FINAL EXAM

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PAVEMENT MATERIAL ENGINEERING

M.S (Civil Engineering)

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QUESTION 01:

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

PART 1: WHY DO WE CARRY OUT GRANULAR (PHYSICAL) STABILIZATION?

ANSWER PART 1:

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:

a. Transfer load without Permanent Deformation
b. Provide Frictional Resistance
c. Bears Volume Stability

They may also contain material with particle sizes less than 0.075mm without violating the requirements given above if:

i. 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
ii. 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 as 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.

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 other hand, need to satisfy conditions of resisting abrasion, penetration of water, and of capillarity to replace moisture lost by surface evaporation.

Therefore, the composition of base and subbase soil-aggregate requires less fine-soil fraction than the composition for wearing surface.

Question 1, PART 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 PART 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:

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

where:

- s = weight percent of the particles with diameter less than d.
- d_{max} = 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 form.

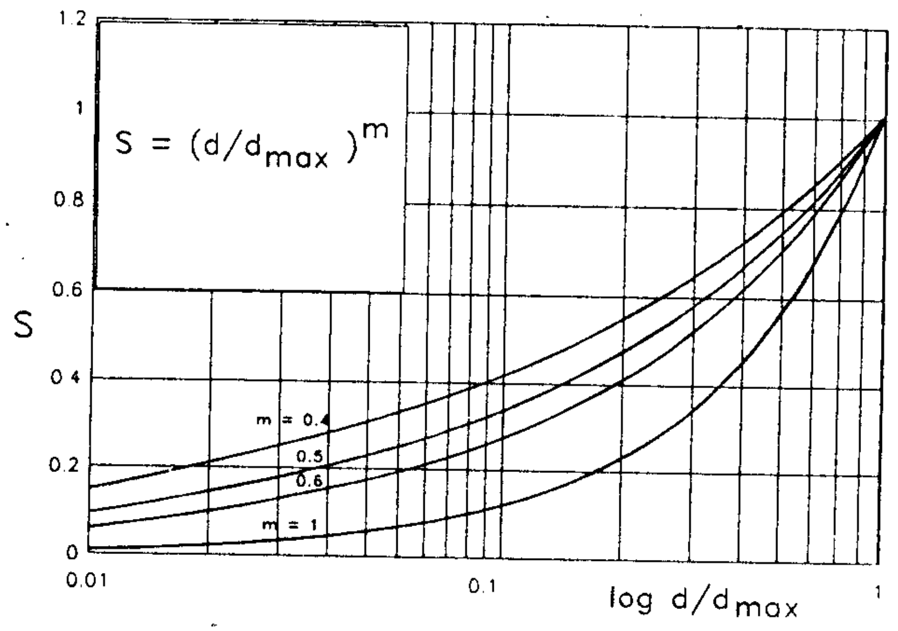
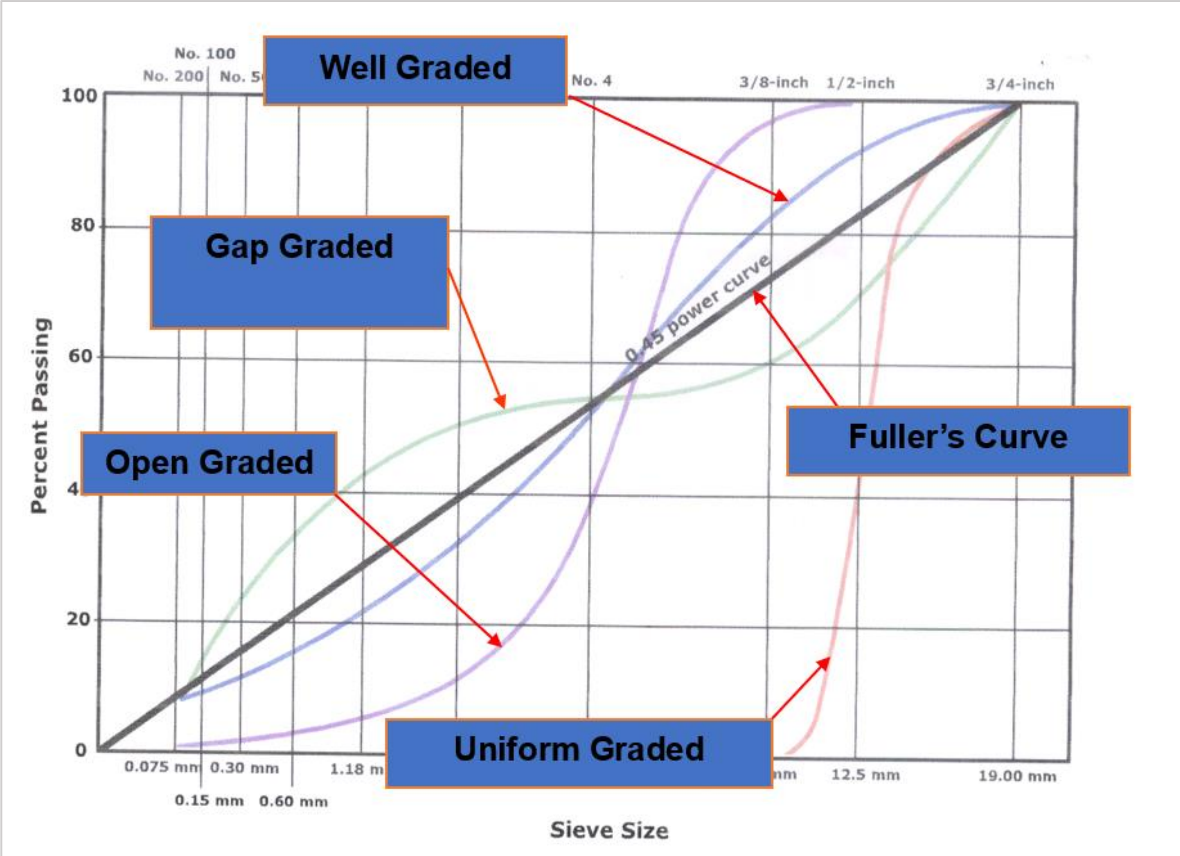
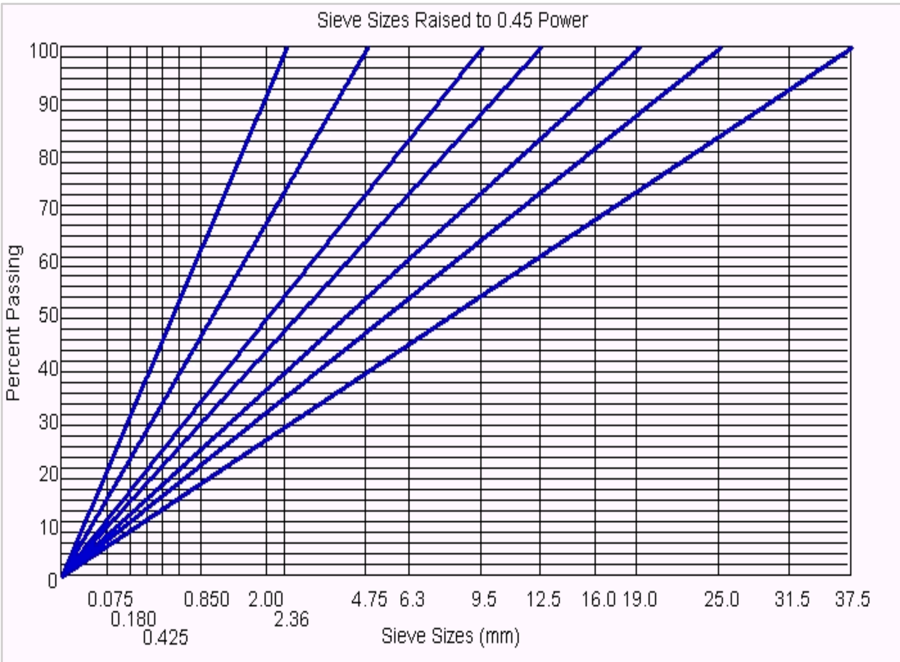


