ID: 14397
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Question No. 1

1. Why do we carry out Granular (Physical) stabilization?

Soils which have particle sizes greater than 0.075 mm are nominated as medium to coarse-grained soils. Upon compaction of these soils, 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
- Volume Stability

There may be soil particles with size less than 0.075mm without violating the requirements given above if:

1. 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
2. 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 nominated as **Granular Stabilization.**

Purpose of soil stabilization

- To make use of low quality material when high quality material is not available.
- To improve the strength of base, sub-bases.
- To improve certain undesirable properties of soils such as excessive swelling or shrinkage, high plasticity.
- To improve permeability.
- To reduce compressibility and settlement.
- To increase load bearing capacity.

Granular stabilization is used in construction of Base, Sub-base, and Surface Courses of paved facilities.
Stone, Gravel, Sand and containing Silt-Clay are compacted to maximum density to get high strength, stability and durability in all weather conditions.
The main objective of granular stabilization is to get well-proportioned mixture of particles with continues gradation and desired plasticity.

2. How do we carry out Granular (Physical) stabilization considering Granulometry and Collametry, Fabric, Soil Binder, collameritics and Specifications of gradation and 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

Soil Binder

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. 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).

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.

COLLAMERITICS.

The below table 9.2 shows properties of the particles, properties of cementing agents and examples of cemented 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).

Specifications on 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

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 optimum results.

The below table 9.3 is for Gradation Requirement for Soil Aggregate Materials

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

Sieve Size (Square Openings)	Weight Percent Passing Square Mesh Sieves					
	Type I				Type II	
	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

The below given Table 9.4 gives GRADING REQUIREMENT FOR FINAL MIXTURES FOR BASES OR SUBBASES

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

Sieve Size (Square Openings)	Design Range[a] (Weight Percentages Passing)		Job Mix Tolerances (Weight Percentages Passing)	
	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

The below Figure 9.3 shows different type of materials Gravel, Stone, Sand, Silt and clay , their equivalent particle diameter and percent passing used for selection of soilelements.

