DEPARTMENT OF CIVIL ENGINEERING

Final Assignment/Quiz (Spring 2020)
Subject: Pavement Material Engineering
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Q.No.1.

1) Why do we carry out granular (physical) Stabilization?

Answer: Soils with particle sizes greater than 0.075 mm are designated as medium to coarse-grained soils. These soils, when compacted, form a granular bearing skeleton through a network of grain-to-grain contact points that can:

- Transfer load without Permanent Deformation
- Provide Frictional Resistance
- Bears Volume Stability

Stabilization of this class of soils is designated "Granular Stabilization".

It involves preparation of Mixture of Soil-Aggregate consisting of

- Stone, Gravel, and Sand and containing Silt-Clay and
- Compacted to maximum density to obtain high strength, stability, and durability in all weather conditions.

Granular stabilization is used in construction of, Base, Sub-base, and Surface Courses of paved facilities.

"The primary objective is to obtain a well-proportioned mixture of particles with continuous gradation (well graded) and the desired plasticity."

2) How do we carryout Granular (physical) stabilization considering granulometry and collametry, fabric, soil binder, collametirics, and specifications of gradation and selection of soil elements?

Answer:

1) **Granulometry and Collametry:**

The pore volume and the size of the pores formed by the granular skeleton determine the transition of a particular soil to one with or without a bearing skeleton.

Fundamentals of Granulometry are applied to establish quantitative definitions of granular skeleton with effective compactness.

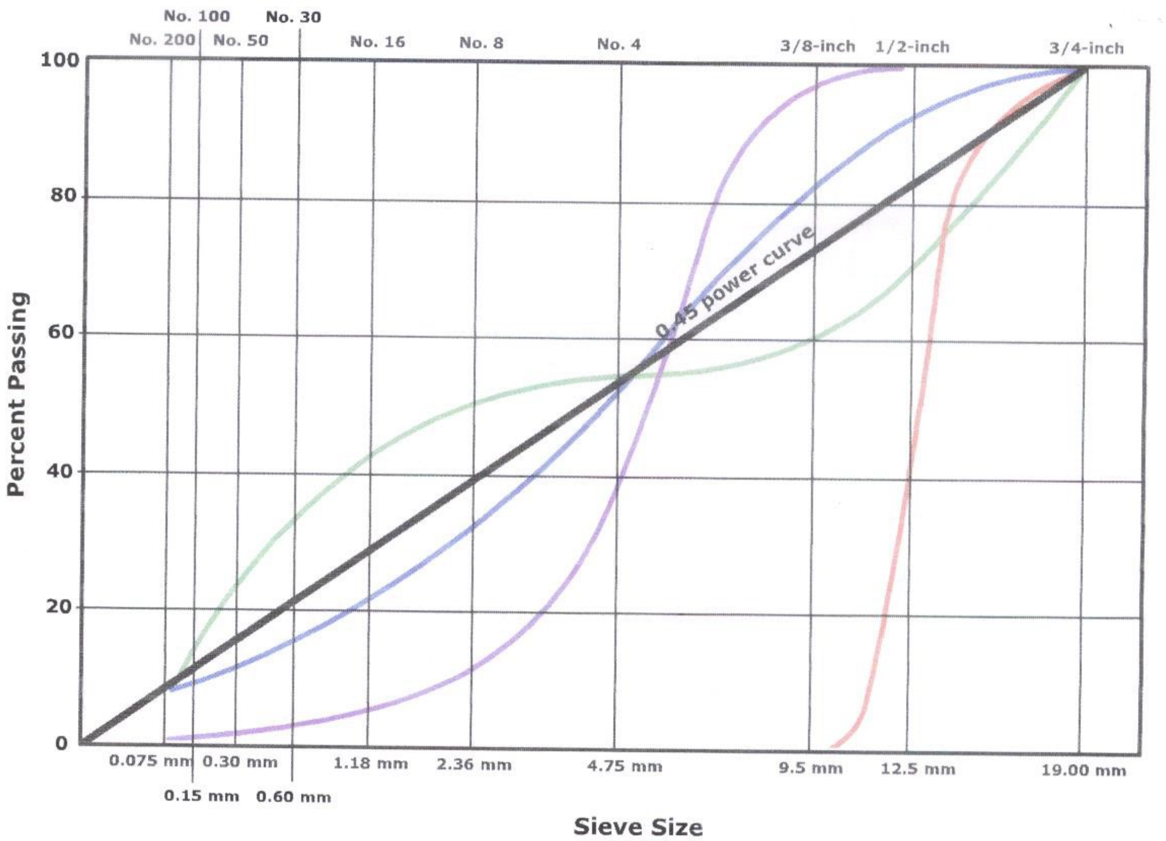
Grain-size distributions that yield minimal porosity values with small densification effort are best presented by the Talbot formula:

$$s=(d/d_{max})^m$$

where

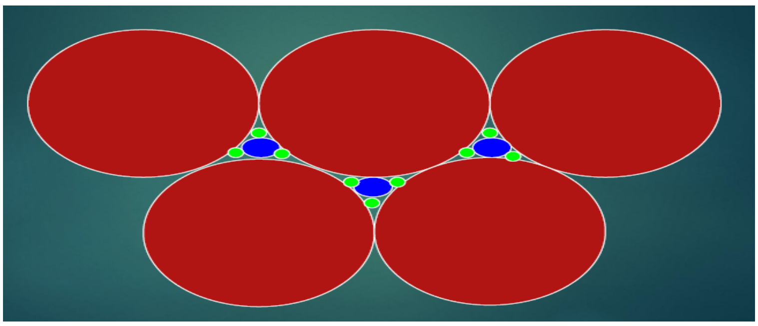
S = Weight percent of the particles with diameter less than d.

- dmax= maximum particle diameter in the mixture
- m = exponent determined empirically
- The factor m varies between 0.11 and 0.66.
- U.S. Bureau of Public Roads recommends 0.45as the best overall value for m.

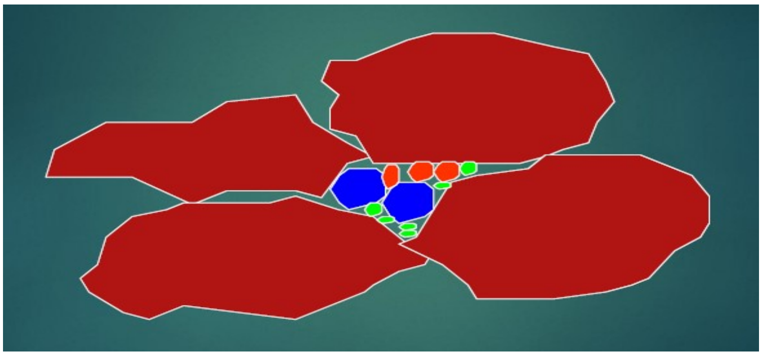


2) Fabrics:

Ideal:



Actual:



3) Soil Binder:

The soil binder or the cementing materials tend to surround the coarse-grain particles and/or form bonding bridges between particles such that the granular system attains rigidity and stability. The strength of such a system is dependent on the strength of the cement and on the shear resistance at the cement-particle interface, as well as on the strength of the granular network. It belongs to the group of:
"MORTARS" where the largest particles are of fine sand size or the size of the openings of No. 40 sieve (0.425 mm).

Complete replacement of natural soil binder in a clay-bonded stabilized gravel (clay concrete) by Portland cement produces Portland Cement Concrete. Partial replacement leads to systems that possess properties intermediate between those of Clay Concrete and a Portland Cement Concrete. Similarly, partial replacement of the soil binder by asphalt leads to waterproofed granular soil stabilization, and complete replacement by bitumen and filler leads to Bituminous Concrete.

4) Collametirics:

Soils with granular bearing skeleton in the densified state possesses volume stability and frictional resistance. They may require

- Bonding or Cementation
- Increase in Cohesion
- Decrease in Permeability or Water Storage Capacity *(if deficient in fines)*

Such stabilized granular soils belong to the class of Collametirics (colla= glue, meros= particle) systems.

TABLE 9.2 COLLAMERITICS—THE SCIENCE OF COMPOSITION AND PROPERTIES OF NONMETALLIC CONSTRUCTION MATERIALS[a].