Fig. 9.1 Curve satisfying the Talbot formula



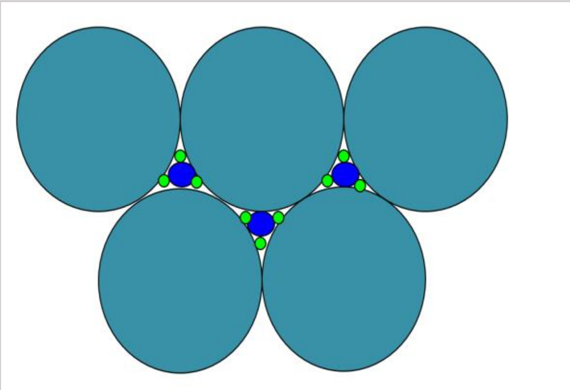
Different Aggregate Gradation



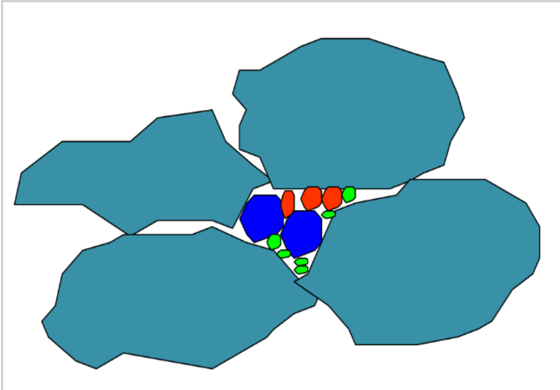
Fuller's Curves

AGGREGATES

FABRIC (Ideal)



FABRIC (Actual)



SOIL BINDER

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

a. Bonding or Cementation
b. Increase in Cohesion
c. 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 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 is 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.

SPECIFICATIONS ON GRADATION AND SELECTION OF SOIL ELEMENTS:

The Desired Mixtures is obtained by addition of proper proportions of the aggregates or fines and 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. 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).

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

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.

