

**FINAL ASSIGNMENT/QUIZ (SPRING-2020)**

**MS TRANSPORTATION  
ENGINEERING**

**NAME: MUHAMMAD IRSHAD  
KHATTAK**

**CLASS ID: 15514**

**SUBMITTED TO:  
ENGR. SHABBIR AHMED**

**IQRA UNIVERSITY PESHAWAR**

### **Q.NO (01): Why do we carry out Granular (Physical) stabilization?**

Ans:

1. Most of stabilization has to be undertaken in soft soils (silty, clayey peat or organic soils) in order to achieve desirable engineering properties.

**“According to Sherwood (1993) fine-grained granular materials are the easiest to stabilize due to their large surface area in relation to their particle diameter”.**

The granular stabilized road is by far the oldest and most commonly used type. Consider a path in any garden or a road on any farm. If in wet weather the path or road become muddy, it is customary for the housewife or farmer to apply some kind of readily available granular material such as ashes, cinders, sand, gravel or crushed rock. These applications are, as a rule, continued until the path or road becomes usable under all weather conditions. On the other hand, if the natural soil is very loose and sandy, small addition of clay soil over a period of time would likewise have produced a satisfactory path or road. These two simple procedures involve all the underlying principles of granular soil stabilization. They may be termed the "cut and try" methods. By this means, surfaces of appreciable thickness, having natural soil and granular material in the right proportion to produce the desired firmness or stability, have been imposed on the underlying soil.

2. Why do we carry out granular (physical) stabilization considering granulometry and collametry, fabric, soil binder, collamertics and specification of gradation and selection of soil elements?

Stabilising a soil implies the modification of the properties of a soil – water – air system in order to obtain lasting properties, which are compatible with a particular application. The parameters involved are:

- Properties of the soil to be stabilized
- Planned improvements
- Project economies
- Construction techniques
- Maintenance of the project

#### **OBJECTIVES**

- Reducing the volume of voids = reducing the porosity.
- Filling the voids that cannot be eliminated = reducing the permeability.

- Increasing the bonding between grains = increasing the mechanical strength.

#### PROCEDURES

- Mechanical – by compaction to reduce the porosity and increase the compressibility.
- Physical – by acting on its texture ( e.g. the controlled mixing of different grain fractions).
- Chemical – by adding other materials or chemicals to modify its properties.

#### Q.NO (2)

- 1. How would you (being a material expert) identify aggregate referring to natural materials, igneous, sedimentary, metamorphic rocks and Residual material and transported deposits?**

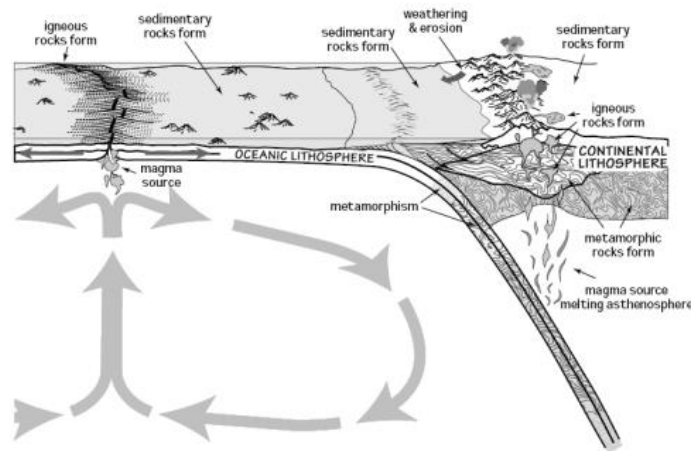
Ans: To identify a rock, three things must be considered:

1. origin,
2. composition, and
3. texture

#### Rock Origin

The first step to identify a rock is to try to categorize the rock into one of the three main types or groups of rocks. These include igneous, sedimentary or metamorphic types. The only rocks which do not fall into one of these categories are meteorites. Igneous, sedimentary and metamorphic rock types are distinguished by the processes which form them.

# The Rock Cycle



## **Igneous rocks:**

Igneous rocks form by crystallization of a melt (molten rock material).

## **Sedimentary rocks:**

Sedimentary rocks form by the compaction small or large grains or fragments of pre-existing rocks, or by the precipitation of mineral matter from a body of water, such as an ocean, lake or stream

## **Metamorphic Rocks:**

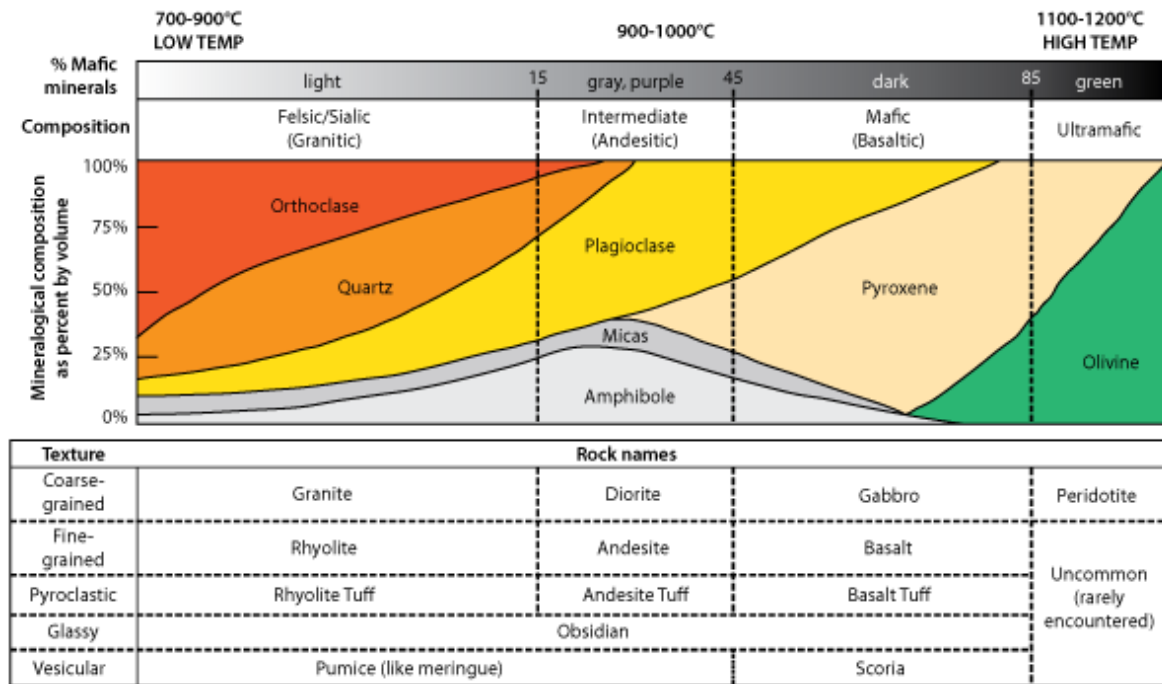
Metamorphic rocks formed from pre-existing igneous, sedimentary or metamorphic rocks by subjecting them to heat and/or pressure and/or migrating fluids, causing the original mineral assemblage of the rock to change to a new assemblage of minerals. The origin is not always obvious, but sufficient training will enable recognition of certain features which point to the most likely origin. Examples include the common presence of bedding or layering in sedimentary rocks, and the presence of mineral foliations or lineations in metamorphic rocks. One must also consider the geologic environment where the rock is found

## **Rock Composition**

The rock composition is found by determining which minerals make up the rock.