Properties of the Particles	*Properties of the Cementing Agents*	*Examples of Cemented Systems*
A. Physical I. Granulometry Laws of arrangement and packing as functions of size, gradation and shape factors II. Mechanical Strength, toughness abrasion resistance B. Physicochemical and chemical I. Interaction and bonding with cementing agents II. Reactivity with deleterious substances in environment	A. Inorganic I. Simple Gypsum and lime plasters II. Complex Sorel-, hydraulic and other cements III. Clay and binder soil B. Organic I. Bituminous Asphalts, pitches, tars II. Natural and synthetic resins and other polymers III. Gums, glues of various types, etc.	1. Mortars with inorganic and organic cements including natural and artificial sand stones 2. Concretes Portland cement, bituminous, resinous, clay, etc., including naturally cemented conglomerates 3. Plastics Powder, paper-, cloth-, and fiber-filled; also natural wood in which cellulose fibers are bonded together by lignin

[a] After Winterkorn (1955a).

5) Specifications of gradation and selection of soil elements:

The properties of the final mixture are generally controlled and judged by gradation, the liquid limit, and the plasticity index.

A granular bearing skeleton may be established by several different methods. The choice depends on

- The soil and other materials available
- Intended use and special properties desired in the stabilized system
- Time constraints for planning and construction.
- **Soil Binder and Water:** These are the two elements that create the adhesion and bonding between the coarse grains and provide the continuity of the structure by filling in the voids of the bearing skeleton. The continuous granular skeleton is strengthened and stabilized by the added cohesion.
- **During dry weather**: Shrinkage of soil binder develops tensile forces on the surfaces of the coarse grains, which has the desirable effect of increased compression on the granular skeleton.
- **During wet weather**: Swelling of the soil binder might be desirable, as it would reduce the permeability and retard penetration of water. However, introduction of excessive volume change to the system might be detrimental to functioning of the bearing skeleton. Therefore, the amount and the properties of the soil binder should be controlled for optimum results.

TABLE 9.3 GRADATION REQUIREMENTS FOR SOIL AGGREGATE MATERIALS [ASTM D1241 (AASHTO M147)].

	Weight Percent Passing Square Mesh Sieves					
	Type I				*Type II*	
Sieve Size (Square Openings)	*Gradation A*	*Gradation B*	*Gradation C*	*Gradation D*	*Gradation E*	*Gradation F*
2 in (50 mm)	100	100	—	—	—	—
1 in (25 mm)	—	75 to 95	100	100	100	100
$\frac{3}{8}$ in (9.5 mm)	30 to 65	40 to 75	50 to 85	60 to 100	—	—
No. 4 (4.75 mm)	25 to 55	30 to 60	35 to 65	50 to 85	55 to 100	70 to 100
No. 10 (2.00 mm)	15 to 40	20 to 45	25 to 50	40 to 70	40 to 100	55 to 100
No. 40 (425 μm)	8 to 20	15 to 30	15 to 30	25 to 45	20 to 50	30 to 70
No. 200 (75 μm)	2 to 8	5 to 15	5 to 15	8 to 15	6 to 15	8 to 15

TABLE 9.4 GRADING REQUIREMENTS FOR FINAL MIXTURES FOR BASES OR SUBBASES (ASTM D2940).

	Design Range[a] (Weight Percentages Passing)		*Job Mix Tolerances (Weight Percentages Passing)*	
Sieve Size (Square Openings)	*Bases*	*Sub-bases*	*Bases*	*Sub-bases*
2 in (50 mm)	100	100	−2	−3
$1\frac{1}{2}$ in (37.5 mm)	95 to 100	90 to 100	±5	+5
$\frac{3}{4}$ in (19.0 mm)	70 to 92	—	±8	—
$\frac{3}{8}$ in (9.5 mm)	50 to 70	—	±8	—
No. 4 (4.75 mm)	35 to 55	30 to 60	±8	±10
No. 30 (600 μm)	12 to 25	—	±5	—
No. 200 (75 μm)	0 to 8[b]	0 to 12[b]	±3	±5