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

PART 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 PART 1:

Aggregate is the major component of materials used in road making. It is used in Granular Bases and Sub-Bases, Bituminous Courses and 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 obtained from two sources,

1. Naturally Occurring Deposits
    a. Processed Material
    b. Blends of Natural or Processed Materials
    c. Stabilized Materials
2. Artificially or Industrially Prepared Deposits (synthetic)

AGGREGATES CAN BE IDENTIFIED ON THE BASIS OF:

i. Origin (Composition)
ii. Mode of Formation & Deposition
iii. Density (Intra-particle voids)
iv. Shape
v. Surface Texture

NATURALLY OCCURRING MATERIALS:

The majority of aggregates used in road construction are obtained from naturally occurring deposits. Natural aggregates from rock of the following geological groups:

a. Igneous Rocks (95% of Earth's Crust) which are formed by cooling of molten material.
b. Sedimentary Rocks (5% of Earth's Crust & 75% of Earth's Surface) which are formed by deposition of granular material
c. 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, in stream beds, sand and gravel bars, and alluvial fans. 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.

AGGREGATE IDENTIFICATION

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

Colluvium Deposits

a. formed by gravity and weathering action of a steeply sloping rock face
b. crushing usually necessary
c. large angular chunks

Glacial Deposits

a. true glacial deposits - transported by glacial ice and have not been subjected to river transportation
b. fluvial-glacial - glacial deposits subjected to stream action
c. glacial deposits may be unsuitable as aggregate sources since they are heterogeneous and require a great deal of processing before, they can be used.
d. fluvial-glacial deposits - are more suitable

Fluvial Deposits

The 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

Eolian Deposits

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
d. wash to remove salts

S. No.	Name of rock	Geological Group	Properties	Suitability for road-making
1.	Granite	Igneous Rock	1. Hard, durable 2. Bulk Density below 2.80 3. Blue, pink in colour 4. Fine-grained to coarse grained texture. 5. Resistant to abrasion 6. Low absorption of water	1. Very good for bituminous courses and cement concrete pavements 2. Suitable for masonry work 3. Suitable for R.C.C. work
2.	Basalt (Also called Trap)	Igneous Rock	1. Hard, durable 2. Bulk Density about 2.8—3.0 3. Blue or dark blue in colour 4. Fine grained 5. Resistant to abrasion 6. Low absorption of water	1. Very good for bituminous courses and cement concrete pavements 2. Suitable for masonry work 3. Suitable for R.C.C. work
3.	Quartzite	Metamorphic Rock	1. Reasonably hard and durable 2. Fine to medium grain size 3. Light brown or pink in colour 4. Resistant to abrasion 5. Low absorption of water 6. Reasonably high bulk density of 2.5—2.8	1. Good for base courses, bituminous courses and cement concrete pavements 2. Used for R.C.C. work 3. Suitable for masonry work
4.	Limestone	Sedimentary Rock	1. Reasonably hard and durable 2. Liable to polish to a smooth surface under traffic 3. Fine grained 4. High water absorption 5. Bulk Density low in the range 1.9—2.2	1. Good for base courses 2. Unsuitable for wearing surfaces because of polishing characteristics
5.	Sandstone	Sedimentary Rock	1. Moderately hard and durable 2. Fine to medium grained 3. Bulk Density in the range 2.3—2.7	1. Good for road bases 2. Generally, unsuitable for wearing courses
6.	Laterites	Decomposition of basalt and other rocks	1. Yellowish to reddish brown in colour 2. Spongy porous open texture 3. Bulk Density varies from 2.2—2.8. 4. Water absorption very high, 5—25 per cent. 5. Soft to medium hard, losing strength when it absorbs moisture.	1. Good for sub-base and base courses 2. Used as surface course in un-important roads
7.	Kankar	Sedimentary rock, impure form of lime stone	1. White to brown in colour 2. Soft to medium hard 3. Bulk Density in the range of 2.2—2.6 4. Water absorption high	1. Good for sub-base and base courses 2. Used as surface course in un-important roads.
8.	Dhandla	Gypsum	1. White in colour 2. Soft and highly abraded 3. Absorbs water to a high degree 4. Bulk Density varies from 2.2—2.5.	1. Used for sub-bases and bases 2. Used as a surfacing material in Rajasthan on unimportant roads

PART 2: IN AGGREGATE INVESTIGATION MATERIAL SOURCING IS REFERRED TO FILED INVESTIGATION. DISCUSS MATERIAL SOURCING IN DETAIL.

ANSWER PART 2:

FIELD INVESTIGATION/ MATERIAL SOURCING

Field Investigation for 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 is must for the Investigation Team.