By definition, a rock is a solid mass or compound consisting of at least two minerals (although there are some exceptions when a rock may consist entirely of one mineral). The minerals comprising the rock can be identified using common field testing methods for individual minerals, particularly where the texture is sufficiently coarse-grained enough to distinguish the individual minerals with the naked eye or a hand

lens.



Where the grain size of the minerals comprising the rock are too fine-grained to recognize discrete minerals, “petrographic” methods (those using a microscope) can be used for reliable identification in many cases.

Petrographic methods involve the use of a microscope to examine the optical properties of discrete minerals magnified through the microscope lens. Properties include the behavior of refracted, reflected and transmitted light either through a thin wafer slice of the rock (called a thin section), or of a sample plug (for reflected light). The light source is adjusted to provide light which polarized in one or two directions.

### X-Ray Diffraction Techniques

Another method to identify small mineral grains is using X-ray powder diffraction. A small amount of material is ground into a powder and bombarded with X-rays. The results are recorded on a film strip in a camera, or in the form of graph. The reflections of the X-rays are measured to determine the ‘d-spacings’ of the unknown mineral. Each mineral has a unique set of peaks corresponding to d-spacings, which are related to the crystal structure.

In X-ray spectrometry, another method to identify minerals, the X-rays cause the emission of photons from the surface of the mineral. The sample is prepared by obtaining a very high polish on its surface. The photons emitted from the surface atoms have characteristic energies for specific elements. By measuring the energy levels of the photons, the mineral composition can be identified.

### Rock Texture

The texture of a rock is defined by observing two criteria: 1) Grain shapes.

**GrainShape:**

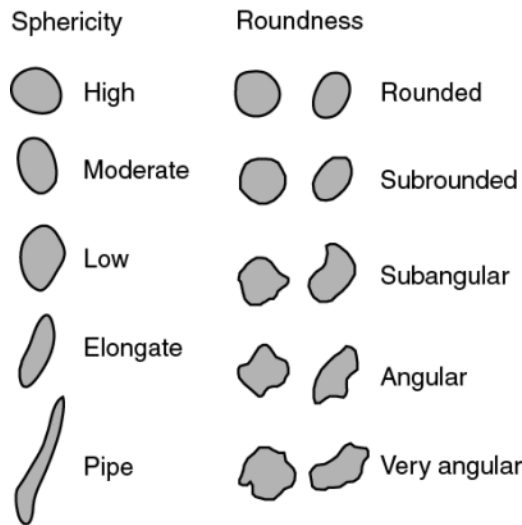
the general shape of the mineral grains (crystal faces evident, or crystals are rounded).

Examples of the size classifications for each of the three major rock types include:

FINE-GRAINED

COARSE-GRAINED

Sedimentary:	Shale	Siltstone	Sandstone	Wacke	Conglomerate
Metamorphic:		Slate	Phyllite	Schist	Gneiss
Igneous:	Rhyolite Granite				



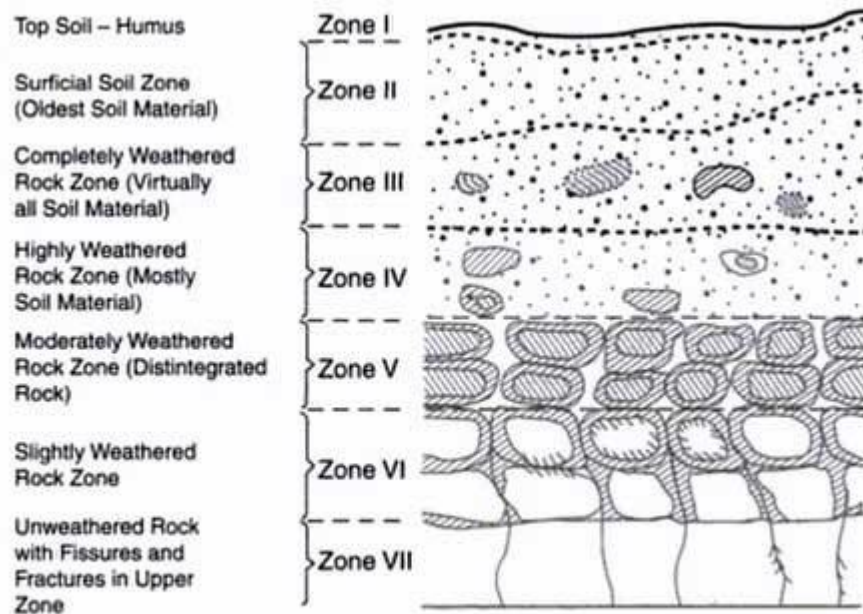
Rock Type	Very Fine Grained	Fine Grained	Medium Grained
<b>Clastic Sedimentary</b>	.06 - .125 mm	.125 - .25 mm	.25 - .5 mm
<b>Metamorphic</b>		< .25 mm	.25 - 1 mm
<b>Igneous</b>		< 1 mm	1 - 5 mm

**Residual Soil**

Weathering (due to climate effects) and leaching of water-soluble materials in the rock are the geological processes in the formation of these soils.

The rate of rock decomposition is greater than the rate of erosion or transportation of weathering material and results in the accumulation of residual soil.

As the leaching action decreases with depth, there is a progressively lesser degree of rock weathering from the surface downwards, resulting in reduced soil formation, until one finally encounters unaltered rock.



Stages of formation of residual soil (*Source: McCarthy, 1982*)

Residual soil generally comprise a wide range of particle sizes, shapes, and composition.

In general, the rate of weathering is greater in warm, humid regions than in cold, dry regions.

Humid, warm regions are favorable to chemical weathering.

Also, because of the presence of vegetation, there is less possibility of transportation of the decomposed materials as sediments.

### **Transported Soil.**

Weathered materials have been moved from their original location to new locations by one or more of the transportation agencies, viz., water, glacier, wind, and gravity, and deposited to form transported soil.

Such deposits are further classified depending on the mode of transportation causing the deposit.

### **Water-transported Soil.**

Swift-running water is capable of moving a considerable volume of soil.

Soil may be transported in the form of suspended particles or by rolling and sliding along the bottom of the stream.

The size of the particle that can be in suspension is related to the square of the velocity of the flowing water.

Particles transported by water range in size from boulders to clay.

Coarser particles are dropped when a decrease in water velocity occurs as the stream or river deepens, widens, or changes direction.

Fine particles still remain in suspension and get deposited in quieter waters downstream.

This is a typical case of a stream moving downhill, passing over a valley, and ultimately reaching a large body of water.

Soils that are carried and deposited by rivers are called **alluvial deposits**.



River deltas are formed in this manner.

Soils carried by rivers, while entering a lake, deposit all the coarse particles because of a sudden decrease in velocity.



