Pavement Materials
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Lecture: 11
Introduction to Mineral Aggregates: Origin and Types

Hello everyone, today, we are going to start a new module, which is a module, where we will be discussing about the mineral aggregate particles. So, let us start with the first lecture of this particular module.

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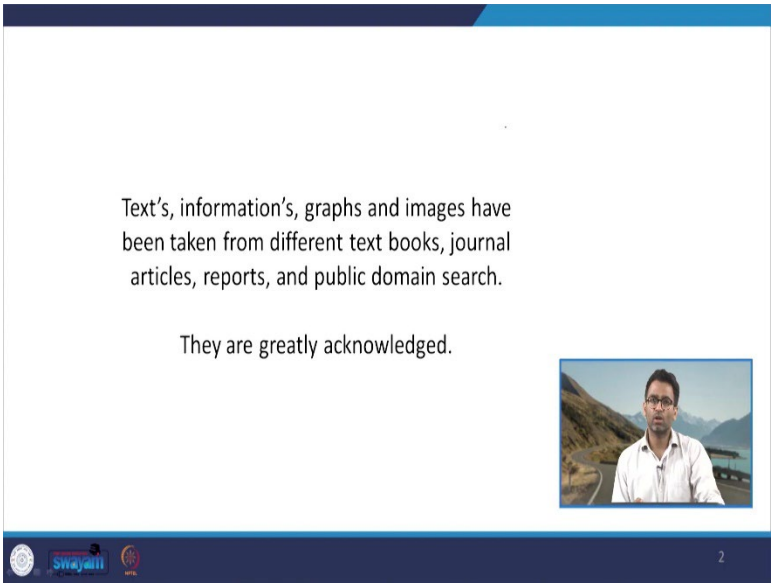

Before we move forward, I wish to inform that various text's, information's, graphs and images that have been used in this presentation have been taken from different textbooks, journal articles, reports, CODAL provisions, and also general public domain search and they are greatly acknowledged in this particular module. Let us see what topics are we going to cover?

Today, we will start our discussion with the origin and types of mineral aggregates. Further, we will discuss about the production process of these mineral aggregates and we will discuss about the storage procedure of the mineral aggregates. We will discuss later about the classification system mostly based on the size of the aggregate and we will spend some time discussing about an important property not specifically of aggregate, but the composite or the mixture of aggregates that is aggregate gradation.

We will also discuss in brief about the mineralogical aspects of mineral aggregate particles and how these mineralogical aspects are related to the performance of mixtures such as hot mix asphalt specifically. We will also discuss about an important property which is not very well defined in the literature that is aggregate shape and the texture of the aggregate.

And we will briefly discuss about the importance of these shape parameters or surface parameters, which is related to the performance of the final mix or the final structure. And finally, we will discuss about various properties, various physical properties specifically about the aggregates and we will look at the test methods that are used to quantify these properties. With this let us start discussing about the Origin and Types of the mineral aggregate particles.

So, today's lecture is specifically focused to understand the mineral aggregate particles, let us get accustomed to this material. So, that whenever in future we refer to the aggregate particles, we can always think about this particular discussion, which we will have today and try to relate what we are discussing today with those parameters or with those properties, which we will be referring to in the near future.