AGGREGATE SOURCES:

1. Natural Aggregate
2. Rock Quarries

NATURAL DEPOSITS:

a. Stream/River Deposits
b. Glacial Deposits
c. Fluvial Glacial Deposits
d. Talus Deposits
e. Wind Blown Deposits

INFORMATION IS OBTAINED FROM

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

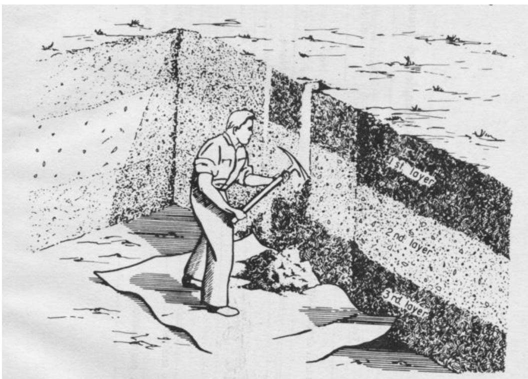
AGGREGATE PROSPECTING

i. Shallow Deposits
ii. Rock Quarries
iii. Deep Deposits

Shallow Deposits

- A grid of test pits/trenches
- Representative Sampling

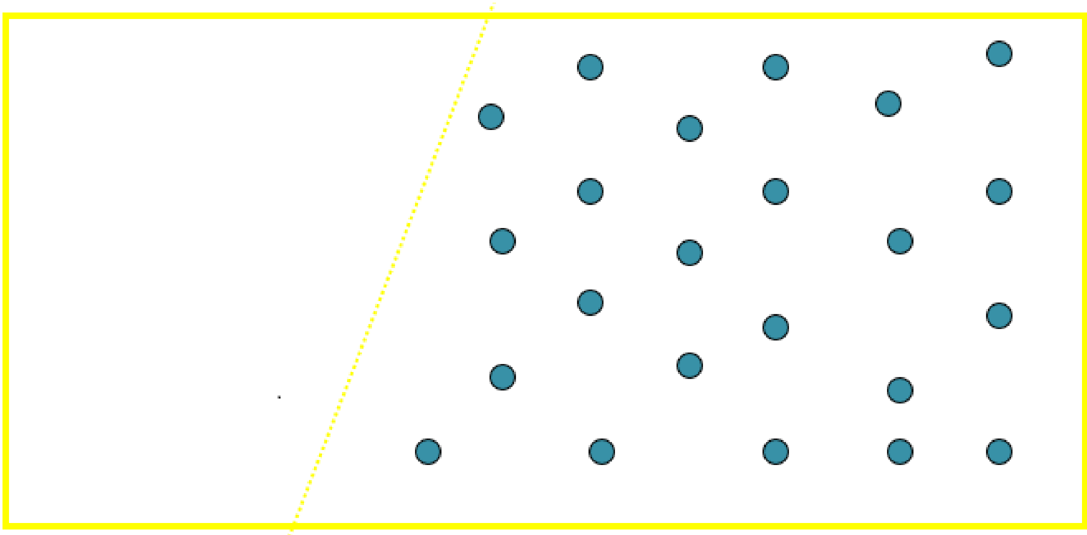
a. from different depths
b. from bottom and sides



Individual samples are taken from each layer of soil.
Composite samples are taken from two or more layers of soil.
Figure 1-1.—Sampling trench. PX-D-4784.

Rock Quarries

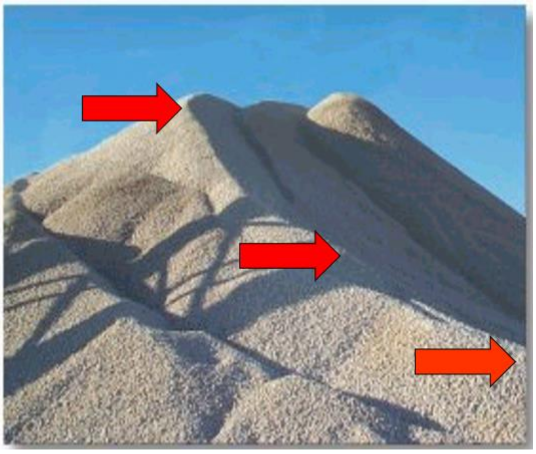
- A grid of boreholes
- large sized holes
- core sampling



Deep Deposits

- Visual inspection through cuts

- Sampling from stockpiles

AGGREGATE SAMPLING:

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 discharge points
3. Sampling from stockpiles
4. Sampling from railway wagons, transporting dumpers/trucks etc.

SAMPLE QUANTITY:

Minimum Quantity depends on the testing desired:

Table 3.2 Minimum Mass of Samples for Testing (BS 812: Part 102: 1989)

Maximum particle size present in substantial proportion mm	*Minimum mass of sample dispatched for testing kg*
28 or larger	50
Between 5 and 28	25
5 or smaller	13

QUESTION 03:

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?

ANSWER 03:

INTRODUCTION:

One of the major types of road construction is Macadam. It was introduced in around 1820 by a Scottish Engineer John Loudon McAdam. 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.

TYPES OF MACADAM ROAD

Macadam roads can be classified into following types:

- Water bound macadam
- Traffic bound macadam
- Bituminous macadam
- Cement macadam

WATER BOUND MACADAM:

It is layer of broken stone aggregates bound together by stone dust or screening & water applied during construction, and compacted by heavy smoothed wheel rollers.

TRAFFIC BOUND MACADAM:

It is wearing course composed of broken stones or gravel, consolidated by action of traffic. This type of surface is generally built gradually by successive application of two or more layers. The compacted thickness of each layer may vary from 2.5 - 5.0 cm.