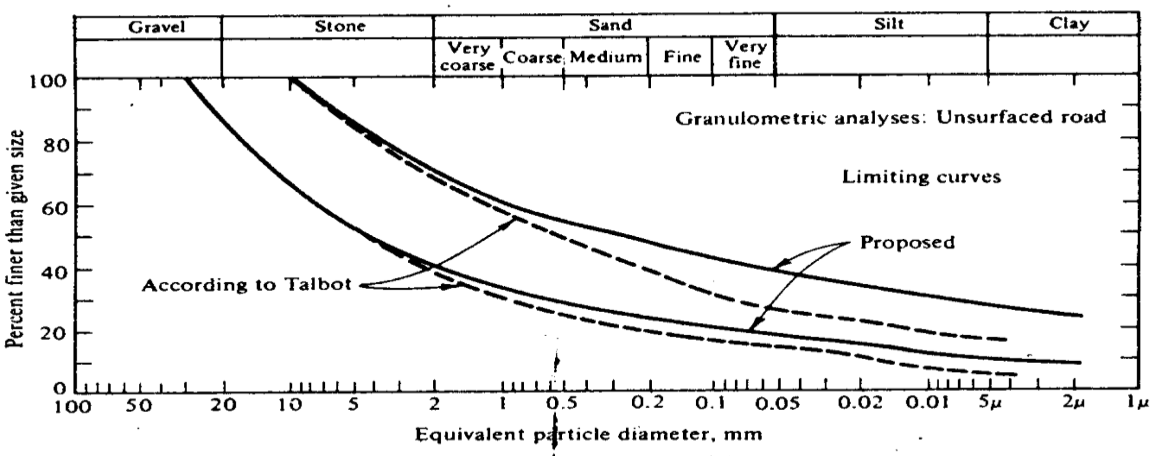


Fig. 9.3 Clay–concrete for laterite soil binder.

Q.No.02.

1) How would you (being a material expert) identify aggregate referring to naturally occurring materials, igneous rocks, Sedimentary Rocks, metamorphic rocks, and residual material and transported deposits?

Answer:

Aggregates can be identified on the basis of:

- Origin (Composition)
- Mode of Formation & Deposition
- Density (Intra-particle voids)
- Shape
- Surface Texture

1) **Naturally Occurring Materials:**

The majority of aggregates used in road construction are obtained from naturally occurring deposits.

Natural aggregates for roadmaking are obtained from rock of the following geological groups:

2) **Igneous Rocks (95% of Earth's Crust):**

Which are formed by the cooling of molten material

3) **Sedimentary Rocks (5% of Earth's Crust & 75% of Earth's Surface):**

Which are formed by deposition of granular material

4) **Metamorphic Rocks:**

Which are igneous or sedimentary rocks that have undergone transformations due to heat and pressure

The weathering product may be of two general types:

5) **Residual Materials:**
   Which may be either weathered or unweathered, generally occur in large deposits and are obtained by quarrying.
6) **Transported Deposits:**
   They are found, for example, in stream beds, sand and gravel bars, and alluvial fans.

2) In Aggregate investigation Material sourcing is referred to Field investigation. Discuss material sourcing in detail.

Answer:

Field Investigation for concrete materials prior to construction are chiefly confined to:

- Prospecting for Aggregates
- Exploration and Sampling of Available Deposits

Judgement and Thoroughness in conducting preliminary field investigations are usually reflected in the Durability and Economy of the completed structures.

Awareness of the Effect of different properties of the aggregates on the behaviour of pavement layers are must for the Investigation Team.

Materials Sources are mainly:

1) Natural Deposits
2) Rock Queries

In natural deposits we have:

- Stream/River deposits
- Glacial deposits
- Fluvial deposits
- Talus deposits
- Wind-blown deposits.

We already have some existing known sources from where we obtained the required materials, for new sources we need:

- Soil survey maps
- Geological maps
- Aerial photographs
- Satellite imageries

Q.No.03. What are the Macadam bases types and discuss the water bound macadam and wet mixing macadam in detail bound, also elaborate the difference between water bound macadam and wet mixing macadam?

Answer: Types of Macadam Bases:

1) Water bound Macadam
2) Dry bound Macadam
3) Wet mix Macadam
4) Penetration Macadam

Water Bound Macadam:

Water bound macadam may be defined as a dense and compact course of a road pavement:

- Composed of stone aggregates
- Bound together by a thin film of cementing medium consisting of fine mineral filler (such as stone screenings or gravel) with cementitious properties and
- Containing a minimum laden moisture to impart to the binder necessary cohesive and adhesive properties to enable it to bind the aggregates together.

The strength of a water-bound macadam course is thus

- Primarily due to the thorough mechanical interlock in the aggregate particles.
- Cohesion between the aggregate particles due to the cementitious film of soil-moisture binder.