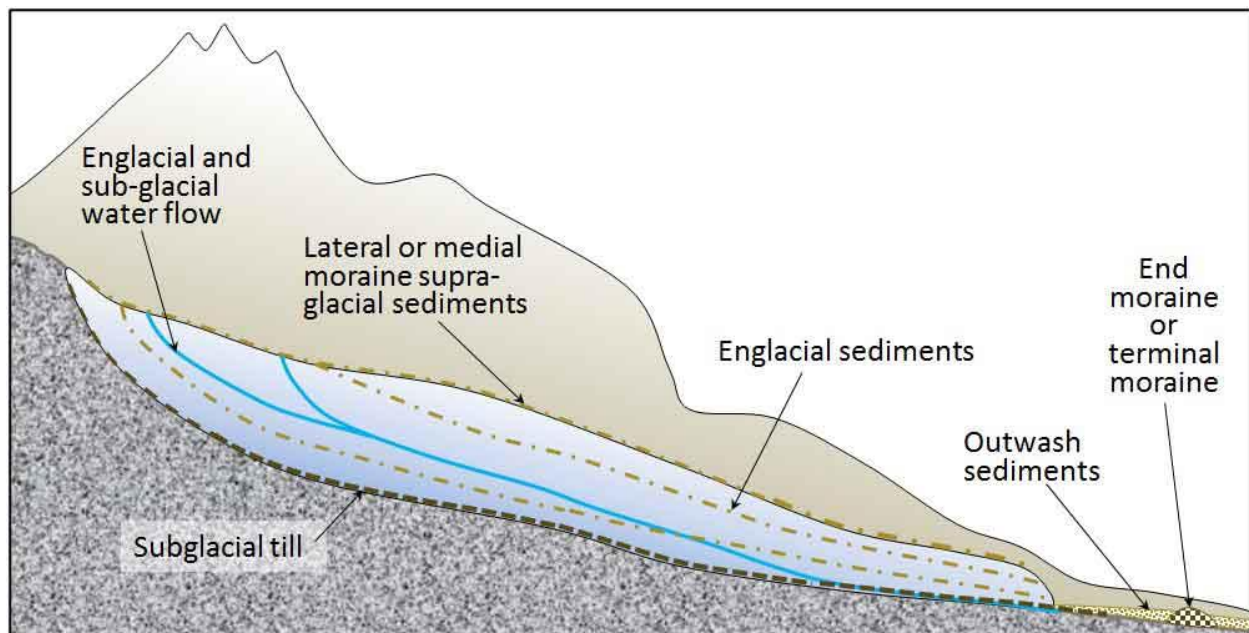
Such coarse soil deposits are called **lake deltas**.

But the fine-grained particles move to the center of the lake and settle when the water becomes quiet.

Alternate layers are formed with the season, and such lake deposits are called **lacustrine deposits**.

## Glacial Deposits.

Compaction and re-crystallization of snow lead to the formation of glaciers. Glacier growth and movement depend on the formation of ice. Glacial deposits form a very large group of transported soil. A glacier moves extremely slowly but deforms and scours the surface and the bedrock over which it passes. Melting of a glacier causes deposition of all the materials, and such a deposit is referred to as till. The land form or topographic surface after a glacier has receded is called a **ground moraine or till plain**.



## Wind-transported Soils.

Like water, wind can erode, transport, and deposit fine-grained soils. Soils carried by wind are subsequently deposited as **aeolian deposits**. Dunes are formed due to the accumulation of such wind-deposited sands. Dunes are a rather common occurrence in the desert areas of Africa, Asia, and the USA. Sands from dunes may be used to a limited extent for construction purposes.



### **Gravity Deposits.**

Gravity can transport materials only for a short distance. As the movement is limited, there is no appreciable change in the materials moved. Gravity deposits are termed **talus**.



They include the material at the base of cliff and landslide deposits. The talus material at the cliff is formed due to the disintegration and subsequent failure of the cliff face. These fragments are generally loose and porous.

### **Swamp and Marsh Deposits.**

In water-stagnated areas where the water table is fluctuating, and vegetational growth is possible, swamp and marsh deposits develop.



Soils transported and deposited under this environment are soft, high in organic content, and unpleasant in odor.

Accumulation of partially or fully decomposed aquatic plants in swamps or marshes is termed muck or peat.

Muck is a fully decomposed material, spongy, light in weight, highly compressible, and not suitable for construction purposes.

## **2. In aggregate investigation Material sourcing is referred to field investigation. Discuss Material sourcing in detail.**

**ANS:**

A good number of infrastructure projects are implemented in construction industries during the last decade and many more are still in pipeline. In the financial year 2017-18 approximately 12.7 million tons of aggregate are used by the construction industries. Local sources could supply only 11% of those aggregate and rest 89% are collected from foreign sources. Due to the wide variation of aggregate sources performance of concrete become unpredictable. Therefore, in the present



study influence of commonly used coarse aggregate characteristics for building sustainable infrastructure are investigated by evaluating the performance of concrete with various aggregate types. To evaluate performance, six mostly used coarse aggregate sources are selected for this study. A series of laboratory test are conducted to evaluate the ACV, TFV, LAA, EI, FI, specific gravity, water absorption and unit weight for all six aggregates. Additionally, chemical composition and petrographic properties are also explored. Keeping the gradation of aggregate constant, two types of concrete mix (w/c ratio 0.3 and 0.4) were prepared to cast concrete cylinders and beams by using six sources of coarse aggregate. Concrete properties including compressive, tensile and flexural strength are determined. The study finds that physical properties of aggregate generally influence the properties of concrete. However, the influence is significant in case of concrete requiring compressive strength higher than 50 MPa. The outcomes of the study will help the engineers to select appropriate sources of aggregate depending on concrete strength requirements.

Construction aggregate is a fundamental raw material for all countries. However, the testing and specification of aggregate is often overlooked or not considered. This has serious implications for the life and maintenance of buildings and infrastructure which can cost a lot of money in the future to repair or replace and at worst lead to structural failure and risk to human lives.

Geological materials have been used in construction since the dawn of time. This is still the case with construction raw materials accounting for the largest volumes of any known production process on the planet. Natural aggregate is the most ubiquitous construction material and is used in buildings, civil engineering projects and transport infrastructure such as roads, railways and airport runways.

The suitability of naturally occurring rock for the production of construction aggregate relies on its testing against national and international standards. Construction aggregate broadly comes in two main categories. Hard rock aggregate is typically sourced from igneous rocks such as granite, dolerite and gabbro, sedimentary rocks such as sandstone and limestone, and metamorphic rocks such as gneiss and marble. These are extracted in quarries by drilling, blasting and crushing. Sand and gravel aggregate is typically sourced from unconsolidated sediments of fluvial, lacustrine or marine origin. These are extracted in quarries by mechanical excavators. Both types of aggregate are washed and screened to create the required construction aggregate products.

The testing of aggregate not only ensures its suitability for different construction applications it is also the basis for consumer specifications and enables the ongoing assurance that it continues to meet the required properties.