BITUMINOUS MACADAM:

It is the compacted layer of clean crushed stone of reasonably uniform in size. Over this layer, a second layer of crushed stone together with bituminous material heavily sprayed. Much of the bituminous material penetrates into the voids and binds the stones together. To fill the surface voids of the first course, a uniform thin layer of smaller aggregate is spread and rolled. Then, again a light application of bituminous material is applied and a thin layer of still smaller aggregates is spread and rolled. This type of road is generally known as penetration macadam.

CEMENT MACADAM:

It is similar to bituminous macadam. The only difference is that in this case, cement is used in place of bitumen.

DIFFERENCES BETWEEN WBM AND WMM:

Wet Mix Macadam (WMM) is an advance form of Macadam using the technological advancement to ease the work. 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. The pavement base course made of crushed or broken aggregates mechanically interlocked by rolling and voids filled by screening and binding material with the assistance of water. WBM (Water Bound Macadam) and WMM (Wet Mix Macadam) are used for Road construction in Base course layer. WMM is a new technology. difference between WBM and WMM can be summarized as below:

PROPERTIES	WBM	WMM
AGGREGATE SIZE	Stone aggregate used in WBM is larger in size compared to WMM. In case of WBM its size varies between 45 mm to 90 mm depending upon the grade.	Stone aggregate used in WMM is Smaller in size compared to WBM. In case of WMM aggregate size varies between 4.75 mm to 20 mm.
OVERLAYING OR CONSTRUCTION SEQUENCE	In case of WBM stone aggregate, screening material and binders are overlaid one after another respectively at the time of construction. ▪ Spreading of coarse aggregates by templates or motor graders and compaction using 80 – 100KN Roller. ▪ Screening is applied in three or more successive layers to fill the voids in CA Accompanied with brooming and dry rolling. ▪ Water is sprinkled & wet screening are distributed evenly and forced into the voids by brooming and dry roller. ▪ Binding material is applied in two or more successive layers, followed by sprinkling of water, and the resultant slurry is swept into the voids by brooming & Rolling.	In case of WMM, aggregate and binding materials are premixed in a batching plant or concrete mixing machine and then brought to site for overlaying and rolling ▪ WMM is prepared in mixing plants, having MC Slightly greater than OMC, accounting for the transit/evaporation losses. ▪ Mix is spread by a self-propelled paver finisher and in case of multi-layer construction bottom layer may be spread using motor graders.
DURABILITY	WBM is less durable and stable comparatively to WMM.	WMM is more durable and stable comparatively to WBM as WMM uses more closely graded material.
LABOUR WORK	Laying WBM is usually more labour intensive than WMM.	Laying WMM is less labour intensive than WBM.
MEASUREMENT UNIT	Quantity of WBM is generally measured in Cubic Meter.	Quantity of WMM is measured in Square Meter.

COMPONENTS	• Coarse Aggregate (90MM - 45MM for Sub Base Coarse) & (63MM – 4MM & 53MM – 22.4MM for Base Coarse) Hand Broken aggregates can be used. • Screening – Stone/Gravel/Moorum – Fraction Passing 75 Micron Sieve < 10%, LL<20 & PI<6. • Binder Material – Fine Grained Material with PI<6	Materials used in WMM are Stone aggregate and binders. • Aggregates needs to be crusher run. ▪ Grading 1(53MM – 75Micron) For Thickness Greater 100MM. ▪ Grading 2(26.5MM – 75Micron) For Thickness <100MM. • OMC Varies between 2% to 6% • Stone dust or Quary dust of PI<6.
COST	WBM is less costly than WMM. ▪ WBM does not require crusher run aggregates ▪ It does not require a mixing plant, a paver and a heavier roller.	WMM is costly than WBM. ▪ WMM require crusher run aggregates. ▪ It requires a mixing plant, a paver and a heavier roller. ▪ More Machinery means more expenses.

QUESTION 04:

1. Discuss in detail the Bituminous Materials-Manufacturing?
2. Bituminous Materials-Chemistry is referred to chemical composition of bitumen. Elaborate in detail.

PART 1: DISCUSS IN DETAIL THE BITUMINOUS MATERIALS-MANUFACTURING?

ANSWER PART 1:

Petroleum Bitumen, normally called “Bitumen” or “Asphalt” is produced by refining crude oil. Used as a binder in road-building products, it is a very viscous, black or dark brown material. The crude oil is pumped from storage tanks, where it is kept at about 60°C, through a heat exchanger system where its temperature is increased to typically 200°C by exchanging heat gained from the cooling of newly produced products in the refining process. The crude is then further heated in a furnace to typically 300° C where it is partly vaporized into an Atmospheric Distillation Column. Here the physical separation of the components occurs. The lighter components rise to the top and the heaviest components (the atmospheric residue) fall to the bottom of the column and pass through a second heat exchanger prior to treatment in a vacuum distillation column. Finally, Bitumen is obtained by vacuum distillation or vacuum flashing of atmospheric residue from the vacuum distillation column. This is "straight run bitumen”. This process is called bitumen production by straight run vacuum distillation. An alternative method of bitumen production is by precipitation from residual fractions by propane or butane-solvent de-asphalting. The bitumen thus obtained has properties which derive from the type of crude oil processed and from the mode of operation in the vacuum unit or in the solvent de-asphalting unit. The grade of the bitumen depends on the amount of volatile material that remains in the product: the smaller the number of volatiles, the harder the residual bitumen. Specialists in bitumen view bitumen as an advanced and complex construction material, not as a mere by-product of the oil refining process.