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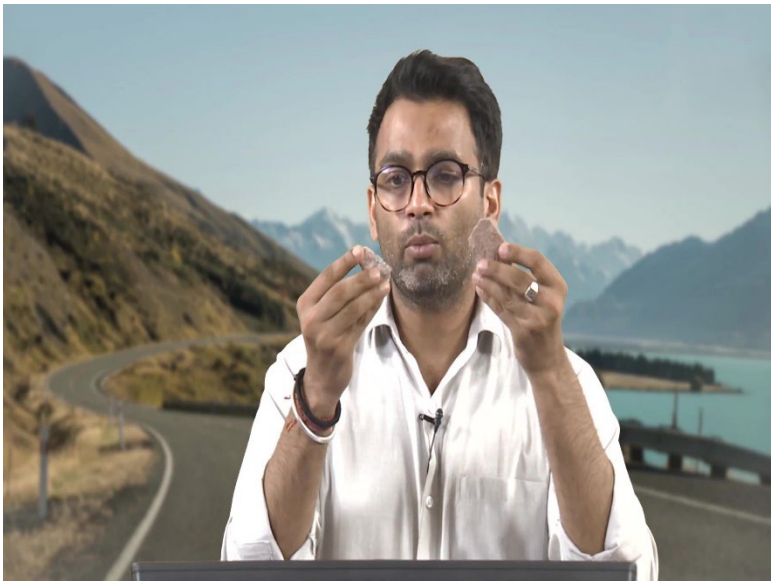
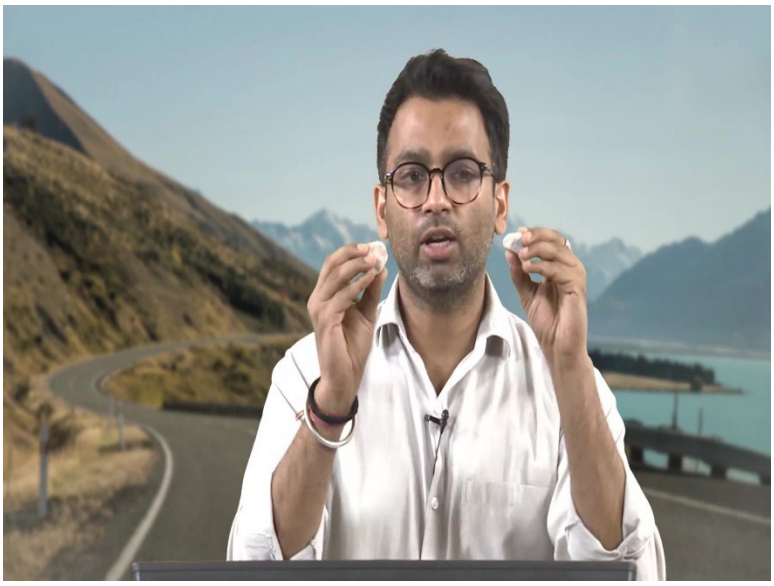
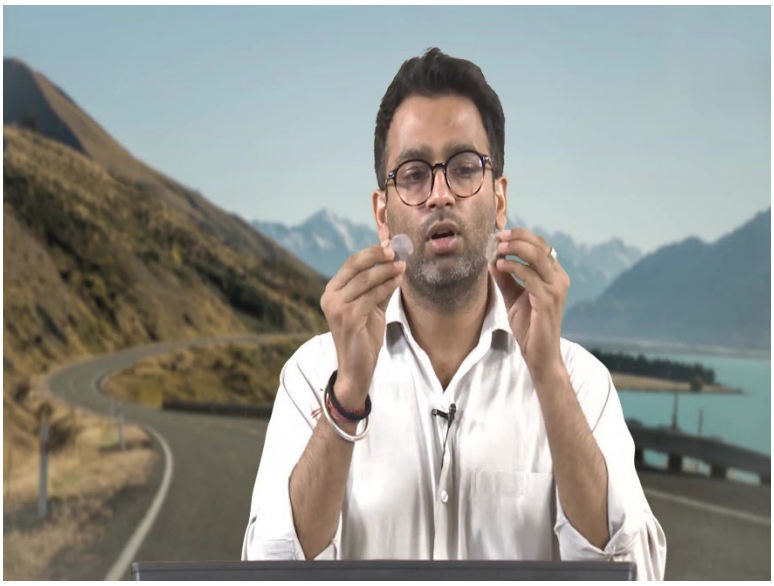
Origin and Types







Before even I start discussing about the aggregates, let me just give you a visual idea or a visual experience about the aggregate particles. So, right now, I have a small aggregate particle in my hand and in fact, today I have several aggregate particles they are I will tell you that how they differ from each other, which is very clear when I am holding them in my hand now. So, you can see I have more aggregate particles here, I have these aggregate particles, which you can see. Then I have a bigger aggregate particle here. And I also have again further smaller particles here.