To ensure that construction aggregates are fit for purpose and meet the requirements of the end-uses it is important to have an understanding of the geology of the resources, production processes, and standards and test methods used to evaluate their suitability. Construction aggregate is normally defined as being hard, granular materials which are suitable for use either on their own

or with the addition of cement, lime or a bituminous binder in construction. Important applications include concrete, mortar, road stone, asphalt, railway ballast, drainage courses and bulk fill. There are three main types: natural aggregate (from mineral sources with nothing more than physical processing, often referred to as 'primary aggregate'), manufactured aggregate (derived from Industrial processes as a by-product, often referred to as 'secondary aggregate') and recycled aggregate (recovered from material previously used in construction)

### **GEOLOGY OF AGGREGATE SOURCES:**

Any naturally occurring geological material can be used as construction aggregate as long as it satisfies the requirements of the end-use specification. Primary aggregates are produced from two main sources, 'crushed rock' and sand and gravel. Crushed rock aggregate is produced from hard, strong rock formations including igneous (andesite, basalt, diorite, dolerite, gabbro, granite, rhyolite, tuff), metamorphic (hornfels, gneiss, quartzite, schist) and sedimentary (sandstone, limestone) rock.

Most limestones and dolomites are hard and durable and useful for aggregate. The quality of the limestone resources and their ease and economy of working may be affected by a number of geological factors such as waste content, dolomitisation and degree of faulting and folding. The suitability of sandstone for aggregate use depends on its strength, porosity and durability. Many types of sandstone are too porous and weak to be used other than as sources of constructional fill. In general, older more indurated sandstones exhibit higher strengths and are suitable for more demanding aggregate uses. Igneous rocks tend to produce strong aggregates with a degree of skid resistance and are hence suitable for many road surfacing applications, as well as for use in the lower parts of the road pavement. The high strength and attrition resistance of certain igneous rocks results in their use as railway ballast. Sand and gravel deposits are accumulations of the more durable rock fragments and mineral grains, which have been derived from the weathering and erosion of hard rocks mainly by glacial and river action, but also by wind.

### **PRODUCTION OF CONSTRUCTION AGGREGATE SOURCE:**

Primary aggregates are produced from two main types of quarrying operation, crushed rock and sand and gravel. They are typically extracted by surface quarrying with underground mining of aggregates relatively rare. Any overburden is removed using a combination of hydraulic excavators, ripping and blasting. Crushed rock aggregate is produced from quarries that are much larger and deeper than sand and gravel pits. Crushed rock aggregate is normally extracted using blasting whereas sand and gravel is usually extracted by front end loaders, bull dozers with rippers or self-elevating scrapers.

Production of crushed rock aggregate involves screening (scalping) to remove fines and waste material followed by crushing and screening to produce material with specified size grades. Crushing is carried out to reduce the size of the excavated material from large blocks (up to a metre across) to a size finer than 20 to 50 mm. Production of sand and gravel involves washing and scrubbing to remove clay, separation of the sand fraction by screening, grading of the gravel, sand

classification and dewatering, and crushing of any oversize gravel to produce a saleable product. Washing removes silt and clay (material finer than 0.063mm), which is present either as surface coatings or as clay-bound agglomerates that need to be broken down.

## **STANDARDS AND TEST METHODS**

The testing of construction aggregate is carried out to international standards. The quality of quarry products used in the UK is controlled by the European Standards for Aggregates for concrete, mortar, asphalt and road construction. The key parameters for aggregates are particle size and shape, physical and mechanical properties and durability. The laboratory evaluation of construction aggregate ranges from simple and low cost to sophisticated and expensive testing. A useful manual for the testing of construction materials, including aggregate, was published by the British Geological Survey in 1994 (Harrison & Bloodworth, 1994).

## **CONCLUSIONS**

To ensure that construction aggregates are fit for purpose and meet end-use requirements it is important to have an understanding of the geology of the resources, the production processes, and the standards and test methods used to evaluate their suitability.

Primary construction aggregate can be produced from any source of rock as long as it meets the specification of the end-user. Production of construction aggregate is a well-known process of extraction, size reduction and screening to produce graded products.

The testing of construction aggregate is carried out to international standards. The particle size distribution ('grading') is the key defining characteristic of construction aggregate and is often used as a product classification. Particle shape, density, strength, mechanical wear and chemical soundness are important criteria for evaluating the suitability of aggregate for use in construction.

**Q.NO (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's bases types and discuss the water bound Macadam and wet Mixing macadam in detail, also elaborate the difference between water bound Macadam and wet Mixing Macadam?**

**ANS:**

John Loudon McAdam was a pioneering Scottish Engineer who single-handedly changed the way roads were built around the world. His innovative shallow camber, crushed compacted stone layered roads would become the standard for road building the world over.

His innovation was the biggest advancement in road building since the Roman Empire. If you are lucky you might still see some existing ones around the world today. The advent of motor vehicles has meant many of the original roads have now been resurfaced or replaced with a tar coating or Asphalt.

Before McAdam's roads, large "flat" rocks were laid together to approximate a level surface. Not only did John Loudon McAdam's design result in a smoother surface and carriage ride, but it was cheaper to build and lasted longer. This "new" roadway surface and construction process have since been immortalized with McAdam's name, though with the Americanised spelling MacAdam or macadam.

At the time, roads were either dirt paths susceptible to rain and mud, or very expensive stone affairs that frequently broke down not long after whatever event precipitated their construction.

McAdam was convinced that massive stone slabs would not be needed to carry the weight of passing carriages, as long as the road was kept dry. McAdam came up with the idea of raising roadbeds to ensure adequate drainage. He then designed these roadbeds using broken stones laid in symmetrical, tight patterns and covered with small stones to create a hard surface. McAdam discovered that the best stone or gravel for road surfacing had to be broken or crushed, and then graded to a constant size of chippings. McAdam's design, called "MacAdam roads" and then simply "macadam roads," represented a revolutionary advancement in road construction at the time.

The water-bound macadam roads were the forerunners of the tar- and bitumen-based binding that was to become tarmac. The word tarmac was shortened to the now-familiar name: tarmac. The first tarmac road to be laid was in Paris in 1854, a precursor to today's asphalt roads.

By making roads both significantly cheaper and more durable, MacAdam triggered an explosion in municipal connective tissue, with roads sprawling out across the countryside. Fittingly for an inventor who made his fortune in the Revolutionary War—and whose life's work united so many—one of the earliest macadam roads in America was used to bring together the negotiating parties for the surrender treaty at the end of the Civil War. These reliable roads would be crucial in America once the automobile revolution began in the early 20th century.

WBM road means water bound macadam road. The wearing surface of WBM road consist of clean and crushed aggregates which are mechanically interlocked by rolling operation. The material is bound with filler material (which are also called as screenings) and water, laid on prepared base course.

### **Materials Required For WBM Road Construction.**

There are mainly 3 types of materials which are used in the construction of WBM road.

- Course Aggregate
- Screenings (filler material)
- Binding Material



**a) Course Aggregate:**

Unlike other course aggregates it consist of mixture of hard and durable crushed aggregates and broken stones. The aggregates used for each layer of the WBM road construction should be properly graded. Below table shows the standard gradation of the aggregates that can be adopted.