STAGES OF MANUFACTURE:

1. Crude Oil Storage Tanks
2. Furnace
3. Atmospheric Distillation
4. Furnace
5. Vacuum Distillation
6. Straight Run Bitumen
7. Transport and Processing
8. Polymer Modified Bitumen
9. Transport and Processing
10. Oxidized Bitumen
11. Transport and Processing

The manufacturing methods that are used to produce bitumen reflect one of two things:

- The quality of the crude as a bitumen feed or
- The other products in the refinery.

Four PRIMARY METHODS are used to manufacture Bitumen:

1. Atmospheric Distillation
2. Vacuum Distillation
3. Solvent Refining
4. Blowing or Air Rectification

ATMOSPHERIC DISTILLATION

The crude is preheated via a heat exchanger after desalting and dewaxing. It is then heated to about 400°C (750°F) by pumping it rapidly through a coiled tube exposed to direct heat in a pipe still or furnace. It is then continuously delivered to the flash zone of the atmospheric distillation tower. The most volatile components are drawn from the top of the tower and the less volatile from the sides. Steam is often used to assist this process. This process is only capable of producing finished bitumen from very heavy crudes such as Boscan (58 percent asphalt residue). The atmospheric residue is used directly as bitumen. A "topped crude" will be produced for subsequent vacuum distillation in most cases.

VACUUM DISTILLATION

The vacuum tower may be used for two purposes:

- To distill an atmospheric residue from any other source or,
- To top or extract kerosene from a cutback bitumen.

LUBE OIL OPERATION

Atmospheric residue must be processed under vacuum to avoid thermal cracking. The vacuum allows lower temperatures to be used. The normal overhead pressure is approximately 21 mm of Hg and approximately 48mm of Hg in the flash zone. In this process, the residue is introduced into the tower after heating. The residue enters a flash zone at approximately 400°C after heating in a furnace. The temperature is set according to the volatility of the feedstock. Superheated steam is injected to maintain temperature and increase the feed rate. The partial steam pressure also increases volatility, aids separation, and minimizes cracking. In the flash zone, light and heavy gas oils are flashed off and the bitumen, the highest boiling component, is the residue. This is often called Vacuum Residue or Vacuum Tower Bottoms (VTB). The VTB may be a finished bitumen. That is, it may meet certain paving or industrial specifications without further processing. This will depend on the crude and the processing parameters used. Rarely is a refinery run for bitumen production. In lube oil refineries, the requirements of lube production must be balanced against the requirements for bitumen. A lighter feed is required for lube production. A heavier feed is preferable for bitumen. The processing parameters must be set in operation of the vacuum tower to take these different needs into account.

CUT BACK PROCESSING

In this process, a finished bitumen is blended with up to 30% kerosene is re fractionated to remove the kerosene. The advantage of such a system is that it allows product from one refinery to supply and manufacturing flexibility. In this case, cutback is made from certified bitumen at and moved to another location by road, pipeline or by ship where it is stored in a tank and allowed to dewater. The cutback is heated by heat exchangers and injected into the flash zone of the vacuum tower. Liquid flows through the stripping section below the flash zone against a flow of stripping steam. Vapor flows up the tower and is refined and condensed in three packed sections. Two kerosene streams, dirty and clean, are withdrawn from the tower. The clean stream is stored and the dirty stream is reprocessed elsewhere. The residue is a finished bitumen and may be used as is or adjusted to harder grades by blowing.

SOLVENT REFINING

This takes advantage of the complex internal solubility parameters of bitumen. An alkane injected into the bitumen disrupts the dispersion of components and causes the polar constituents to precipitate. Two similar techniques are employed:

- Propane De-asphalting (Extensively used)
- ROSE Supercritical Process

The materials produced by both techniques allow the possibility of optimizing bitumen composition by blending.