So, why I am showing you these aggregate particles now, is to understand visually that we can have various types of aggregate particles. Now, these aggregate particles which I have just showed, they differ from each other in various forms and therefore, their use in the construction will also have variable effect on the performance. So, before beginning to discuss the technical aspects just by looking at the aggregate particles, we can try to figure out that what are these attributes which make them unique in nature or which makes then relatively different from each other.

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So, one attribute is the color of the aggregate particle. So, now, I am just talking like a layman to understand what I am seeing and to infer or to come up with some idea about my visual inspection. So, I have an aggregate particle here of the same size or probably a little smaller size, I have another aggregate particle.

So, if just by visually I want to analyze these particles, one thing which I could say that they differ in color from each other, this gives us some indication that if they differ from each other, which means their sources must be different, which means that their mineralogical composition or the chemistry also must be different. So, this is something which differentiates between these two aggregate particles, which I have just shown.

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Well, if I try to see more such aggregate particles, one obvious difference will be in size, that aggregate particles can be of different sizes, then, in addition to the color, the angularity or the shape of these aggregate particles also differ from each other. For example, if you see here I have a smaller aggregate particle which is more of rounded in nature, here I have a bigger aggregate particle which is more of crushed in nature, there are other shape attributes for example, we can have a flat aggregate here and then we can have a more angular aggregate also. So, of course, shape is one of the parameter again just by touching the aggregate by looking at it I can differentiate between various aggregate particle that shape is also one of that attribute.

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Further, which I will not be able to explain visually, I mean by looking visually is the surface texture or the smoothness. So, if you hold these aggregates in hand, and if you try to just feel the surface, you will see that these aggregate particles also have very distinct surface characteristics in terms of smoothness.

So, an aggregate particle can be rough textured, or the surface will be more rough in nature, like a sandpaper type, it can also be very smooth in nature. So, again, surface texture of the aggregate particles will also be different from each other. Now, something which of course, by visualizing or just by filling the surface is not obvious is what will be the strength of these aggregates?

Now, since these aggregates must have come from different sources, which means that when I put a load in these aggregates, they will have a different failure point. So, this we will not be able to understand by visualizing or by touching the aggregate or by filling the surface of the aggregate and of course, later we will see that there are tests available, which can help us to quantify even the strength parameters of the aggregate particles, let us start this particular presentation.

So, the first question is why are we studying or trying to study the mineral aggregates here? Since, we are talking about pavement materials, in pavement, we have broadly concrete pavement and we have flexible pavement. So, in the entire pavement structure, we use aggregates in different layers.

So, if you talk about the flexible pavement system from beneath where the soil or the subgrade starts, as we keep moving up, we will have aggregate particles of different sizes, different shapes and different strength requirements within the cross section, if we talk about asphalt mixture, which is the most important component of the flexible pavement system.

So, the asphalt mixture itself comprises of about 80 to 85 percent by a volume of mineral aggregate particles. So, therefore, the response of this mixture to any given loading condition will also be a function of the properties of these aggregate particles. On the other hand, in concrete pavement the concrete comprises of coarse aggregate particles, we have fine aggregate particles, we have cement, we have water and we can also have admixtures.

So, here also a considerable amount of volume more than 60 percent of the volume of the concrete comprises of aggregate particles. So, therefore, it is important for us to learn or to understand about the properties about the behavior of the aggregate particles. So, that, when we are constructing when we are doing the design, we can choose or we can make an appropriate choice of the aggregate particles which should be suited for the purpose for which I am trying to design or construct the pavement.