Grading number	Size range (mm)	Sieve size (mm)	Percentage by weight passing the sieve
1.	90 to 40	100	100
		80	65 – 85
		63	25 – 60
		40	0 – 15
		20	0 – 5
2.	63 to 40	80	100
		63	90 – 100
		50	35 – 70
		40	0 – 15
		20	0 – 5
3.	50 to 20	63	100
		50	95 – 100
		40	35 – 70
		20	0 – 10
		10	0 – 5

The course aggregates used in the construction of WBM road should hold the following properties.

- It should be hard and durable.
- The course aggregate should be free from flaky and elongated particles.
- The course aggregate should be in acceptable shape and size.

Physical requirements of course aggregates required for construction of WBM road in terms of test values for different pavement layers is given below.

Sr. no.	Property	Requirements for pavement layer (maximum percent)		
		Sub-base	Base course	Surfalling course
1.	Los Angeles abrasion value	60	50	40
2.	Aggregate impact value	50	40	30
3.	Flakiness index	—	15	15

### b) Screenings:

The material which is used up to fill up the excess voids present in the compacted layer of course aggregate is called as screenings.

Screening material is nothing but the aggregates of smaller size than the course aggregates. Below table shows the standard grading required of screening for construction of WBM road

Grading classification	Size of screenings (mm)	Sieve size (mm)	Percentage by weight passing the sieve
A	12.5	12.5	100
		10.0	90-100
		4.75	10-30
		0.15	0-8
B	10.0	10.00	100
		4.75	85-100
		0.15	10-30

In order to reduce the overall cost of WBM road, IRC has recommended to use non-plastic materials such as kankar nodules, murum or gravel.

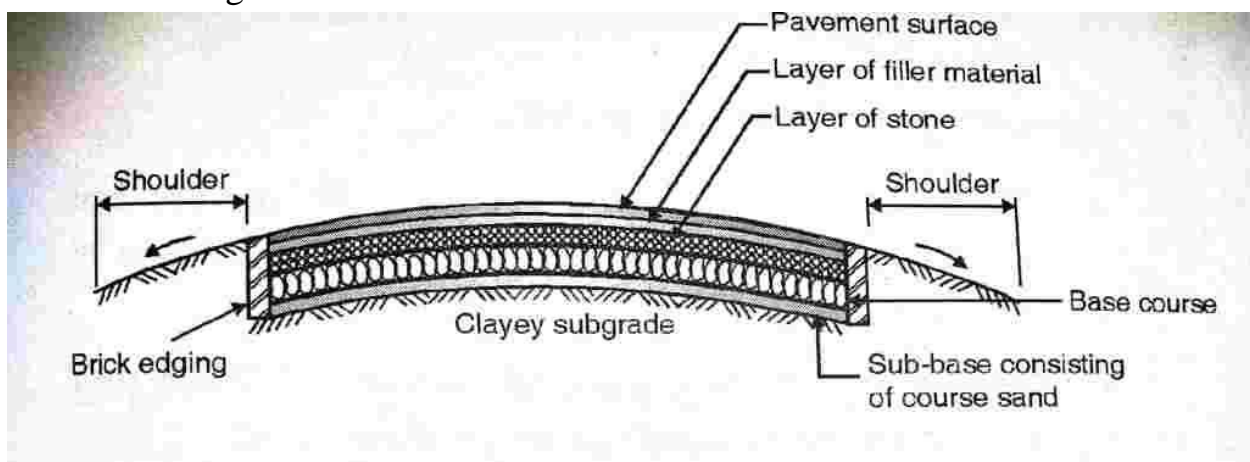
### c) Binding Material:

Binding material which is going to be used for the construction of WBM road should be properly approved by engineer and it should have plasticity index value less than 6.

Generally the binding materials are not required if screenings used for the construction of WBM road is murum or gravel as they have crushable property.

### Construction Procedure of WBM Road.

As shown in figure below:



### 1) Preparation of Foundation for WBM Road :

The subgrade or base course is properly prepared for the required grade and camber of WBM road. The potholes and the depressions on the surface of the road are properly filled up and compacted.

## **2) Provision for Lateral Confinement:**

Before laying of aggregates the shoulders having thickness as that of compacted WBM layer should be constructed. They should be constructed with proper quality of murum or earth.

The main purpose of constructing shoulders is that the road surface to be constructed retain in between them and it becomes easy for further laying of course aggregates.

## **3) Spreading of Course Aggregates:**

The course aggregates are uniformly spread on the prepared base after the construction of the shoulders. Total number of layers and thickness of WBM road depends upon the details of design pavement.

In general for ordinary roads, single layer of compacted thickness 75 mm may be sufficient. For special roads, 2 layers of 150 mm each compacted thickness may be provided. If the course aggregate is used of number 1 grade as shown in above course aggregate grading table then it is compacted to thickness of 100 mm.

## **4) Rolling Operation:**

Rolling operation is carried out for compacting the course aggregates. Generally it is done with the help of 3- wheeled power rollers weighing 6-10 tonnes or with the help of vibratory rollers. Skilled operators should be used for driving the rollers as the fault rolling operations causes formation of corrugations, unequal finish of road surface, wearing of road in few months of construction.

## **5) Application of Screenings:**

After the rolling operation is properly finished screenings is applied to properly fill the voids remained after the compaction of aggregates. The screening may be applied in 3 or more layers as per the site conditions.

After uniformly spreading of screening compaction is carried out with the help of dry rollers for each layer of screenings. After compaction brooming of the each layer should be properly done to remove the uncompacted screening material.

## **6) Sprinkling of Water and Grouting:**

After the application of screening the road surface is properly sprinkled with plenty of water. After the water is sprinkled brooming is done to sweep the wet screening properly into the voids.

Rolling operation is further carried out for proper compaction. If the voids are still visible then additional screenings can also be applied and properly compacted.

### **7) Application of Binding Material:**

Same procedure is used for the application of binding material as that of screenings. Here after each layer water is sprinkled and rolling operation is carried out.

### **8) Setting and Drying of Surface:**

After the final rolling operation the road is allowed to cure or set over-night. The next day if the depressions or voids are visible then again sufficient amount of screenings or binding materials can be used and compaction is done.

### **9) Preparation of Shoulders:**

At the time of Curing of road, shoulders are constructed alongside by filling earth to specified cross slope. They are properly compacted.

### **10) Open for Traffic:**

After proper drying and without any depressions, the road is then made upon for traffic. For few days the traffic should be well distributed over full width of road by placing obstacles longitudinally in the form of drums, barricade etc.

### **Maintenance of WBM Road:**

- Whenever the potholes and ruts occur on the road by the period of time, they should be filled with adequate materials and proper compacting should be done.
- The corrugations occurred on the roads should be removed by means of dragging. If not could make the condition worse.
- Broken materials of the roads should be properly restored by fresh materials.
- The surface of the road should be renewed in 2-5 years or based according to the traffic volume.
- The loose aggregates starts coming on the top of the surface of the road, they should be removed and levelled surface should be added by fresh binding material and it should be properly watered and compacted.