AIR BLOWING/AIR RECTIFICATION

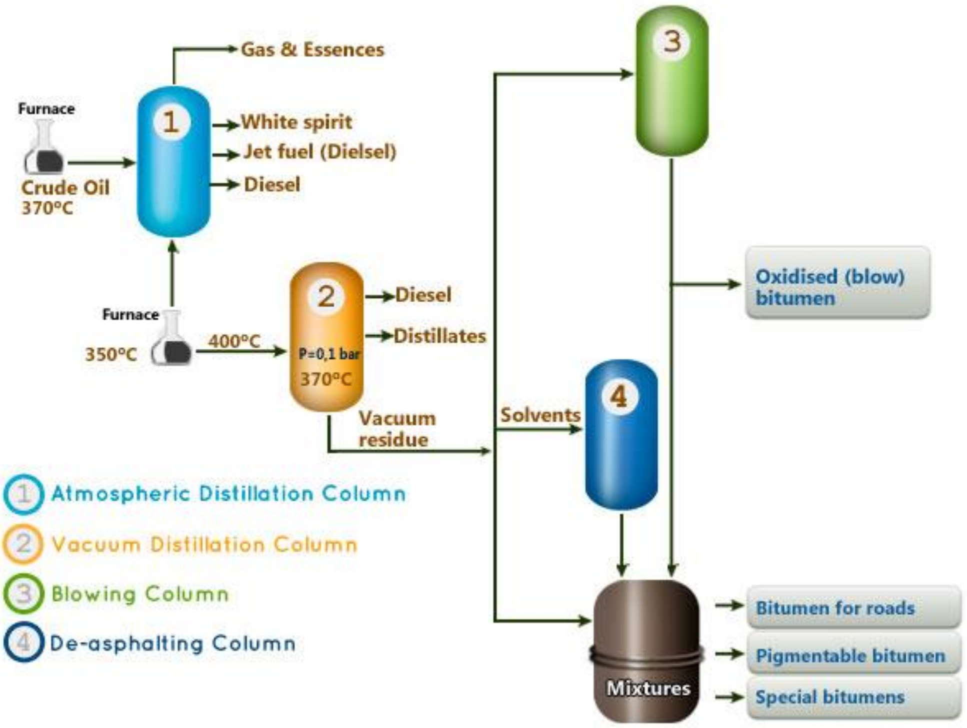
For light crudes, or where industrial bitumen are required, blowing a bitumen with air, or bringing it into contact with air, at elevated temperatures is used to increase the viscosity to meet specification. This process is often termed oxidation. However, only a small amount of oxygen is actually incorporated in the bitumen during the process. The process may be controlled by controlling temperature, air rate, and the use of the catalyst. The properties of the blown asphalt are highly dependent on the composition of the feedstock and the degree of blowing. Although air blowing has been used extensively for paving asphalts in the past, it is now out of favor due to its tendency to create binders that are brittle, particularly at low temperatures. Air rectification (a more controlled, light blowing process) is useful for paving grade bitumen but requires careful attention to the feedstocks used and the degree of blowing. Air blowing remains the method of manufacture of industrial asphalts.

