Final Term Assignment (Spring 2020)

Subject : PAVEMENT MATERIAL ENGINEERING

- **Name: Hasnain Ahmad**
- **Reg. ID: 14869**
- **Semester : 4th**
- **Program: M.S (T.E)**

Q. No.(01)

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

Answer 1): Granular (physical) stabilization of soil is carried out in order to modify the engineering properties such as the California Bearing Ratio (CBR), the Particle size distribution, and/or the plasticity to manufacture materials with properties equal to or better than unbound granular materials used by conventional methods.

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, to Provide Frictional Resistance and Bears Volume Stability

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

Granular stabilization is used in construction of Base, Sub-base, and Surface Courses of paved facilities and has applications in all intrastructure types.

--------------------------------------xx---------------------------------xx--------------------------------

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?

Answer 2): **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 0.45 as the best overall value for m

SOIL BINDER:

Soils with granular bearing skeleton in the densified state possess volume stability and frictional resistance.

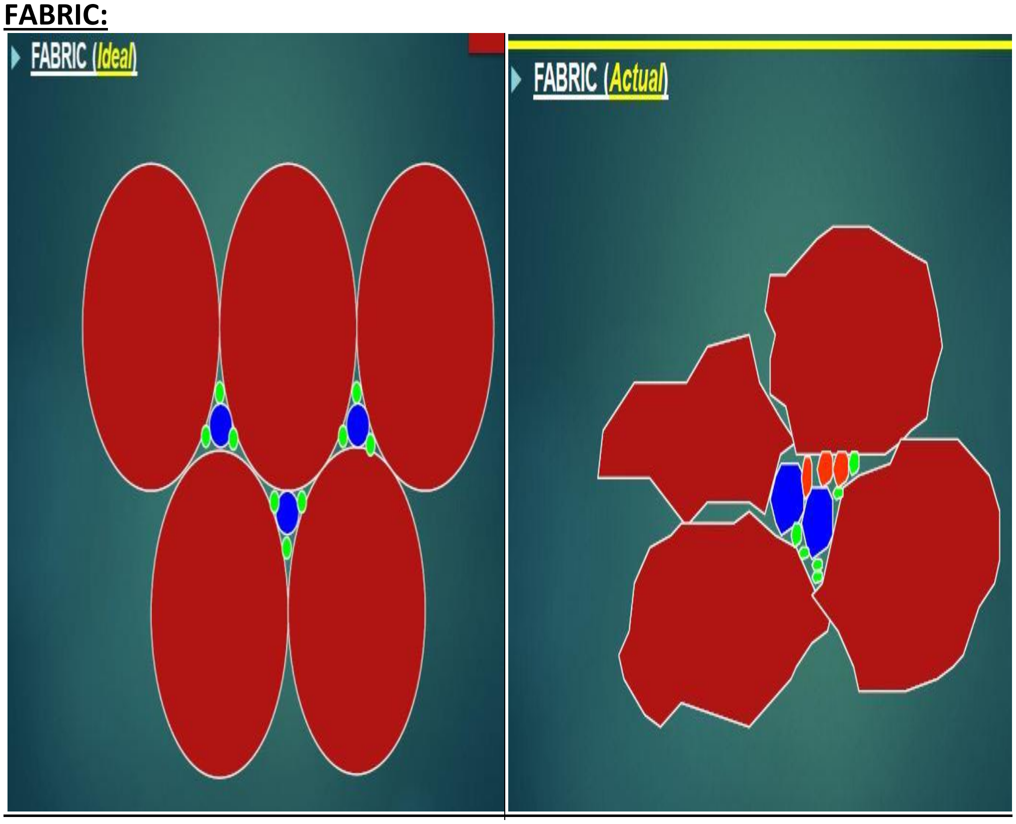
They may require:

- ✓ 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).

FABRIC:



The latter types of materials are also called "soil binder."

Complete replacement of natural soil binder in 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:

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

<u>Specifications on Gradation and Selection of Soil Elements:</u>

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.

--xx---

Q. No.(02)

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?

Answer): Aggregates referring to Naturally occurring materials, Igneous Rocks, Sedimentary Rock, Metamorphic and Residual material and transported deposits can be identified on the basis of their;

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

Aggregates from Naturally occuring Materials:

The majority of aggregates used in road construction are obtained from naturally occurring deposits. Natural aggregates consists of granular materials such as crushed stone sand created by crushing bedrock, or naturally occuring unconsolidated sand and gravel.

Aggregates from Igneous Rocks:

Igneous rocks are the most common source of processed quarry aggregate and may include basalt, dolerite, andesite, granite etc. These rocks are formed by the cooling of molten material.