Materials used in WBM are:

- Coarse aggregate:
  - Broken Stone Aggregates (Hard varieties such as Granite, Basalt, Diorite, Quartzite, etc.) and (Softer varieties such as Sandstone, Limestone, Kankar, Laterite etc.)
  - Over-burnt Bricks
- Screening (Choke):
  - Moorum, other mixtures.
- Binding Materials (soil binder):
  - Limestone Dust, P.I => 6

Size and grading requirements of Coarse Aggregates:

The main source of strength of a water bound macadam surface is due to the mechanical interlock in the aggregates and it is thus apparent that the aggregates should be well graded. Well graded aggregates can be obtained only by a crusher whereas hand breaking can yield single size aggregates. For soft aggregates such as Kankar, laterite or brick ballast which get crushed excessively under roller, the grading is not very important.

Requirements of Screening and Binding Materials:

The screenings, also known as "choke" materials, fill in the voids left in the coarse aggregates after they are consolidated and help to cement the stone aggregates together. To effectively perform these functions, the screenings should be properly graded and also should have some plastic material in them to impart cementitious properties. Excess of plasticity is harmful since, 'under the influence of moisture, the material may lose its stability. Screening materials may be dispensed with in case of soft
aggregates such as Kankar, laterite, brick ballast etc.

Thickness of courses:

The water bound macadam is constructed by spreading loose metal which gives a consolidated thickness of 75 mm 100 mm. A compacted layer less than 75 mm thickness is not desirable, and a compacted layer more than 100 mm is equally undesirable. If the thickness of the base is more than the above value, the construction is done in multiple layers.

Wet Mix Macadam:

- Wet Mix macadam is a specification in which a well graded aggregate is mixed with water in a mechanical mixer and the resultant mixture is laid by pavers and compacted.
- The aggregate is generally crusher run and includes fines also. Because of the close grading, the course will have good interlock with excellent density. It is well graded.
- The optimum moisture content for mixing is determined by conducting suitable density tests. The moisture content during mixing is maintained at this optimum 0.5 per cent. The moisture content is usually in the range 2 5% by weight.
- **Construction:** The mixing can be done in a suitable mechanical mixer. Specially designed mixers can be fabricated for this specification. Otherwise, a bituminous macadam plant can be used. Ordinary concrete mixers can also be used. Laying is done by paver finishers and compaction by 8-10 tons smooth wheel rollers.

Difference between Water bound Macadam and Wet Mix Macadam:

1) The main advantage of wet-mix macadam over water-bound macadam is that it is composed of a well-graded mixture. This ensures good interlock and high stability.
2) Addition of water while mixing facilitates the handling of the mixture. The operation of laying is much simpler than that of water-bound macadam, where the screenings and binding material have to be added in stages and forced into voids. If a crusher-run material is used, there is no possibility of plastic fines entering into the mixture.

3) The compaction is greatly facilitated by the moisture added which lubricates the individual particles.

4) One disadvantage of the wet-mix macadam is that it is slightly costlier than water-bound macadam. This is because the specification involves the use of mixing plant and paver. On the other hand, water-bound macadam has been traditionally a labour-oriented specification.

5) The aggregates for wet mix macadam will have to be crusher-run, whereas the aggregates for water-bound macadam are generally hand-broken.

Q.No.04.

1) Discuss in detail the bituminous materials-manufacturing?

Answer: Bituminous Materials Manufacturing:

The major methods used for the production of asphalts

- Atmospheric Distillation
- Distillation at Reduced Pressure
- Air Blowing
- Solvent Refining

Early refinery methods consisted of a simple distillation in a retort with attached condenser. The procedure was to pump a quantity of crude oil into the vessel and apply heat to the bottom causing the lower boiling point fractions to boil off leaving a residue which, depending on the type of crude, could be axle grease, bunker fuel oil, or asphalt. Only certain types of crude containing relative high asphalt contents could be used for the productions of asphalt by this method.

Distillation remains by far the most common process.

