of:.

1. *Aggregate base.* A simple base course of crushed aggregate has been a common option since the early 1900s and is still appropriate in many situations today.
2. *Stabilized aggregate or soil (see Figure 2.23).* Stabilizing agents are used to bind otherwise loose particles to one another, providing strength and cohesion. Cement treated bases (CTBs) can be built to as much as 20 - 25 percent of the surface course strength (FHWA, 1999). However, cement treated bases (CTBs) used in the 1950s and early 1960s had a tendency to lose excessive amounts of material leading to panel cracking and settling.

8.2 Base Course cont'

3. *Dense-graded HMA.* In situations where high base stiffness is desired base courses can be constructed using a dense-graded HMA layer.
4. *Permeable HMA.* In certain situations where high base stiffness and excellent drainage is desired, base courses can be constructed using an open graded HMA. Recent research may indicate some significant problems with ATPB use.
5. *Lean concrete (see Figure 2.24).* Contains less portland cement paste than a typical PCC and is stronger than a stabilized aggregate. Lean concrete bases (LCBs) can be built to as much as 25 - 50 percent of the surface course strength (FHWA, 1999). A lean concrete base functions much like a regular PCC surface course and therefore, it requires construction joints and will crack over time. These joints and cracks can potentially cause reflection cracking in the surface course if they are not carefully matched

8.2 Base Course cont'

Figure 2.23: Completed CTB with Curing Se

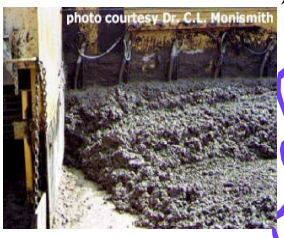


Figure 2.24: Lean Concrete Base Material

8.3 Subbase Course

- The subbase course is the portion of the pavement structure between the base course and the subgrade. It functions primarily as structural support but it can also:

1. Minimize the intrusion of fines from the subgrade into the pavement structure.
2. Improve drainage.
3. Minimize frost action damage.
4. Provide a working platform for construction.
5. The subbase generally consists of lower quality materials than the base course but better than the subgrade soils. Appropriate materials are aggregate and high quality structural fill. A subbase course is not always needed or used.

9. Conclusion

Function of pavement

- To distribute load from surface to base, sub-base and sub-grade as following
- To protect abrasion of surface
- To protect shear-failure under surface
- To protect water and humidity

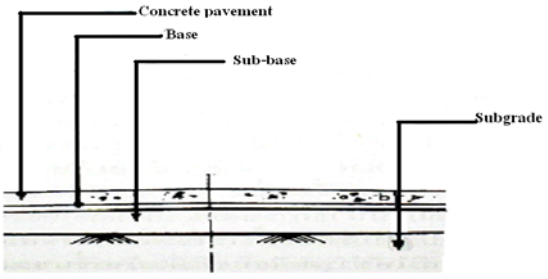
Type of pavement

- Flexible pavement
- Rigid pavement

Flexible pavement

- Surface treatment
- Road mixed bitumen surface
- Penetration macadam
- Asphaltic concrete
- Slurry seal (repair old surface)
- Cape seal (surface treatment+slurry seal)
- Base course

Rigid pavement



Cross section of concrete pavement

Rigid pavement

Advantage in using sand under rigid pavement

- Protect pumping action
- Protect frost action
- Drain under surface
- Protect swelling and shrinkage in subgrade
- Strengthen of subgrade and easy in construction

Highway and Runway

	Highway	Runway
Repetition of load	more	
load		more
Distribution of traffic	1 m of edge	9 m
Geometry of pavement		

Reference:

- http://www.asphaltwa.com/wapa_web/modules/02_pavement_types/02_pavement_types.htm

Question?

Thank you for your kind attention