Aggregates from Sedimentary Rocks:

These rocks are formed by deposition of granular material. Aggregates formed by such rocks include coarse grained (such as songlomerate, sandstone) and fine grained (siltstone, shale). Sedimentary rocks especially sandstone, limestone and dolomite are among the most important aggregate sources because their mode of foration, their characteristics and properties are highly varied, as is their durability. Shale and siltstone are less durable and used mostly in fills.

Aggregates from Metamorphic Rocks:

Metamorphic rocks such as hornfels, quartzites, schists etc are used as asphalt aggregates and are igneous or sedimentary rocks that have undergone transformations due to heat and pressure.
Whereas the materials/ products formed as a result of weathering may be of two 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 deposits.

A summary of various types of deposits based on their mode of deposition is as follows.

Colluvium Deposits (Talus)

These areformed by gravity and weathering action of a steeply sloping rock face.
Crushing is usually necessary for the product With large angular chunks .

Glacial Deposits

These are true glacial deposits - transported by glacial ice and have not been subjected to river transportation
fluvial-glacial - glacial deposits subjected to stream action.
fluvial-glacial deposits - are more suitable.

Glacial deposits may be unsuitable as aggregate sources since they are heterogeneous and require a great deal of processing before they can be used

Fluvial Deposits

materials which have been transported and deposited by running water.
a. stream-bed - from beds and banks of existing rivers
b. terrace deposits - older stream bed deposits laid down as a stream bed, earlier age
c. alluvial deposits - fans or cones deposited at the mouth of ravines, gullies, or canyons, arid and semiarid regions
d. Flood-plain - deposited outside normal stream channels during flood periods

EolianDeposits

a. deposits laid down by the wind
b. finer sands of narrow size range
c. well rounded and hard and durable

Marine Deposits

a. usually contain hard, durable particles as a result of weathering
b. particles are normally very well rounded
c. usually narrow size range

---xx-------------xx--

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

Answer): <u>MATERIAL SOURCING:</u>

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 layersis must for the Investigation Team.

Aggregate Sources:

Aggregates sources may include;

- Natural Aggregate or Rock Quarries.
- Natural Deposits including 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 Photographs or Satellite Images

Aggregate Prospecting

Shallow Deposits:

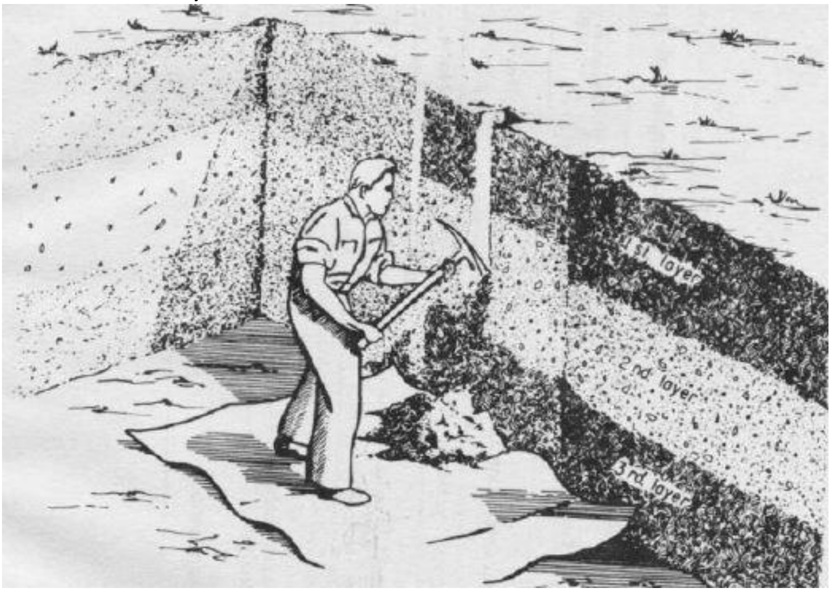
A grid of test pits/trenches are made for the said purpose wherein **Representative Sampling** is conducted.

Sampling is conducted from different depths and from bottom and sides. Typical of the average properties are then taken into account.