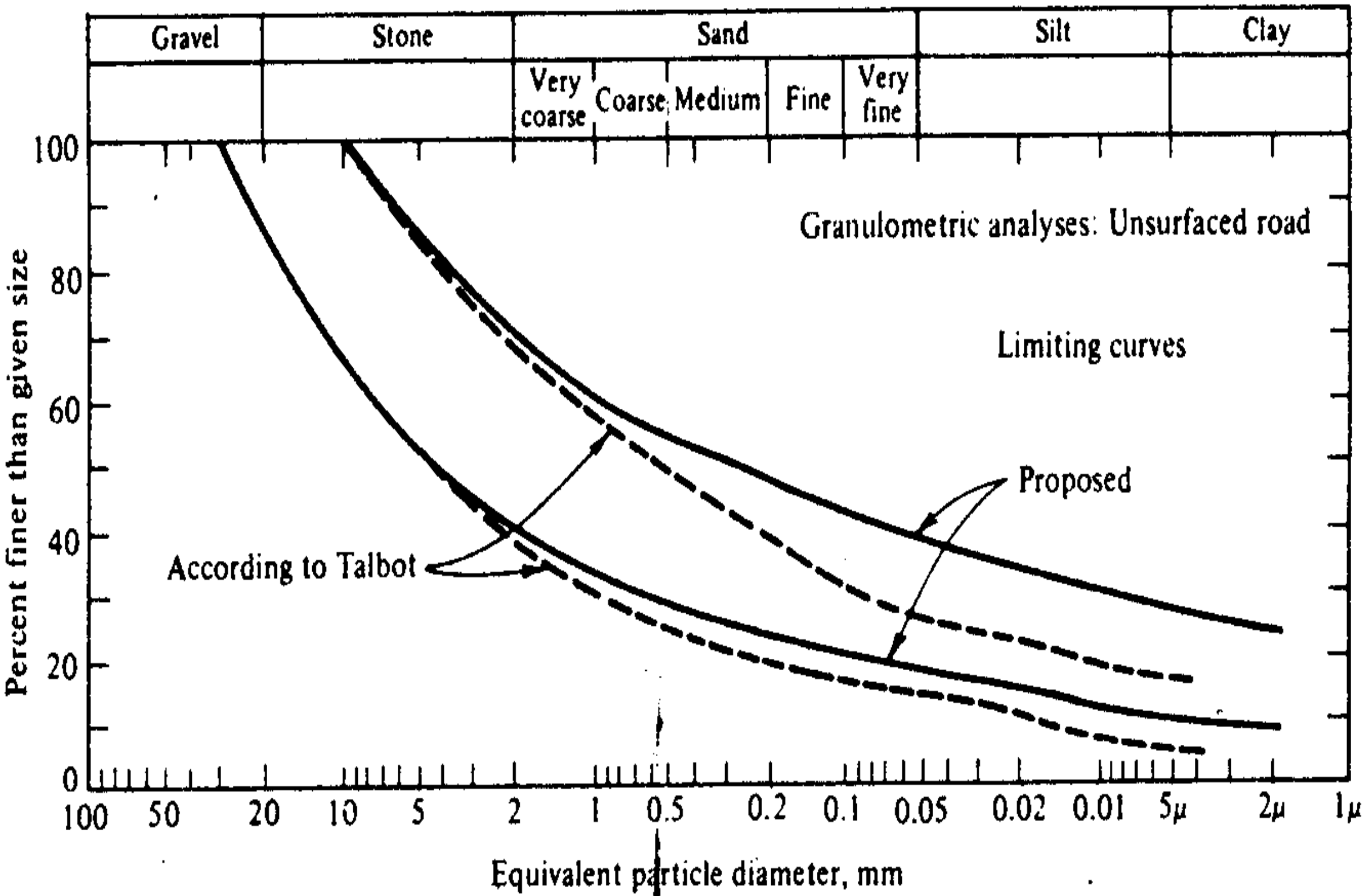

Fig. 9.3 Clay–concrete for laterite soil binder.

Question No. 2

1. How would you (being a material expert) identify aggregate referring to Naturally occurring materials, Igneous Rocks, Sedimentary Rock, Metamorphic and Residual material and transported deposits?

Aggregate is the major component of materials used in road making. It is used in

- Granular Bases and Sub-Bases
- Bituminous Courses
- Cement Concrete Pavements

A study of the Types of Aggregates, Their Properties and Tests is of great importance to a highway engineer.

Aggregates can be identified on the basis of

- Origin (Composition)
- Mode of formation and Deposition
- Density
- Shape
- Surface Texture

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

It is 98% of Earth Crust. Igneous rock is formed through the cooling and solidification of magma.

Igneous rocks can be identified by the determination of the composition and texture of the rock. Once these two characteristics have been identified, then it is easy to identify them.

Sedimentary Rocks

It is 5% of Earth's Crust & 75% of Earth's Surface. They are formed by the deposition of small particles and subsequent cementation of mineral or organic particles

Sedimentary rock identification is primarily based on composition. Texture will still be used but in a different sense than for igneous rocks.

Texture of sedimentary rocks in lab will be taken to indicate origin or type of sediment found in the rock.

Metamorphic Rocks

Igneous and sedimentary rocks eroded by wind, weather and water become metamorphic rocks. Metamorphic rocks which are igneous or sedimentary rocks that undergone transformations due to heat and pressure.
The weathering product may be of two general types:

Residual Materials

Residual Materials which may be either weathered or un-weathered, generally occur in large deposits and are obtained by quarrying.

Transported Deposits

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

2.In aggregate investigation Material sourcing is referred to Filed investigation. Discuss Material sourcing in detail.

Field Investigation for concrete materials prior to construction are chiefly restricted to

a) Prospecting for Aggregates
b) Exploration and Sampling of Available Deposit

AGGREGATE/MATERIAL SOURCES

1. **Prospect Sources**
2. **Existing Sources**

Information is obtained from

- Geological Maps
- Soil Survey Maps
- Aerial Photographs
- Satellite Imageries

1. **Aggregate Prospecting/Prospect Sources**

- Shallow Deposits
- Rock Quarries

Shallow Deposits

- A grid of test pits/trenches
- Representative Sampling from different depths and from bottom and sides

  Sampling trenches:

  Individual samples are taken from each layer of soil and composite samples are taken from two or three layers of soil.

Rock Quarries

- A grid of boreholes
- large sized holes

- core sampling

2. **Existing Sources**

- Shallow Deposits
- Deep Deposits

Shallow Deposits

A similar procedure is adopted.

- A grid of test pits/trenches
- Representative Sampling from different depths and from bottom and sides

  Sampling trenches:

  Individual samples are taken from each layer of soil and composite samples are taken from two or three layers of soil.

Deep Deposits

- Visual inspection through cuts is carried out. Mechanical machinery like excavator is used to make cuts. The material is inspected for further procedure.
- Sampling is done from stockpiles

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:

- Sampling from stationary conveyor belt
- Sampling at belt and chute discharge points
- Sampling from stockpiles
- Sampling from railway wagons, transporting dumpers/trucks etc.

Question No.3

Mc-Adam was a Scottish engineer who introduced, in the early nineteenth century, the idea of constructing roads composed of small size stones held together by means of a binding material. 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?

Different types of Macadam bases are

i. Water Bound Macadam
ii. Dry Bound Macadam
iii. Wet Mix Macadam
iv. Penetration Macadam

Water Bound Macadam

Water Bound Macadam (WBM) is a dense and compact course of a road pavement composed of stone aggregates held together by a film consisting of gravel or screenings with a minimum amount of water.