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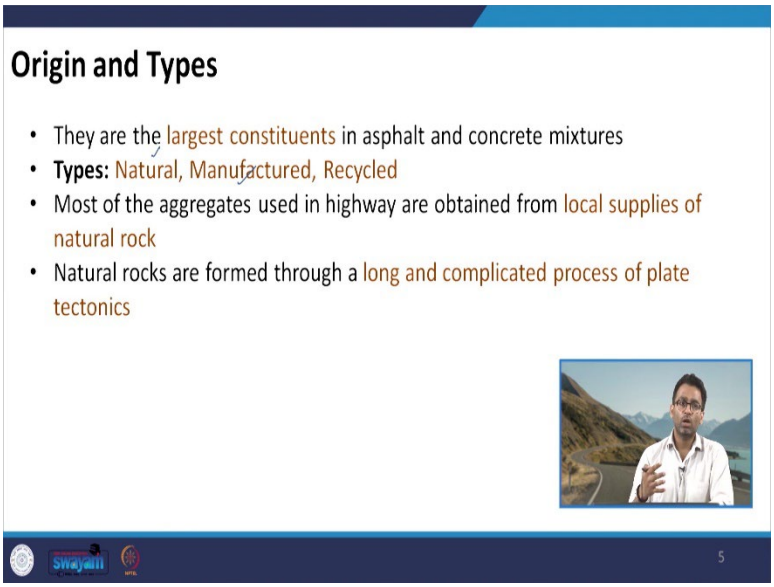

Talking about the types of aggregate particles there are various types of aggregate particles which can be present for example, if we try to classify it with respect to the source we can have natural aggregate particles or natural aggregates, let us say so, natural aggregates they are obtained from the Earth crust once they are obtained from the Earth crust, we use some mechanical process to break down these aggregates into smaller sizes. So, that they can be used for construction.

We can also have manufactured aggregates and these manufactured aggregates they are obtained from industrial processing for example, we can have blast furnace slag, which comes from iron and steelmaking industry, which can also be used as an artificial aggregate you can see. We can also have recycled aggregate which can be obtained from already constructed structures or already constructed pavement and they are obtained after milling or after removing of these structures once they complete the end of their life or if they are subjected to any maintenance in between.

Most of the aggregates like out of all these aggregate sources of course, natural aggregate is the most common source in the recent times the government has put a lot of pressure on using natural sources because they are non-renewable in nature, and they are depleting over a period of time, but generally natural aggregates are the most commonly used source of aggregates for construction of infrastructure specifically pavements.

So, if you see that in highway construction, most of the aggregate particles which we use, they are obtained from local supplies of natural rock. Natural rocks, how they are formed? This is again one important question a basic question to understand. So, natural rocks they are formed through a long and complicated process of plate tectonics. So, and this process could have started long back when the earth was very hot, and it was building up into a dense mass. And over a period of time, when this process started, different layers were formed in the Earth crust.

And these layers they tend to move about each other and that is the process of plate tectonics and therefore, different regions can have different types of rocks, different sources of rocks and therefore, the aggregates which we will procure from these sources will also be different and will be unique in nature. So, based on the rock cycle, the natural rocks can be divided into igneous rock, sedimentary rock and metamorphic rocks.

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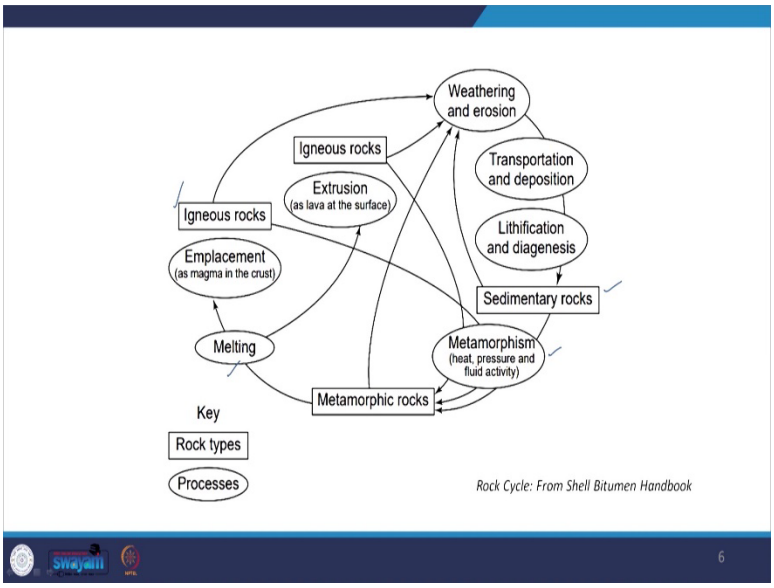