Shallow Deposits

Sampling Trenches:

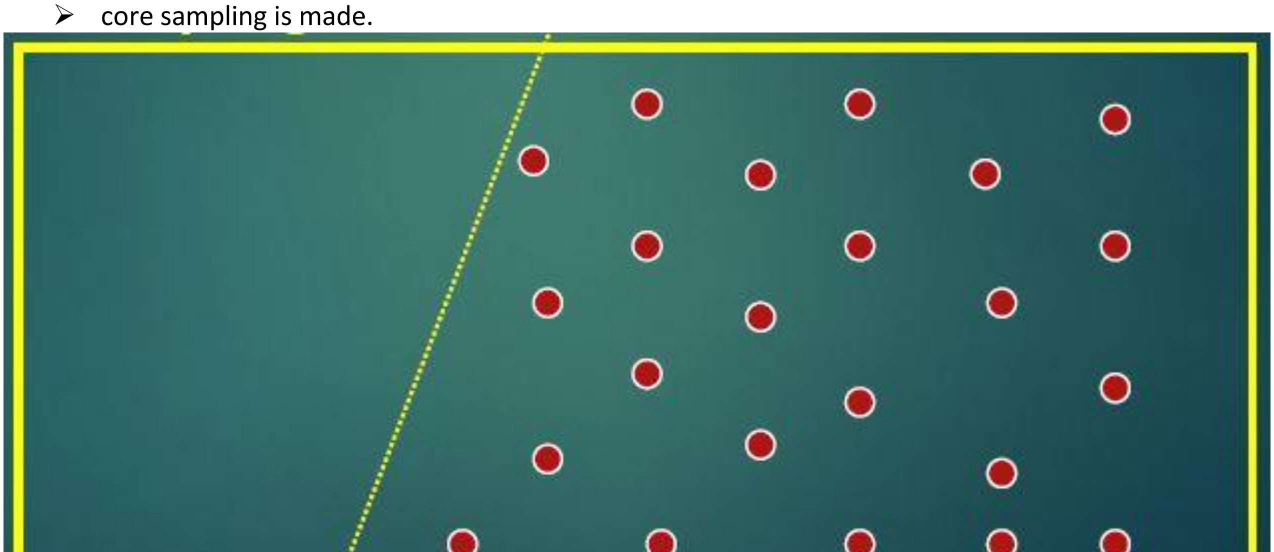
Individual samples are taken from each layer of soil wheres composite samples are taken from two or more layers.



Rock Quarries:

A grid of boreholes is made where;

- large sized holes are executed and
- core sampling is made.



---xx---

Q 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?

Ans) Macadam Bases types:
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.

This concept had revolutionized the road building science then, aided as it was by the invention of the stone crusher in 1858by Blake, the steam road roller by Aveling in 1867and by the use of bituminous materials early in the twentieth century.

In macadam bases single-sized crushed stone layers of small angular stones are placed in shallow lifts and compacted thoroughly. A binding layer of stone dust (crushed stone from the original material) may form; it may also, after rolling, be covered with a binder to keep dust and stones together. The method simplified what had been considered state of the art at that point.

There are 4 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 (WBM) is a dense and compact course of a road pavement composed of stone aggregates held together by a thin film of cementing medium consisting of fine mineral filler (consisting of gravel or screenings) with a minimum amount of water to enable the aggregates to held together.

The strength of a water-bound macadam course is thus;
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 of Water Bound Macadam:

Coarse Aggregate:

- Usually 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 with 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 : includes the following steps/procedure;

1. Spreading metal
   Either byManual Method or Mechanical Method
2. Rolling of Aggregates
   Dry Rolling or Wet Rolling
3. Application of Screenings
4. Application of Binding Material

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.

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 wet mix mcadam and water bond macadam:

- The main difference b/w wet-mix macadam and water-bound macadam is that it is composed of a well-graded mixture which ensures good interlock and high stability.
- 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 wet-mix macadam 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.

---xx--

Q.4)
1. Discuss in detail the Bituminous Materials-Manufacturing?

Ans: Bituminous materials consists of bitumen which is a black or dark coloured solid or viscous cementitious substances consists chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide.

Manufacturing process:
The major methods used for the production of asphalts are;

- 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. However, Distillation remains by far the most common process.

