Subject : Pavement Material Engineering

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FINAL TERM PAPER

Q . N O . (01) ANSWER (BELOW)

PART .(1)

WHY WE DO CARRY OUT GRANULAR (PHYSICAL STABILIZATION

OBJECTIVE

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

Granular Stabilization: involves the mixing of two or more materials to modify the engineering properties such as the Californian Bearing Ratio (CBR), the particle size distribution (PSD) and/or the Plasticity (PI) to “manufacture” materials with properties equal to or better than unbound **granular** materials used by.

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 is able to :

- ***Transfer load without Permanent Deformation***
- ***Provide Frictional Resistance***
- ***Bears Volume Stability***
- They may also contain material with particle sizes less than 0.075mm without violating the requirements given above if:

- The volume of the silt-clay size (< 0.075 mm) fraction plus that of the water, normally required to satisfy the capillary and physicochemical sorption capacity, does not exceed the volume of the pore space left by the stable continuous granular skeleton; and
- The ratio of the size of the smallest bearing grain to that of the largest silt-clay particle is such as to cause no detrimental interference of grain-grain contact of the granular skeleton.
- 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.

REQUIREMENTS FOR COMPOSITION

- The requirements for composition of mixtures intended for use as bases generally differ from those for use as wearing surfaces.

- For example, the compositions for base and sub-base courses are required to have high stability to transfer load and low capillarity, to resist softening with accumulation of moisture.
- The compositions for wearing surfaces, on the other hand, need to satisfy the conditions of resisting abrasion and penetration of water, and of capillarity to replace moisture lost by surface evaporation. Therefore, the composition of base and sub base soil-aggregate requires less fine-soil fraction than the composition for wearing surface.

PART (2) Q. N0.1

HOW WE DO CARRY OUT GRANULAR STABILIZATION CONSIDERING GRANULOMETRY & COLLAMETRY, FABRIC, SOIL BINDER,COLAMERITICS, SPECIFICATION OF GRADION & SELECTION OF SOIL ELEMENTS.

Granulometry and Collametry

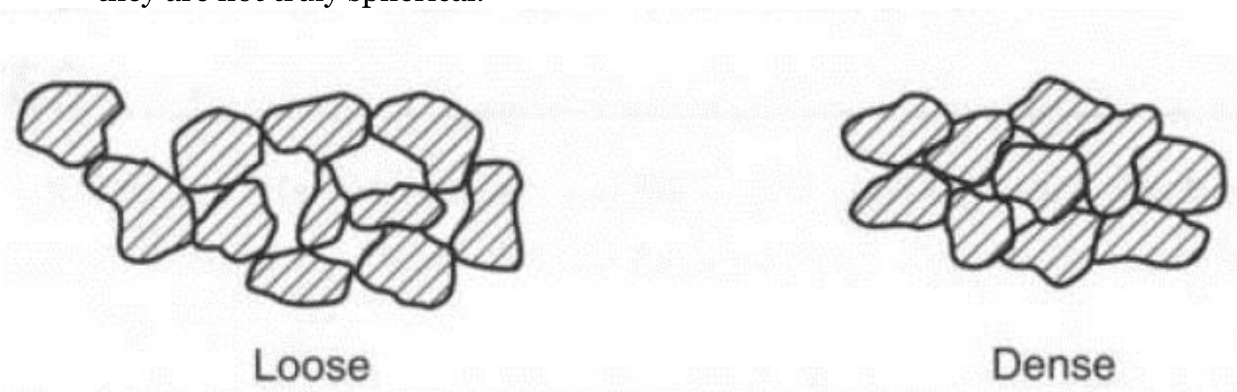
The pore volume and the size of the pores formed by the granular skeleton determine the transition of a particular soil to one with or without a bearing skeleton.

- ***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/dmax)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.

Fabrics

- Fabric units in clays that are visible to naked eye are known as peds. Fabric units that can be distinguished using an optical microscope are called clusters. Several clusters together form peds. Individual clay particles can be distinguished using a TEM or SEM, and these fabric units are called domains or factoids or packets. In soils containing montmorillonite mineral, it may not be possible to distinguish individual particles using SEM or TEM.

