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Pavement Material Engineering

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Q1:part A

Why do we carry out Granular (Physical) stabilization?

The Basic purposes of Granular Physical Stabilization are:

- Transfer load without Permanent Deformation.
- Provide Frictional Resistance.
- Bears Volume Stability.
- Low Capillarity to resist moisture.

Main Objective:

- To obtain a well-proportioned mixture of particles having such a gradation that consists of all Size particles.
- To get the desired plasticity.

Q1: part B

❖ **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:

❖ **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

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

❖ **Fabrics:**

- It is an ideal case having each single type of particle is equal in number.
- Also having an ideal position.

❖ **Collaerities:**

Properties of particles:

1) Shape, size and gradation
2) Strength
3) Toughness abrasion resistance
4) Interaction and bonding with cementing agent

Properties of cementing agent:

1) Inorganic: gypsum, lime plasters etc
2) Organic: asphalt, gums etc

❖ **Specifications on Gradation and Selection of Soil Elements**

- 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.

    - ✓ ASTM and AASHTO Specifications
    - ✓ Formulae for Mixing of Aggregates
- 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.

Q2: Part A

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?

Aggregates can be identified on the basis of:

- Process of aggregate formation.
- Origin of the aggregate.
- Shape attain in process Aggregate formation.
- Surface Texture of Aggregate.
- How dense aggregate are.

Naturally Occurring Aggregate:

- 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
- Aggregate from Igneous Rock consists of 95% of Earth's Crust material.
- Such material are formed by the cooling of molten material

❖ Sedimentary Rocks
- Aggregate from Sedimentary rock consist of 5% of Earth's Crust & 75% of Earth's Surface Material.
- Such material are formed by deposition of granular material

❖ Metamorphic Rocks
- Metamorphic Rock are igneous or sedimentary rocks that have undergonetransformations due to heat and pressure

Further the weathering product may be of two general types:

❖ Transported Deposit are found, for example, in stream beds, sand and gravel bars, and alluvial fans.
❖ Residual Material may be either weathered or unweather generally occur in large deposits and are obtained by quarrying.

Q2: part B

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

There are two main sources of Aggregate:

- Natural Aggregate
- Rock Quarries

Aggregate of Natural sources includes:

Stream/River Deposits: The pressure of water breaks away rock particles from the river bed and banks. The force of the water hits river banks and then pushes water into cracks. Air becomes compressed, pressure increases and the riverbank may, in time collapse. Where velocity is high e.g. the outer bend of meaner, hydraulic action can remove material from the banks which may lead to undercutting and river bank collapse.

Glacial Deposits: Granular material carried away from the melting ice before being deposited are outwash deposits. Out wash tends to have fewer coarse particles and is better sorted. Process includes glacial erosion and deposition are extremely complex and dynamic.

Fluvial Glacial Deposits: Fluvial deposits are sediments that are transported and deposited by rivers in a continental environment

Talus Deposits: Talus is a collection of broken rock fragment at the base of crags , mountain cliffs , volcanoes that has accumulated through periodic rock fall from adjacent cliff faces.

Wind Blown Deposits: when wind slows down it drops the sediment it's carrying. This often happens when the wind has to move over or around an obstacle. A rock or tree may cause wind to slow down. As the wind slows, it deposits the largest particles first. Different types of deposits form depending on the size of the particles deposited.

Aggregate of Rock Qurries includes:

Igneous Rocks Aggregate: it is very hard, tough and dense and make an excellent source of crushed stone, it is too porous and make a good aggregate.

Metamorphic Rocks Aggregate: Flat, flaky, and elongated pieces are obtained on crushing metamorphic rocks. Such rocks will pose a problem if used as concrete aggregates. Also, some metamorphic rocks show directional properties because of their foliation. Foliation produces planes of weakness which are undesirable in aggregate.

Sedimentary rocks Aggregate: Sedimentary rocks, especially sandstone, limestone, and dolomite (dolostone) are among the most important aggregate sources. Because their mode of formation, their characteristics and properties are highly varied, as is their durability. Shale and siltstone are less durable, and used mostly in fills.

Que No 3

Types of Macadam bases:

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 withυ 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

❖ **Water Bound Macadam (WBM)**

- Macadam means the pavement base course made of crushed or broken aggregate mechanically interlocked by rolling and voids filled with screening and binding material with the assistance of water.
- **WBM** may be used as a subbase base or surface course.
- Thickness of each compacted layer of **WBM** ranges from 10cm to 7.5cm

Material Required for **WBM** Road construction:

- Course Aggregate:
  1) Should be hard and durable
  2) Should be free from flaky and elongated particles
- Screenings (fillers):
  1) It is the material fill up the excess voids of the compact layer of course aggregate
  2) It is generally aggregate having smaller size than course aggregate.
- Binding Material:
  1) Material used should have PI less than 6

Steps of WBM Formation:

- Preparation of foundation: The subbase or base course are properly prepared.
- Provision of lateral confinement: shoulders are made that the road structure retains in b/w them.
- Spreading of course aggregate: it should be spread uniformly after shoulder construction.
- Rolling: Rolling pass are given with roller of 6-10 ton roller.

- Application of screenings: it is provided in various layers, decided by the designer.
- Sprinkling of Water: water applied and brooming are done after it.
- Application of binding material: binding material are applied and rolled properly.

❖ **Wet Mixing Macadam:**

- Density: specified by laboratory result.
- Thickness: greater than 75mm and less than 250mm.
- 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 material are suggested to use.
- 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

Water Bound vs. 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.

- 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.

Q4 part A

Discuss in detail the Bituminous Material- manufacturing?

Bituminous Material- 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 ofcrude oil into the vessel
- 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 highflash distillates have also been used as blending materials with hard asphalts

Q4 Part B

Bituminous Materials referred to chemical composition of bitumen:

Bitumen is a product of oil refining and is a long chain complex hydrocarbon. It typically contains 82–88% carbon and 8–11% hydrogen, the rest being sulfur, oxygen and nitrogen. There are four fractional components making up the chemical composition of bitumen

Bitumen Components- 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. 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 bitumen.
- The components containing the heteroatomic compounds can vary in content and characteristics in bitumen 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, in dole 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 in bitumen are:

1. Asphaltenes
2. Resinous components (polar aromatics)
3. Non-polar aromatics (naphtene aromatics) and
4. Saturates