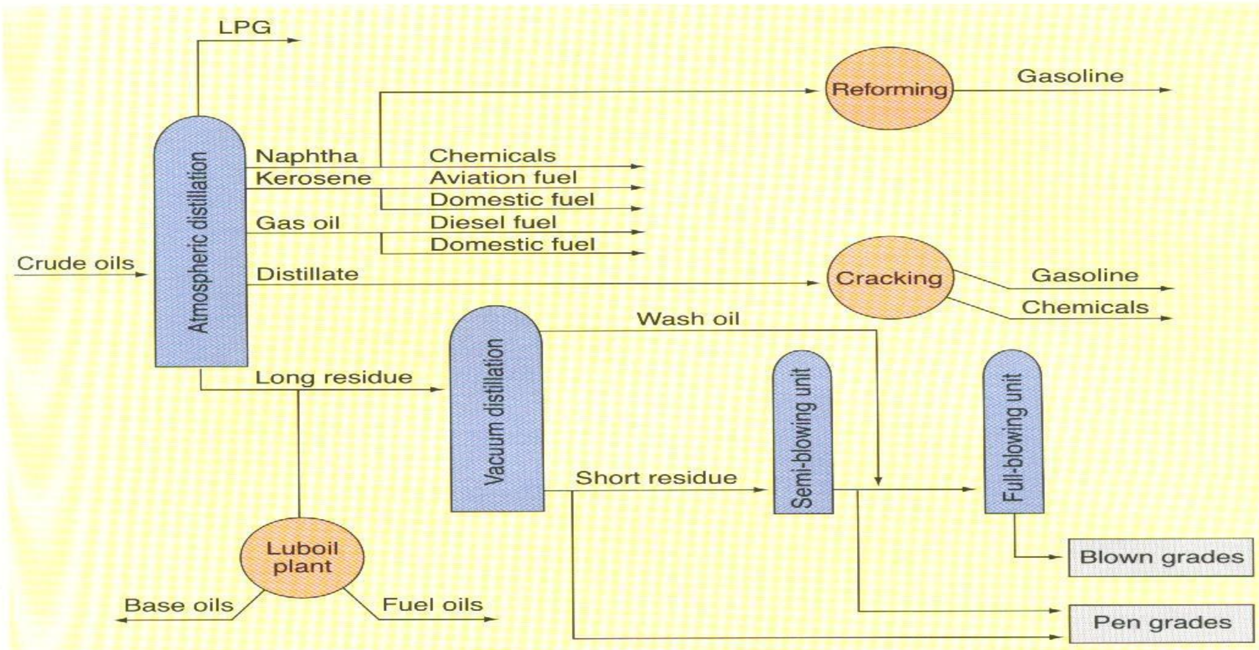


Fig. 2.2 Schematic representation of the crude oil distillation process

The consistencyof 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.

--xxxxxxxx--

02) Bituminous Materials-Chemistry is referred to chemical composition of bitumen. Elabourate in detail ?

Ans: **Chemical composition of bitumen:**

The chemical bitumen components are generally similar, but with some variation depending upon the original crude oil and on the processes used during refining and blending. Bitumens can generally be described as complex mixtures of hydrocarbons containing a large number of different chemical compounds of relatively high molecular weight. There is considerable uncertainty as to the molecular weight distribution of bitumen. The smallest size, approximately 300 Dalton, is determined by the distillation ‘cut point’ during the manufacture of the bitumen. The largest size has not been finally concluded; earlier research suggested that molecular weights up to 10000 Dalton are present, while some research indicates that there are probably very few if any, molecules larger than 1500 in bitumen.

The molecules present in bitumens are combinations of alkanes, cycloalkanes, aromatics and hetero molecules containing sulfur, oxygen, nitrogen, and metals.

A typical elemental analysis is given in Table 1.

Table 1. Elemental analysis of bitumens from various sources[27]

Element	Range
Carbon, %w	80.2 - 84.3
Hydrogen, %w	9.8 - 10.8
Nitrogen, %w	0.2 - 1.2
Sulphur, %w	0.9 - 6.6
Oxygen, %w	0.4 - 1.0
Nickel, ppm	10-139
Vanadium, ppm	7-1590
Iron, ppm	5-147
Manganese, ppm	0.1 - 3.7
Calcium, ppm	1-335
Magnesium, ppm	1-134
Sodium, ppm	6-159

Bitumen functionality relates to how molecules interact with each other and/or with other materials, e.g. aggregate surfaces and water. The content of sulfur, nitrogen, oxygen, and metals in some molecules makes them slightly polar. The significance of molecules containing heteroatoms in bitumen chemistry is the ability to form molecular associations, which strongly influence the physical properties and performance of bitumens. The components containing the heteroatomic compounds can vary in content and characteristics in bitumens obtained from different crude sources.

The sulfur content may be 1-7% by mass in bitumen and can consist of many different sulfur compounds such as thiophenes and sulfides. Studies have shown that the hetero-atoms, sulfur, and nitrogen, occur largely in stable ring configurations. Although nitrogen compounds are not as common, pyrrole, indole and carbazole groups are found in some bitumens. Oxygen is mainly present in functional groups as carboxylic acids and esters. The metals appear mainly in porphyrin-like structures.

Chemical Components of bitumen are;

1. Asphaltenes
2. Polar aromatics
3. Non polar aromatics and
4. Saturates