Now, this is a typical rock cycle here. So, you see that most of these sources will be igneous in nature, because that is the basic source which comes out once the molten magma has cooled down. So, these igneous rocks they can further be subjected to weathering action, movement, or erosion from water and several other environmental factors. And when this process takes place, this weathered rock gets transported, and they could get deposited in different forms in layers, thus forming other source of rock such as sedimentary rock again sedimentary rock is derived from igneous rock, but through a process.

Now, these igneous and sedimentary rocks they can be further subjected to changes in pressure and temperature conditions and more weathering, which can convert them into metamorphic rocks. So, therefore, you see there is a cycle of conversion of one form of rock to another. And finally, this metamorphic rock when subjected to further temperature or heated condition and after melting, they can again form the part of the magma and again can build up as igneous rock. So, this is a typical rock cycle, which tells us about how the process goes on.

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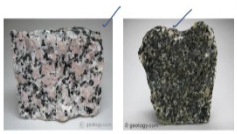
Igneous



- Formed by cooling of molten magma as it move towards the surface of the earth
- Crystalline: Extent depends on the cooling rate. Extrusive cools quickly (small grains), while intrusive cools slowly (more crystalline)
- **Examples:** Basalt (extrusive), granite (intrusive), gabbro (intrusive), etc.
- Classified by the size of grains or as acidic/basic
  - **Acidic:** Silica > 66%; SG: <2.75; Light in color; free quartz is present. Example: Granite
  - **Basic:** Silica < 55%; SG: >2.75; Dark in color; Free quartz is not present. Example: Gabbro, Basalt

So, now, let us start discussing about each of these types of rocks and we will try to see that under each category, which are the common types which we use for construction of pavements and which are the types which are generally not preferred for use in pavement construction. So, talking about the igneous rock, so let us see how igneous rocks are formed, they are formed by cooling of molten magma as it moves towards the surface of the earth, igneous rocks are crystalline in nature.

But the extent of this crystals it depends on the cooling rate that how fast the magma is cooling, it can happen that the magma cools outside the surface once it comes outside the cooling rate becomes very fast and these aggregates they are called as extrusive aggregates or extrusive rocks. And one of the characteristics of this type of rock is that they will have small crystals, which sometimes may not be very, very strongly visible with naked eye, but they have small crystal grains.

Now, the igneous rocks which cools inside they are called as intrusive rocks. Now, since they are cooling inside where the temperature is high, so, the cooling rate is slow and these rocks they tend to be more crystalline in nature. And visually it will be very clear that how these crystals looks like some of the examples of igneous rocks common examples are basalt. Basalt is an extrusive type of rock. So, therefore, it has finer grains, we have granite, granite is an intrusive form of rock.

So, this has more prominent crystals, we have Gabbro, which is again intrusive rocks. So, these are some examples of the different types of igneous rocks for example, this is a granite form of igneous rock and we can see some visible crystals here, this is a form of gabbro here, which also have crystals but not very strongly visible. And then, this is an example of basalt here, which is still darker in nature. And as I said the crystals are not strongly visible. If we talk about the classification of igneous rocks, they are basically classified based on the size of this crystal grains and based on their acidic or basic nature.

So, acidic igneous rocks are those in which the silica content is very high, it is typically greater than 66 percent. And the specific gravity of these types of rocks or the aggregates derived from this type of rocks is usually less than 2.75. One of the visual characteristics is that they are light in color and they have free quartz and an example is granite.

And here I have an example of granite in my hand also if you can see that we have very visible crystals in this particular aggregate and this is a typical granite which is used for construction. Talking about the basic form of igneous rock they have less amount of silica typically less than 55 percent, their specific gravity is high more than 2.75, they are relatively dark in color.