- Soil fabric for clays is different from that of sands or other coarse-grained particles because of their shape. As evident from the mineral structure, clay particles are formed by combinations of silica and alumina sheets.
- Thus, the individual clay particles are in the shape of a sheet or plate with thickness considerably less than the other dimensions. This is in contrast to the sand particles that are more or less equi-dimensional in all directions, though they are not truly spherical.



Soil Binder

- The latter type of materials are also called **"soil binder."**
- 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.
- *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.*

- 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 **Collameritic** (colla= glue, meros= particle) systems.
- In the terminology of materials science, such bonded soils belong to the class of
- "CONCRETES" if the maximum particle size is larger than the openings of No. 4 sieve (4.76 mm),
- "MORTARS" if the largest particles are of fine sand size or the size of the openings of No. 40 sieve (0.425 mm).

Collameritics

COLLAMERITICS - THE SCIENCE OF COMPOSITION AND PROPERTIES OF NONMETALLIC CONSTRUCTION MATERIALS:-

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

Specifications on Gradation and Selection of Soil Elements

- **Treatment with waterproofing of cementing material**

- 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
- (A) *the soil and other materials available*
- (B) *intended use and special properties desired in the stabilized system*
- (C) *time constraints for planning and construction*.
-

Soil Binder and Water

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 optimim results.

Exceptions to Gradation Requirements

- Cases may occur in which certain natural materials that do not meet gradation requirements may develop satisfactory CBR values in the prototype .
- Exceptions to the gradation requirements are permissible when supported by adequate in-place CBR tests on similar construction that has been in service for several years.

Q . N O . (02) ANSWER (BELOW)

PART .(A)

Aggregate Identification

- **Naturally Occurring Materials**
  - The majority of aggregates used in road construction are obtained from naturally occurring deposits.
  - Natural aggregates for road-making are obtained from rock of the following geological groups :

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

  which are formed by the cooling of molten material

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

  which are formed by deposition of granular material

- **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:

- **Residual Materials:**

  which may be either weathered or unweathered, generally occur in large deposits and are obtained by quarrying.

- **Transported Deposits**

  are found, for example, in stream beds, sand and gravel bars, and alluvial fans.

Naturally Occurring Materials

Mineral aggregates may be classified in a number of different ways. Each classification technique is useful in developing an understanding of the type of material to be used in the pavement.

Pedological

- It is extremely helpful if the rock can be classified with respect to its general geologic type.
- It is not necessary that the person involved with highway materials be a geologist to make this classification.
- An understanding of geology and mineralogy are, however, extremely helpful, particularly in interpreting and predicting the performance of aggregates produced from the various available.

PART(2) OF Q 02

Field Investigation

- **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 behavior of pavement layers ismust for investigation team.*

MATERIAL/Aggregate Sources

- **Natural Aggregate**
- **Rock Quarries**

Natural Deposits

- **Stream/River Deposits**
- **Glacial Deposits**
- **Fluvial Glacial Deposits**
- **Talus Deposits**
- **Wind Blown Deposits**

- **Prospect Sources**
- **Existing Sources**

- ***Information is obtained from***
- **Geological Maps**
- **Soil Survey Maps**
- **Aerial Photograph**
- **Satellite Imageries**

- **Shallow Deposits**
- **Rock Quarries**

Shallow Deposits

- A grid of test pits/trenches
- Representative Sampling
- from different depths
- from bottom and sides
- Typical of the average properties.

Rock Quarries

- A grid of boreholes
- large sized holes
- core sampling.

- **Deep Deposits**
  - visual inspection through cuts

- sampling from stockpiles

- First and foremost, it needs to be emphasized that the repeatability and reproducibility of test results depend primarily on the SAMPLING.
- A laboratory sample is obtained from a bulk sample collected, either in a number of increments or in one go, from a batch or a stockpile.
- Samples are normally collected using a sampler which is in the form of metallic tube or a scoop whose Opening is 3 times the maximum aggregate size.
- Sampling of aggregates is sometimes done at various production sources in order to avoid the segregation which occurs in stockpiles, Some of the sampling procedures followed are :
- 1. Sampling from stationary conveyor belt
- 2. Sampling at belt and chute discharge points
- 3. Sampling from stockpiles
- 4. Sampling from railway wagons, transporting dumpers/trucks etc.