### **WMM (Wet mix macadam) road construction:**

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(Plasticity Index) not less than 6%*) are premixed in a batching plant or in a mixing machine. Then they are brought to the site for overlaying and compaction.

The PI(plasticity Index) of the binding material is kept low because it should be a sound and non plastic material. If the plasticity index is more then there are the chances of the swelling and more water retention properties. So this value should be kept in mind.

### **Comparison of the WBM and WMM road construction:**

Although the cost of construction of the WMM is said to be more than that of the WBM sub-base and bases but the advantages given below will compensate for that. Here are the points of difference:

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

### **Q.N0 (04):**

**1. Discuss in detail the Bituminous Materials-Manufacturing?**

**2. Bituminous Material-Chemistry is referred to chemical composition of bitumen. Elaborate in detail.**

ANS:

1. Materials that are bound together with bitumen are called bituminous materials. The use of bituminous materials were initially limited to road construction. Now the applications

have spread over the area of roof construction, for industrial purposes, carpet tiles, and paints and as a special coating for waterproofing.

## **History of Bituminous Materials**

Before the era of bitumen, tar was used as the binder material for bituminous materials.

After the 20th century, the new types of vehicles with pneumatic tires came into its existence in the UK. The time was when tar was used in road construction in larger areas.

The road was constructed using water bound and graded aggregates as per the principles that were developed by Macadam. Macadam roads produced large amount of dust due to the action of the pneumatic tires and the speed of the vehicles moving. This led to binding the surface of the road with this tar.

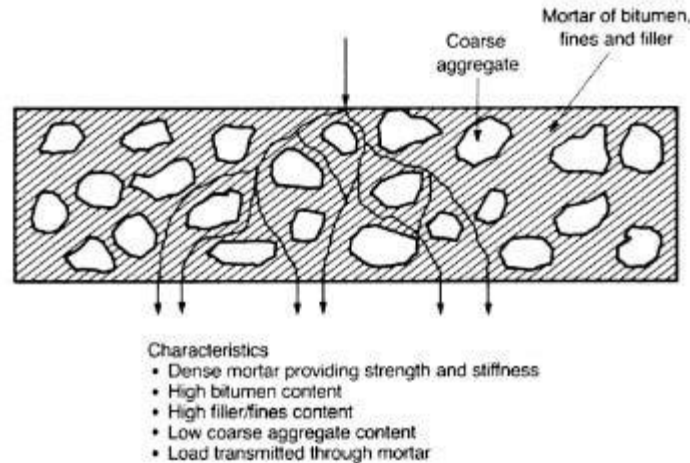
Tar would act as a dressing to coat the surface. It is well suited for the purpose as it can be made semi-fluid and sprayed accordingly. This on cooling will get stiffened and protects the road from water attacks.

The history of bitumen came from the refinery bitumen that was used in Mexican oil fields in the UK, around 1913. But in 1920, the Shell Haven refinery was the one who has a role in bringing the bitumen into road construction.

## **Types of Bitumen**

To go with a wide variety of circumstances, a wide variety of bituminous mixtures were developed. The main variation is brought by the change in the bitumen content, the bitumen grade, the aggregate type used and the size of the aggregates.

Traditionally in UK, the bitumen is categorized into two. The first one is “**asphalt**” and the second one is “**macadam**“. In North America, the asphalt is called as bitumen itself. Asphalts are bitumen mixture whose strength and stiffness is gained through the mortar property. While in the case of macadam, the strength is dependent on the aggregates that are used in the mix (i.e. grading of the aggregates). For each case mentioned, the property of the bitumen change. It is found that the asphalt properties are more governed by the bitumen properties than in the case of macadam.



## Constituents of Bituminous Materials

Graded aggregate and bitumen are the compositions of bituminous material. There is a small proportion of air present in the same, which make the bituminous material a three-phase material.

The whole property of the bituminous material is highly dependent on the individual properties of each phase and their respective mix proportions. The two solid phases i.e. the bitumen and the aggregate are different in nature. The aggregate is stiff and hard in nature. The bitumen is flexible and vary under temperature as they are soft. So, the whole performance of the material is greatly influenced by the bitumen proportion in the whole mix. The supply of bitumen can be carried out in a variety ways based on whether the demand is for laying or is to facilitate some other performance. When the quality and the performance of the bituminous material is concerned, the aggregate constituent quality is also a primary factor. We can either go for continuously graded aggregates, which are called as asphalt concrete (Before in the UK, it was called as macadam as discussed in before sections) or else the aggregates used can be gap graded, which are known as hot rolled asphalts or stone asphalt (This was known before as asphalts in the UK).

The filler is the fine component of the aggregates that would pass through 63 microns. The graded aggregate mix might contain some quantity of fillers. But when it is not adequate, extra filler either in the form of Portland cement, or hydrated lime, or limestone dust are used.

## Sources of Bitumen

The bitumen has mainly two sources, they are:

- Natural Bitumen
- Refinery Bitumen



## **Natural Bitumen or Natural Asphalts**

The bitumen is obtained from petroleum naturally with the help of geological forces. They are found to be intimately connected with the mineral aggregates. They are found deposited at bitumen impregnated rocks and bituminous sands that have only a few bitumen in percentage.

The Val de Travers region of Switzerland and the 'tar sand' area of North America gain notable range of bitumen deposits. The rock asphalts gain bitumen in 10%, in the form of limestone or sandstone impregnated bitumen.

Lake asphalt composes of bitumen 'lake' that is found as dispersed finely divided mineral matter in bitumen. The roads in the UK make use of bitumen from the deposits of before mentioned lake deposits found in the Trinidad Lake.

The asphalt found from the lake are refined to a partial state by heating it to a temperature of 160°C. This is done in open skill to remove out the excess water. Later the material is filtered. This is then barreled and transported.

It is hard to use the material directly on the roads as it consists of 55% of bitumen, mineral matter of 35% and 10% of organic matter. This even after treatment is blended with refinery bitumen before use.

## **Refinery Bitumen**

This bitumen is the residual material that is left behind after the crude oil fractional distillation process. The crudes from different countries vary based on their respective bitumen content.

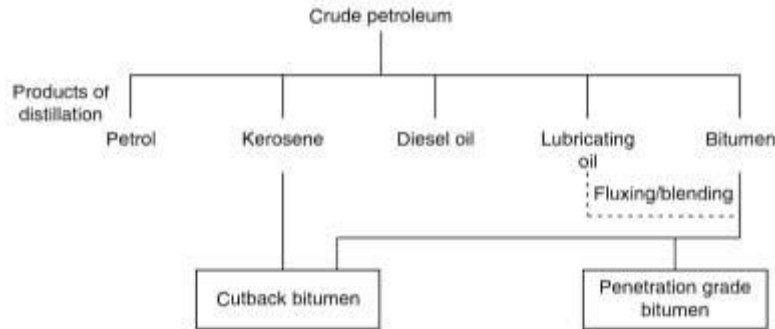
It is found that crudes from Middle East and the North Sea have to undergo further process even after distillation to get final bitumen. These sources have a very small bitumen content.