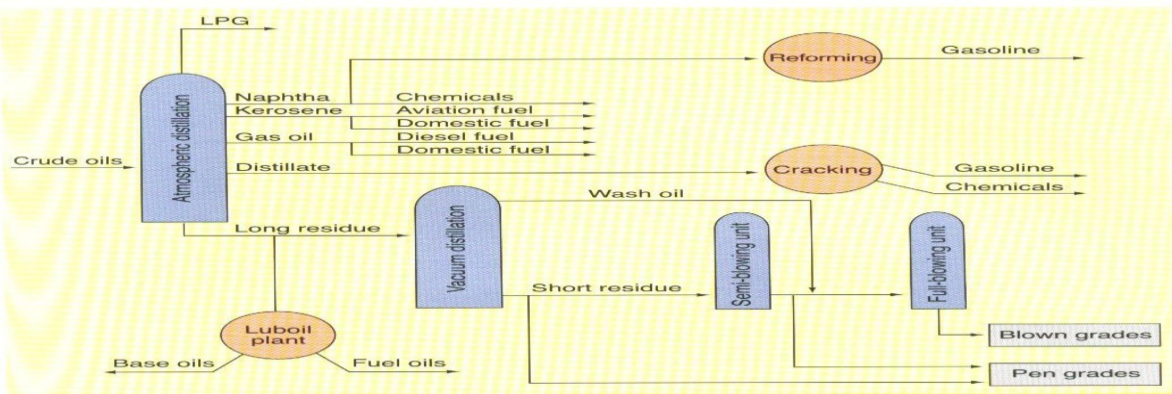


Fig. 2.2 Schematic representation of the crude oil distillation process

The consistency of the material is controlled by:

- Temperature
- Quantity of Steam
- Pressure
- Amount of Reflux
- Type of Crude
- Rate or Time of Processing

It is often, not economical for a refinery to produce asphalt to a number of paving grades directly. Hence, blending is utilized.

Refineries may stock two grades of asphalt: one at each end of the viscosity spectrum and blend to produce, intermediate grades.

Relatively high flash distillates have also been used as blending materials with hard asphalts.

Tars and pitches do not occur in nature since they are the product of chemical change. For example, tars are products of the destructive distillation (as distinguished from fractional distillation in the case of asphalt) of a number of organic materials such as coal, wood and sugar.

Tar obtained from the destructive distillation of bituminous coal is a crude Tar which must undergo further refinement to obtain road tar. Tar can also be produced from petroleum by chemical rather than physical change; that is, the destructive distillation of petroleum.

2) Bituminous Materials-Chemistry is referred to chemical composition of Bitumen. Elaborate in detail?

Answer: Asphalts are Complex Mixtures of Hydrocarbons. Hydrocarbons are compounds that contain carbon and hydrogen. Moreover, the chemical composition of the materials will, in all probability, vary in the different molecular weight ranges, depending upon the crude oil source.

Some generalizations can be made, however, with regard to the chemical composition of the semi solid materials. According to Simpson they generally consist of:

- Carbon (70 85%)
- Hydrogen (7 12%)
- Nitrogen (0 1%)
- Sulfur (1 7%)

- Oxygen (0 5%)

- And small amounts of metals either dispersed in the form of oxides and salts or in metal containing organic compounds.

The lighter molecular weight materials contain a considerable amount of carbon and hydrogen in the form of chain type or aliphatic organic compounds. As the molecular weight increases the tendency toward ring type (naphthenic or aromatic) organic compounds is more apparent with the side chains attached to the ring sections. The very high molecular weight compounds consist primarily of the ring type materials with very few side chains of the aliphatic variety present. It is in the higher molecular weight ranges where the other elements mentioned above, i.e., nitrogen, oxygen, sulfur.

For convenience, the wide spectrum of organic compounds contained in an asphalt are separated into a number of components, one commonly used classifications state that asphalts can be separated into:

- Asphaltenes (High molecular weight Materials and of Aromatic Nature. Asphaltenes have been defined by ASTM as: the components of the bitumen in petroleum, petroleum products, malthas, asphalt cements, and solid native bitumen, which are soluble in carbon disulfide but insoluble in paraffin naphtha's)

- Resins (Intermediate molecular weight materials and contains more side chains than asphaltenes)

- Oils (they are the lighter molecular weight materials in the asphalt and generally have a large number of chains in proportion to the number of rings).

It should be emphasized at this point that the asphaltenes, resins, and oils are not three distinct compounds. Rather, there exists a range in molecular weights in the oil fraction, the resin fraction, and the asphaltene fraction. Moreover, the composition of the materials in each fraction and in each asphalt will vary, depending upon the crude source and method of manufacture.