Q . N O . (03) ANSWER (BELOW)

Macadam Bases-*Types*

▶Water Bound Macadam (WBM)

if the stone materials are held together by the addition of water and filler

▶Dry Bound Macadam

if the aggregates are held together by mechanical interlock only

▶Wet Mix Macadam

if graded stones are mixed with water and compacted

▶Penetration Macadam

if a bituminous material is sprayed over the stones and allowed to penetrate into the course and by "premix" macadam if the bituminous material is mixed with the aggregates prior to laying.

- **Sequence**
- Concept
- Materials
- Construction

(A) Water Bound Macadam

- **Concept**
- 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**
- Coarse Aggregate
- Broken Stone Aggregates
- Hard varieties such as Granite, Basalt, Diorite, Quartzite, etc.

- Softer varieties such as Sandstone, Limestone, Kankar, Laterite etc.
- Over-burnt Bricks
- Screening (Choke)
- Moorum, Other Mixtures
- Binding Material (Soil Binder)
- Limestone Dust, PI => 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 Screenings and Binding Material**
- 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

- **CONSTRUCTION**
- Spreading metal
  Manual Method
  Mechanical Method
- Rolling of Aggregates
  Dry Rolling

Wet Rolling

- Application of Screenings
- Application of Binding Material

(B) Wet Mix Macadam

- **Concept**
- 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.

- **Grading**

Well-Graded

Moisture content

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 ton smooth wheel rollers.

DIFFERENCE BETWEEN WBM VS WMM & ALSO ADVANTAGES & DIS-ADVANTAGE

- The WMM roads are said to be more durable.
- The WMM roads gets dry sooner and can be opened for traffic withing less time as compare to the WBM roads which take about one month for getting dry.
- WMM roads are soon ready to be black topped with the Bituminous layers.
- WMM roads are constructed at the faster rate.
- The consumption of the water is less in case of the WMM roads.
- Stone aggregates used in WBM is larger in size which varies from 90 mm to 20 mm depending upon the grade but in case of the WMM size varies from 4.75 mm to 20 mm.
- In case of WBM, stone aggregates, screenings and binders are laid one after another in layers while in WMM, aggregates and binders are premixed in the batching plants and then brought to the site for overlaying and compacting.
- Materials used in the WBM are the stone aggregates, screenings and binder material(Stone dust with water) while in WMM material used are only stone aggregates and binders.
- Quantity of the WBM is generally measured in cubic meters while that of the WMM in square meters.

- 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.
- 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.
- The compaction is greatly facilitated by the moisture added which lubricates the individual particles.
- 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.
- The aggregates for wet mix macadam will have to be crusher-run, whereas the aggregates for water-bound macadam are generally hand-broken.

Q . N O . (04) ANSWER (BELOW)

PART (1)

Bituminous *Materials-Manufacturing*

- **Manufacturing Processes**

- 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.

- **The consistency of the material is controlled by**

(1) Temperature
(2) Quantity of Steam
(3) Pressure
(4) Amount of Reflux
(5) Type of Crude
(6) 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.

- Asphalt is a very diverse material and has widespread usage. For convenience, asphalt will be categorized into three classifications which cover the majority of uses. These are
  (1) Paving
  (2) Roofing, and
  (3) Protective Coatings

Paving

- The paving asphalts are the materials used in road construction and are produced primarily by the vacuum and steam and quite often will contain finely divided mineral fillers, in which case the materials are referred to as filled asphalts.
- Asphalts blown in the presence of special catalysts, such as P_2O_5, and referred to as catalytically blown asphalts are included in this category.

Bituminous Materials-*Paving Grades*

Asphalt Cement

- A fluxed or unfluxed asphalt specially prepared as to quality and consistency for direct use in the manufacture of bituminous pavements, and having a penetration between 5 and 300.
- Depending on the classification system 5 to 6 types of asphalt cements are available. These materials vary in consistency from a solid at room temperature to a semi-liquid at the same condition. The materials are classified by either penetration or viscosity as will be discussed later.