But crude from the Caribbean and around countries give the higher content of bitumen that can be extracted with great ease.

## **Manufacture of Bitumen**

The manufacture of bitumen is a lengthy process which is represented briefly in the below flowchart. The bitumen is a residual material. The final bitumen property will depend upon the extent of extraction, the viscosity, and the distillation process.

The present refinery plant has the capability to extract bitumen more precisely as the required viscosity and consistency.



## Structure of Bitumen

The hydrocarbons and its derivatives formed in a complex colloidal system will compose to form the bitumen structure.

Bitumen is a colloidal system that dissolves in trichloroethylene. This solvent is used to determine the constituents that are present in the bitumen.

The bitumen constituents can be subdivided as follows:

- **Asphaltenes:** These are found to be insoluble in light aliphatic hydrocarbon solvents
- **Maltenes:** These are soluble in n-heptane

The colloidal system of bitumen is a system with solid particles of Asphaltenes, that together form a cluster of molecules or these can be micelles; a continuum of Maltenes.

Based on the micelles dispersion, the bitumen can either exist in the form of a sol or in the form of a gel. Sol is formed when there is complete dispersal. The gel is formed when the micelles undergo flocculation to become flakes.

The bitumen take a gel character, when it has a higher quantity of saturated oil of molecular weight less. That bitumen with aromatic oils show sol character. This is one with more Asphaltenes.

## Influence of Bitumen Constituents in the Material Properties

The individual fractions that form a bitumen surely have some contribution towards the properties of the bitumen material.

- The Asphaltenes is the fraction that shapes body for the material.
- The resin in the bitumen contributes to adhesiveness and ductility of the material.
- The viscosity and the rheology of the material are taken care by the oils present in the bitumen material.
- The stiffness of the material is governed by the sulfur that is present in significant amounts mainly in high molecular weighed fractions.

- The presence of a certain complex of oxygen will affect the acidity of the bitumen. The acidity of the bitumen is a factor whose determination will help in knowing the adhering capability of the bitumen with the aggregate particles.

## 2. CHEMISTRY OF BITUMEN

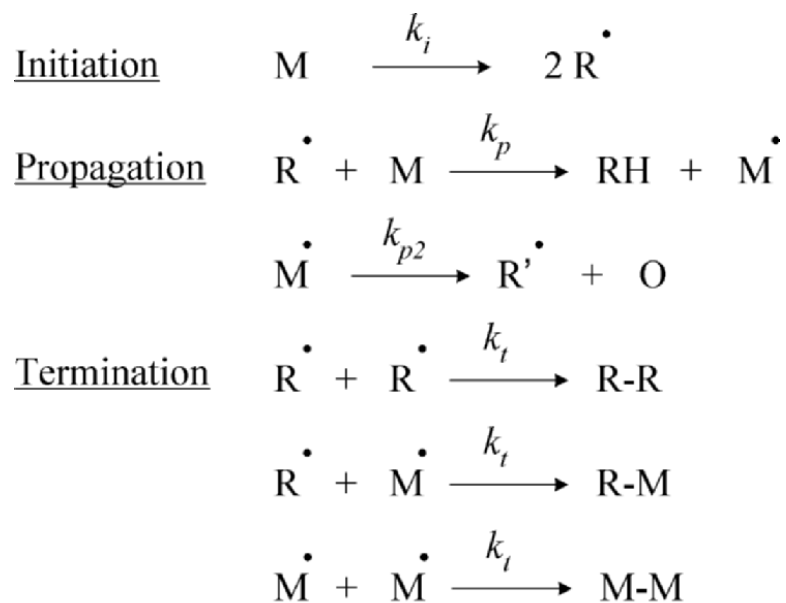
It is well documented that the conversion of resid to lighter products, whether or not in the presence of hydrogen and/or a catalyst, is largely thermally driven.<sup>91,96</sup> The hypothetical molecular structure of bitumen and consists mostly of C-C, C-H, C=C (in the aromatic rings) and to a lesser degree C-S, C-O, C-N, S-H, and O-H. The metal impurities are mostly attached to nitrogen in porphyrin and non-porphyrin structures. Since most of the chemical reactions during bitumen upgrading are thermally driven, there is no selectivity in bond cleavage. Under non-selective thermal reaction conditions, the weakest bonds break first. The bond dissociation energies of the most common bonds are shown in Table 7. According to this table, C-S (sulphide) has the lowest bond dissociation energy and will break first at a relatively moderate severity. At low to moderate severities in typical visbreaking conditions (380°C-410°C), 10-20wt% pitch conversion can be achieved without major coke formation. Under these conditions, the changes to the molecular structure of bitumen are relatively small since most of the CC bonds remain intact. A significant MW reduction must take place before bitumen molecules are converted to distillates. The following chemical reactions are known to occur during this transformation to distillates:

- homolytic cleavage of C-C bonds;
- side chain fragmentation (cleavage);
- ring growth;
- hydrogen shuttling;
- hydrogenation of aromatics/dehydrogenation of cycloparaffins;
- ring opening;
- heteroatom and metals removal.

*Table 7. Bond dissociation energies*

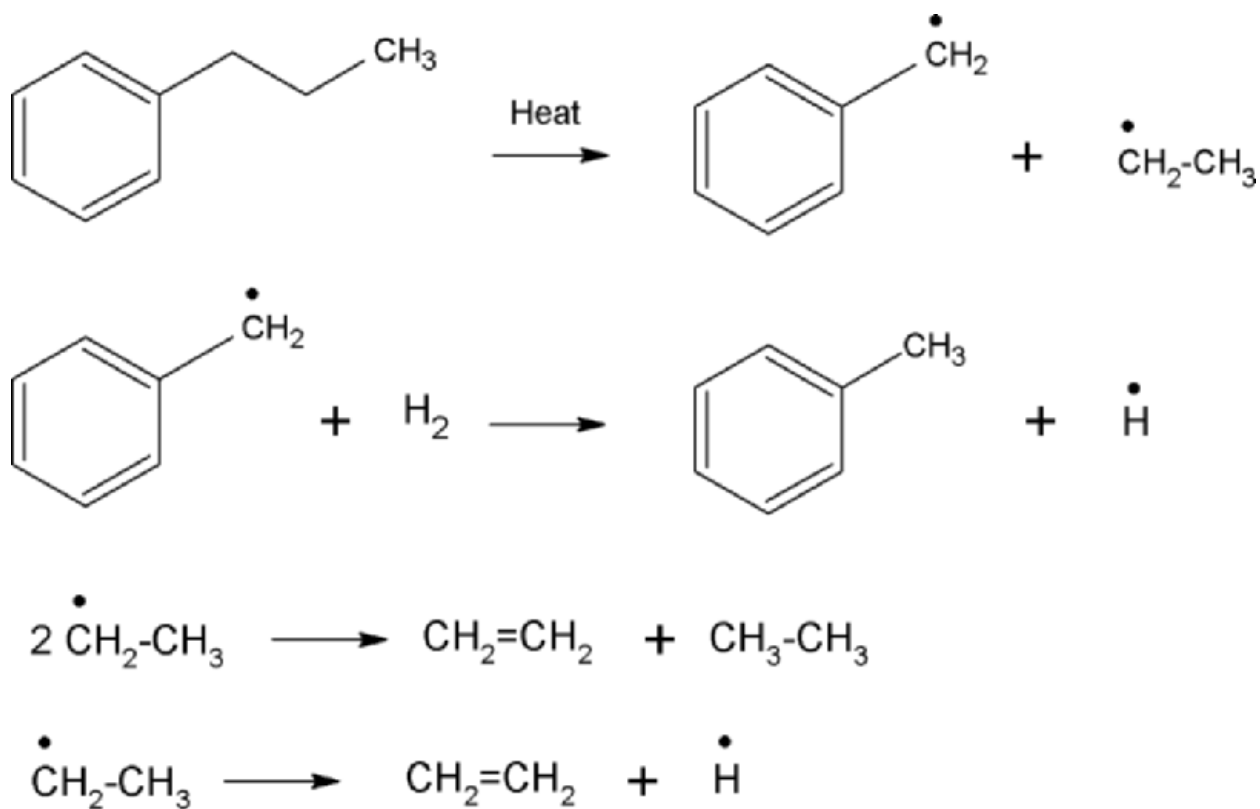
Bonds	Kcal/mole
H-H	103
C-C	83-85
C-H	96-99
N-H	93
S-H	82
O-H	110-111
C=C	146-151
C-N	69-75
C-S	66
Ar-CH <sub>2</sub> -CH <sub>2</sub> -Ar	71
Ar-H	111