For example, I have again one example of a basic igneous rock which you can see here and they have smaller crystals not very strong crystals, but still it is visible and they are typically darker in color in comparison to the acidic aggregates. And they have the free quartz is not present in the basic aggregates. The typical common examples are gabbro and basalt that are used for construction.

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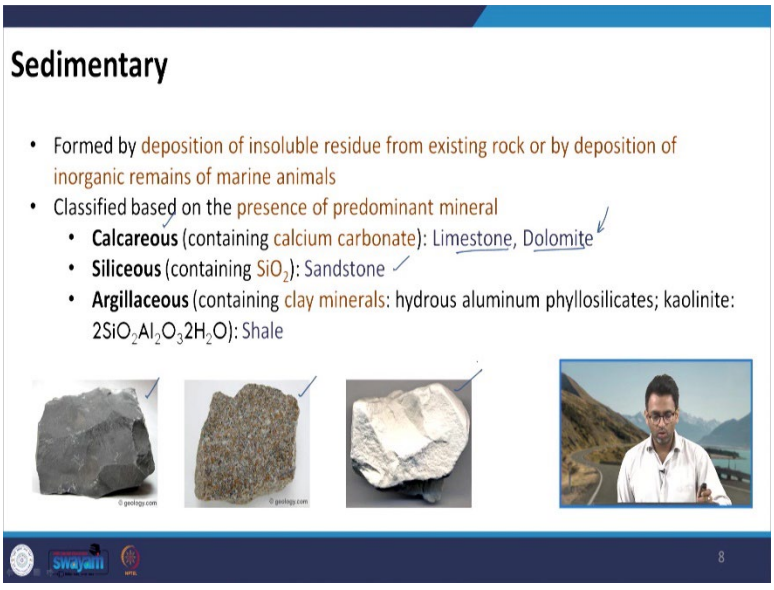

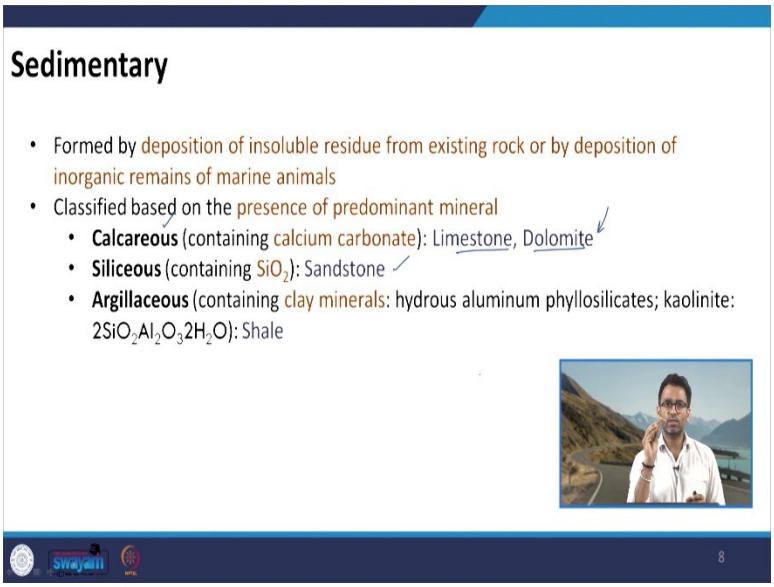

Talking about the sedimentary rock they are found by deposition of insoluble residue from existing rock or by deposition of inorganic remains of marine animals. So, both things can lead to formation of sedimentary rocks which are basically a layered system of different deposits.

And these deposits can be formed either by weathering of the existing rocks or through transport of particles through the movement of water also, they are classified based on the predominant mineral present we have calcareous type of sedimentary rock they contain calcium carbonate examples are limestone and dolomite. If we see the formation of limestone, limestone can also be formed in different forms. For example, inorganic remains of marine animals or deposit of calcium rich existing rocks can lead to formation of limestone.