Bituminous Emulsions

- (a) a suspension of minute globules of bituminous material in water or in an aqueous solution
- (b) a suspension of minute globules of water or of an aqueous solution in a liquid bituminous material.

Cut-Back Products

- Petroleum or Tar residuum which have been blended with distillates.

Cut-Back Products

- Three types of cutback asphalts are available.
- **(1) Rapid Curing (2) Medium Curing (3) Slow Curing**
- The rapid and medium curing materials are referred to at times as cutbacks and the slow curing materials as road oils.

- **Rapid Curing (RC)** liquid asphalts are produced by dissolving a relatively hard asphalt cement (85-100 penetration) in a gasoline or naphtha-type solvent. The proportions of solvent are varied to produce different grades of RC materials. These grades are assigned numbers depending on their viscosity.
- **Medium Curing (MC)** liquid asphalts are produced by dissolving a softer base asphalt cement (generally a 120-150 penetration) in a kerosene-type solvent.
- As with the RC asphalts, by varying the proportion of solvent, different grades are obtained.
- **Slow Curing (SC)** liquid asphalts are produced in either of two ways. In the first case, they may be reduced directly to grade in the distillation process in the same manner as the asphalt cements.

➢ **Modified Asphalts**

- Polymer Modified

PART (2) OF Q (04)

Bituminous Materials-*Chemistry*

- *Asphalts are Complex Mixtures of Hydrocarbons*
- Hydrocarbons are compounds that contain carbon and hydrogen.
- ▶**Organic Chemistry**
- In organic chemistry, hydrocarbons are classified on the basis of chemical behavior as saturated or unsaturated.
- Essentially, saturated hydrocarbons have no multiple linkages between carbon atoms.
- ▶**Unsaturated hydrocarbons** contain one or more double or triple bonds between carbon atoms and, as a consequence, have a great reactivity with other elements.

➢ **Asphalt Composition**

- Asphalts are a complex mixture of hydrocarbons, varying, in the case of semi-solid asphalt cements, from low molecular weight (approximately 300) materials to very high molecular weight materials (larger than 5000).
- If materials have the same consistency at a specific temperature, 77 F (25C), it can be seen that the size distribution is different. It is quite probable that these materials will react differently to changes in temperature and behave differently under load.

- Moreover, the chemical composition of the materials will, in all probability, vary in the different molecular weight ranges, depending upon the crude oil source.

- **Asphalt Composition**

- 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.

- **Asphalt Composition**

- **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,.

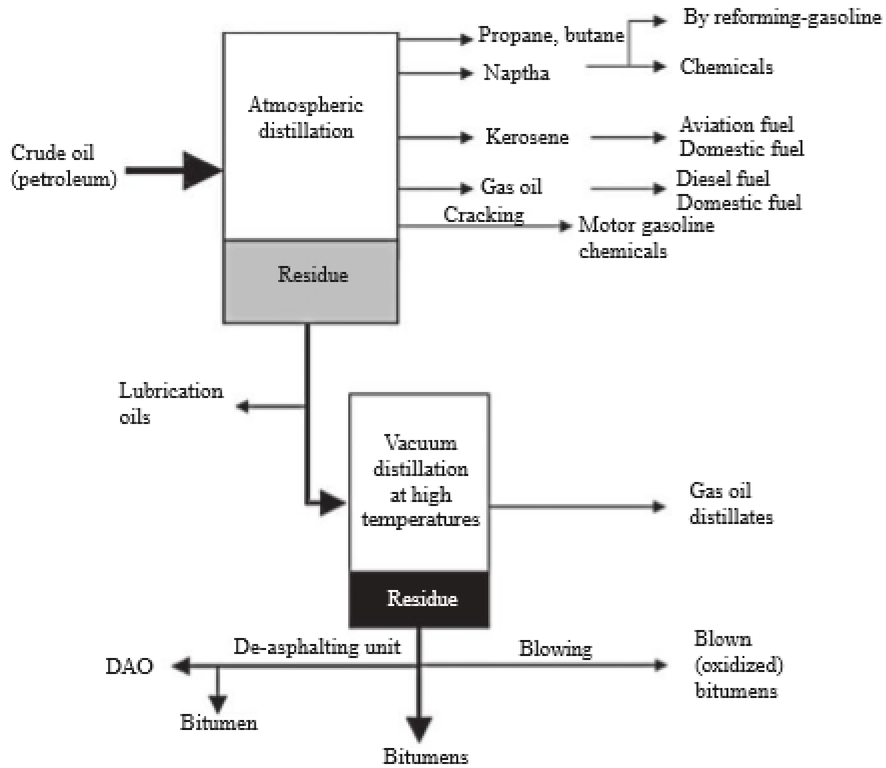


Figure 3.1 Simplifed representation of crude oil distillation process for bitumen production and other materials.