The most important reaction in upgrading that leads to a significant molecular weight reduction and produces distillate fractions is probably cleavage of the C-C bonds. The bond dissociation energies for C-C bond cleavage can vary depending on the type of molecules. It has been suggested that the reaction mechanism for the cleavage of C-C bonds during upgrading is free radical in nature, and proceeds through a free radical chain mechanism.<sup>97</sup> The reaction kinetic (homolysis) of a hypothetical molecule (M) proceeding through a free radical chain mechanism is shown in Figure 2. The overall reaction rate is related to the rate of the initiation step. If one assumes that the initiation step involves the homolytic cleavage of the C-C bond, then one can calculate the half-life ( $t_{1/2}$ ) for the reaction. For example, the  $t_{1/2}$  for the cleavage of the C-C bond in PhCH<sub>2</sub>-CH(CH<sub>3</sub>)<sub>2</sub> is 2.4 hours at 540°C and 46.3 days at 440°C. The fact that thermal hydrocracking of bitumen's and heavy oils can be accomplished at a much lower temperature and a relatively high conversion indicates that the cleavage of C-C bonds is not a rate-determining step. The initiation step may involve cleavage of the C-S bond, or the breakage of the C-C bonds must be accomplished by a mechanism other than homolytic cleavage.



$$\text{Rate} = k_p \left( \frac{k_i}{2k_t} \right)^{1/2} [M]^{2/3}$$

Figure 2. Radical chain mechanism for homolysis of a hypothetical molecule M



An alternative reaction mechanism to unfavorable homolytic C-C bond cleavage is the electron transfer mechanism shown in Figure 6. In this reaction, an electron is transferred from an aromatic core of a molecule to a metal (Ni, V, or Fe) to produce a radical cation. An electron transfer mechanism has been proposed for the reaction of the model in the presence of carbon black, and with tetralin as the solvent.<sup>101</sup> In this model, selective C-C bond cleavage (at the position of poly condensed aromatic moiety) is achieved at 320°C in the presence of carbon black where no thermal reaction is known to occur. The authors rationalized their observations based on the aforementioned electron transfer mechanism. The selective C-C bond cleavage occurs by an electron transfer from the condensed aromatic ring to the carbon black surface, which has become positively charged at a reaction temperature of 320°C. This reaction mechanism has been recently disputed by Penn et al.<sup>102</sup> They argue the C-C bond cleavage is caused by a radical hydrogen transfer mechanism in which the H atom adds to the ipso position of the polyaromatic moiety. It is also possible that this electron transfer may occur during bitumen and heavy oil upgrading since there is a significant concentration of transition metals capable of accepting electrons from highly condensed poly aromatics.

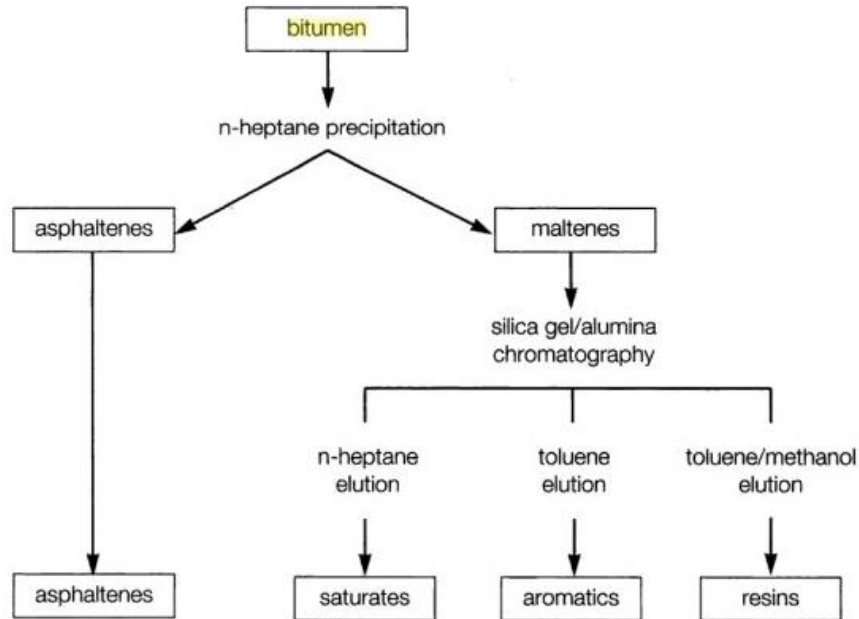
## **Bitumen Components- Chemical composition of bitumen**

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. A typical elemental analysis is given in Table 1. 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.

**Table 1. Elemental analysis of bitumens from various sources<sup>(27)</sup>**

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

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.



**Figure 4.1 — Schematic for the separation of chemical constituents in bitumen**

### **Bitumen Components- Chemical characterization of bitumen**

Bitumen is a viscoelastic material; therefore chemical polarity is an important property to measure. The most polar components create structural components which give bitumen stiffness (modulus) properties. Whereas the least polar components give asphalt its flexibility and low-temperature properties, the intermediate polarity components in bitumen compatibilized the least and most polar components. Since bitumen contains a continuous range of molecules it is impractical to analyze each individual compound. Common practice is, therefore, to divide bitumen into four broad, increasingly polar fractions: saturates, aromatics, resins, and asphaltenes (SARA). The asphaltenes are usually separated using solvent precipitation while the three other fractions are defined by using chromatography. There are several standard methods available for separation of bitumen into these four fractions and the naming of the fractions, which is not descriptive of the chemical composition, which may vary.