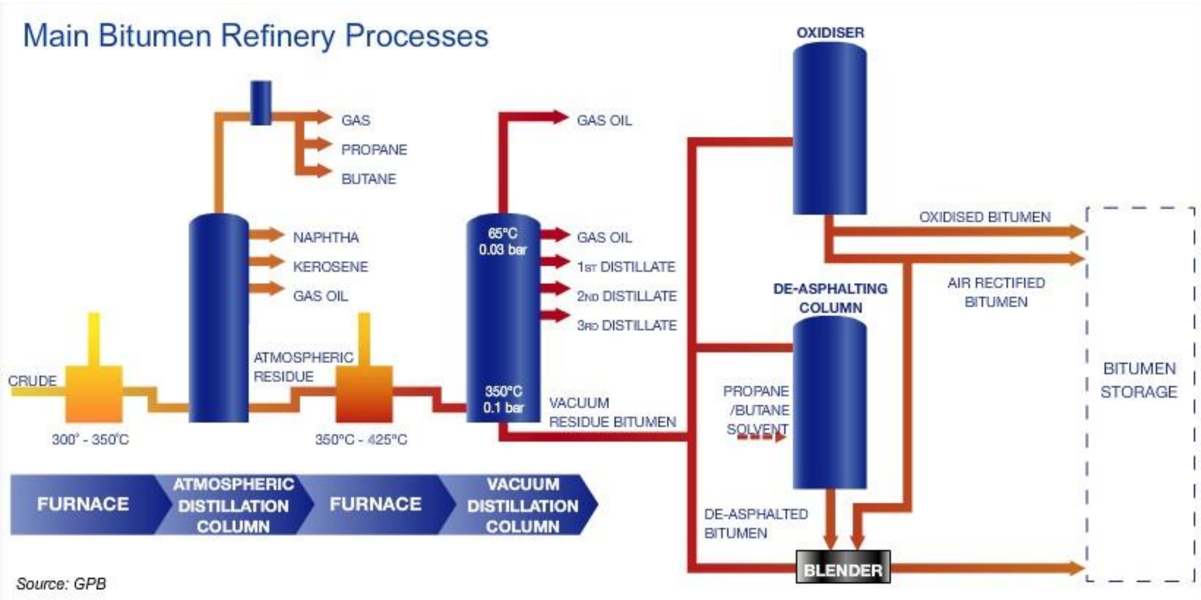
NON-CATALYTIC BLOWING

- Reactions that increase molecular size and degree of association of polar compounds including formation of carbonyl compounds in the form of carboxyl groups, esters, anhydrides, and ketones. In air blowing, the combination of air and temperature (200°C to 275°C) results in most of the oxygen being incorporated as esters.
- This fact allows condensation reactions that lead to linking of polar molecules such as asphaltenes. It also increases polarity resulting in increased molecular associations and structure. The result is an increase in molecular weight and concentration of asphaltenes and a significant increase in viscosity. Volatilization may occur as light ends are driven off. Reactions that do not increase molecular size.
- These include dehydrogenation and formation of cyclic compounds with water as a byproduct. Reactions that decrease molecular size.
- These include separation of side branches and formation of blown distillates, water, and carbon dioxide. In blowing, the chemical reaction process is stepwise.
- Peroxides and hydroperoxides are produced initially and progress to ester and carbonyl group formation. The formation of carbonyl and ester products is favored at lower temperatures; molecular size increase is optimized at approximately 250°C.
- The effect is increased as the aromaticity of the feed is increased.
- When fractionated after blowing, asphalt will usually exhibit a significant increase in asphaltenes, a slight increase in resins, and a reduction in aromatic oils.

CATALYTIC BLOWING

- "Catalytic" blowing is not strictly catalytic as the additive is used up in the reaction.
- The blowing time is reduced, however, and the softening point/penetration relationship is altered higher penetration for a given softening point.
- Common catalyst types are ferric chloride and phosphorus pentoxide.
- Acids such as sulphuric and hydrochloric have also been used.





Bitumen Production Process, Source: GPB

PART 2: BITUMINOUS MATERIALS CHEMISTRY IS REFERRED TO CHEMICAL COMPOSITION OF BITUMEN. ELABORATE IN DETAIL.

ANSWER PART 2:

INTRODUCTION:

Bituminous materials consist 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. Materials in bituminous family are:

TAR:

Coal tar is a brown or dark black liquid of high viscosity, which smells of naphthalene and aromatic hydrocarbons. Being flammable, coal tar is sometime used for heating or to fire boilers. It can be used in coal tar soap, and is used in medicated shampoo to kill and repel head lice, and as a treatment for dandruff. Depending upon its source of origin, TAR is classified as:

- Coal Tar
- Wood Tar
- Mineral Tar
- Coal Tar Pitch

CHEMICAL COMPOSITION OF BITUMEN:

Molecular weight wise, bitumen is a mixture of about 300 - 2000 chemical components, with an average of around 500 - 700. Elementally, it is around:

- 95% carbon and hydrogen (± 87% carbon and ± 8% hydrogen),
- up to 5% sulfur
- 1% nitrogen
- 1% oxygen
- 2000ppm metals

Bitumen is composed mainly of highly condensed polycyclic aromatic hydrocarbons. They also contain several elements, a number of which are toxic.

CHEMICAL COMPONENTS IN BITUMEN:

1. ASPHALTENES:

Asphaltenes are molecular substances that are found in crude oil, along with resins, aromatic hydrocarbons, and saturates (i.e. saturated hydrocarbons such as alkanes). The word "asphaltene" was coined by Boussingault in 1837 when he noticed that the distillation residue of some bitumen had asphalt-like properties. Asphaltenes in the form of asphalt or bitumen products from oil refineries are used as paving materials on roads, shingles for roofs, and waterproof coatings on building foundations.

COMPOSITION OF ASPHALTENES:

- Asphaltenes consist primarily of carbon, hydrogen, nitrogen, oxygen, and sulfur, as well as trace amounts of vanadium and nickel.
- The C:H ratio is approximately 1:1.2, depending on the asphaltene source.
- Asphaltenes are defined operationally as the n-heptane (C_7H_{16})-insoluble, toluene ($C_6H_5CH_3$)-soluble component of a carbonaceous material such as crude oil or coal.
- Asphaltenes have been shown to have a distribution of molecular masses in the range of 400 u to 1500 u, but the average and maximum values are difficult to determine due to aggregation of the molecules in solution

2. MALTENES

Maltenes are the n-alkane (pentane or heptane)-soluble molecular components of asphalt, which is the residue remaining after petroleum refiners remove other useful derivatives such as gasoline and kerosene from crude oil. Asphaltene compounds are other primary component of asphalt. Maltenes contain Resins(R), Saturates (S) and Aromatics (A).

COMPOSITION OF MALTENES:

- As viscous liquids, maltenes consist of heavy, dark-colored asphaltic resins, first acidaffins, second acidaffins, and saturates,[1] combined with lighter colored oils.[2] The resins provide the adhesive qualities in asphalts; the oils are the carrier medium for both the maltene resins and the asphaltene compounds. Maltenes are characterized by their lower molecular weight and their solubility, in comparison with asphaltenes. Using adsorption chromatography in the presence of an acid reagent, maltenes can be separated into four fractions:
- The polar compounds are highly reactive petroleum resins that act as a colloidal dispersion stabilizer for the asphaltene substrate.
- First acidaffins are aromatic hydrocarbons, with or without oxygen, nitrogen and sulfur. They provide a chemically compatible dispersing agent for peptized asphaltene.
- Second acidaffins are straight chain or cyclic unsaturated petro-hydrocarbons (aka olefins). They are somewhat oily and somewhat resinous.
- Saturates (aka paraffins) are either straight or branch chain saturated hydrocarbons. They are the truly oil component of asphalt binder, and function as the gelling agent for the asphalt compounds.