- **Asphalt Composition**

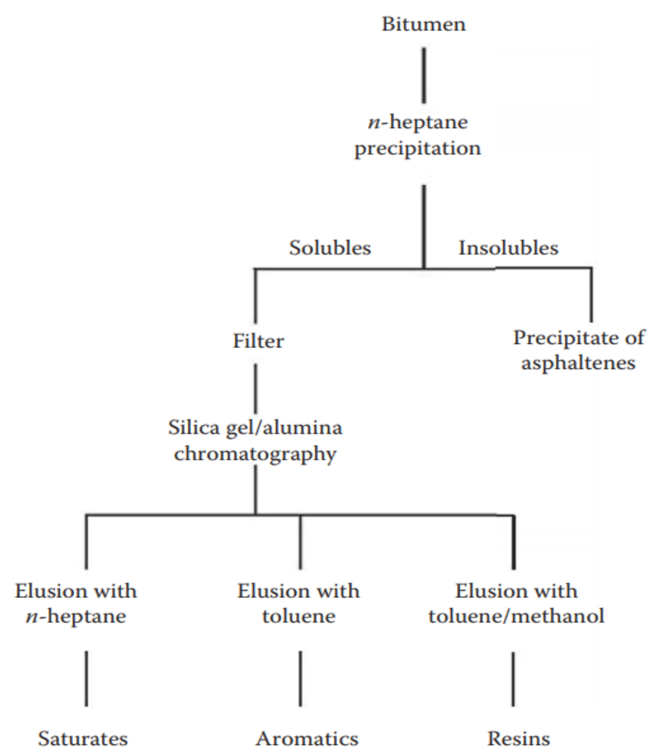
- For convenience, the wide spectrum of organic compounds contained in an asphalt are separated into a number of components, one commonly used classifications states that asphalts can be separated into:
- ASPHALTENES
- RESINS
- OILS

ASPHALTENES are the high molecular weight materials and are primarily of an aromatic nature with very few side chains attached. The hypothetical asphaltene molecule shown in Figure illustrates qualitatively, at least, this composition. It will be noted that sulfur and nitrogen are incorporated in the ring structure in this type of material.

Asphaltenes have been defined by ASTM as: the components of the bitumen in petroleum, petroleum products, malthas, asphalt cements, and solid native bitumens, which are soluble in carbon disulfide but insoluble in paraffin naphthas.

RESINS are the intermediate molecular weight materials and contain more side chains than the asphaltenes. Some sulfur and nitrogen is also included in these materials, but to a lesser extent than in the asphaltenes. The resins are polar molecules resulting from their aromaticity and the inclusion of sulfur. This polar nature gives resins the ability to be adsorbed by and to dissolve the asphaltenes.

OILS are the lightest molecular weight materials in the asphalt and generally have a large number of chains in proportion to the number of rings. A number of the materials in this range are naphthenic-type closed chains.



Asphalt Composition

▶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.

▶In addition to the classification listed above, other terminology has also been used to describe the various components of asphalt. For example, the oils plus resins are at times referred to as maltenes.

▶*Actually, there are many methods used to separate asphalts into components for study. Some separation techniques are based on chemical reactivity while others are based on molecular weight or a combination or both.*

The solution and precipitation method developed by Rostler-Sternberg

▶The chromatic method advance by Corbett, *have been the most widely used.*

Corbett method

Studies have indicated that
(1)SATURATES are better plasticizers than NAPHTHENE AROMATICS
(2) ASPHALTENES are solution thickeners
(3)SATURATES and ASPHLATENES produce low temperature sensitivity
(4)POLAR AROMATICS control the ductility of the asphalt

THE END