WBM is constructed by broken aggregates that are interlocked mechanically by rolling and voids filled with screening and binding materials with the help of water.The strength of a water-bound macadam course is primarily due to the thorough mechanical interlock in the aggregate particles and Cohesion between the aggregate particles due to the cementitious film of soil-moisture binder.

Materials used in Water Bound macadam are

i. **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

ii. **Screening (Choke)**

- Moorum, Other Mixtures

iii. **Binding Material (Soil Binder)**

- Limestone Dust PI => 6

Size and Grading Requirements of Coarse Aggregates

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.
Screening materials may be dispensed with in case of soft aggregates such as kankar, laterite, brick ballast etc.

Thickness of courses

The thickness of each layer ranges from 7.5 cm to 10 cm depending on the size of aggregates used.
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 of Water Bound Macadam

The construction follows the sequence of steps

- Spreading the aggregates manually
- Dry rolling
- Wet rolling
- Application of screenings, watering and rolling
- Application of binding material, watering and rolling
- Spreading a thin layer of coarse sand and light-rolling

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.

Aggregates used are of the smaller sizes, varies between the 4.75 mm to 20 mm sizes and the binders(stone dust or quarry dust having PI not less than 6%) are premixed in a batching plant or in a mixing machine.

Grading

Well graded aggregates are used in Wet Mix Macadam.

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 of Wet Mix Macadam

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 Water Bound Macadam and Wet Mix Macadam

- 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.
- 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
- 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.
- 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
- 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.
- WMM roads are constructed at the faster rate.

Question No. 4

1. Discuss in detail the Bituminous Materials-Manufacturing?

Bitumen Manufacturing Processes is as under
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

a) Temperature
b) Quantity of Steam
c) Pressure
d) Amount of Reflux
e) Type of Crude
f) Rate or Time of Processing

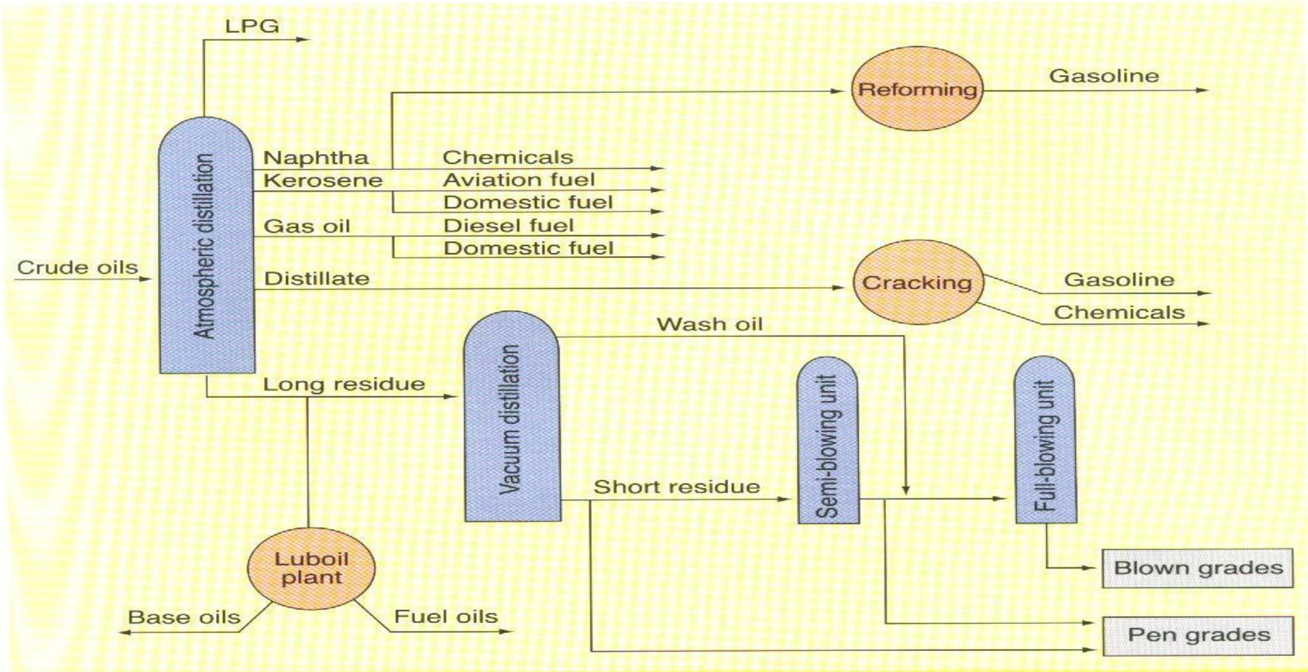

Fig. 2.2 Schematic representation of the crude oil distillation process

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.

2.Bituminous Materials-Chemistry is referred to chemical composition of bitumen. Elabourate in detail.

In American Terminology both Asphalt and bitumen are the same

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).

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%)
- 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 states that asphalts can be separated into:

- Asphaltenes
- Resins
- Oils

ASPHALTENES

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.

RESINS

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

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.

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.