So, what happens here that water when it is moving, they can pick up minerals from the existing rocks and they will get deposited at some other location leading to the formation of limestone. Afterwards what happens when this water takes these deposits, water gets evaporated and this deposition they get converted into sedimentary rocks.

Water can also remove calcium carbonate from seabeds from the remains of marine animals. And later again after the evaporation of the water they can get converted into limestone. Dolomite on the other hand is a form of limestone and when the limestone basically gets altered by magnesium rich groundwater they get converted into dolomite and therefore, dolomite predominantly contains calcium magnesium carbonate.

Then we have Siliceous type of sedimentary rock which contains mostly SiO_2 an example is a sandstone, then we have Argillaceous form of sedimentary rock which contain clay minerals, this can be hydrous aluminum phyllosilicates, we can also have clay minerals like kaolinite present and a typical example is shale. So, here I have sandstone available with me right now, which is more of flake in nature presently. So, this is an example of sandstone.

So, these are again some pictures taken from the internet we have a limestone example here this is sandstone, this is an example of shale. Now, shale being more weaker in nature, they are not typically used for construction of pavement especially in the upper layers. So, they tend to break when they are loaded. So, they are usually not taken as strong construction material.

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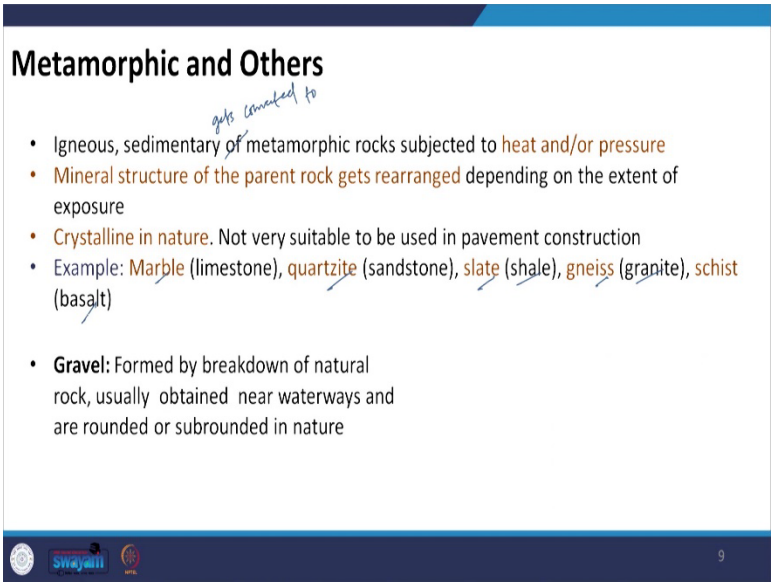

And the last category is the metamorphic rock and then we have some other forms which I will be discussing now, metamorphic rock as I was mentioning is a converted form of igneous and sedimentary rock. So, igneous and sedimentary rock they gets, I think, we can rephrase the sentence here. It gets converted to metamorphic rocks, when they are subjected to heat and or pressure in different forms.

What happens here, since the parent rock is igneous and sedimentary, but the structure or the mineral structure changes, when they are exposed to these varying temperature and pressure conditions. So, they get rearranged from the parent rock and they take a different form and this different form can altogether have a different strength properties and different mineralogical properties.

They are crystalline in nature and are not very suitable for using pavement construction. When I say not suitable, I am only talking about generally not suitable or generally are not used, but their forms are sometimes used in different ways in pavement construction. For example, marble is derived from

limestone, though marble are not typically directly used in construction, marble dust for example, are sometimes used as filler in pavement construction. We have quartzite which is a derived form of sandstone, we have slate derived form of shale, we have gneiss which is derived from granite, schist which is a derived form of basalt.

Then, in other categories, we have gravel. So, gravel is formed by the breakdown of natural rock, which are usually obtained near the existing natural waterways and they are mostly rounded or sub rounded in nature, and they need further crushing before they can be used for pavement construction.

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So, you can see we have rounded gravel here and this needs to be further crushed. Specifically, when we want to use them in the upper layers of pavement construction, which requires more of Angular form of aggregates.

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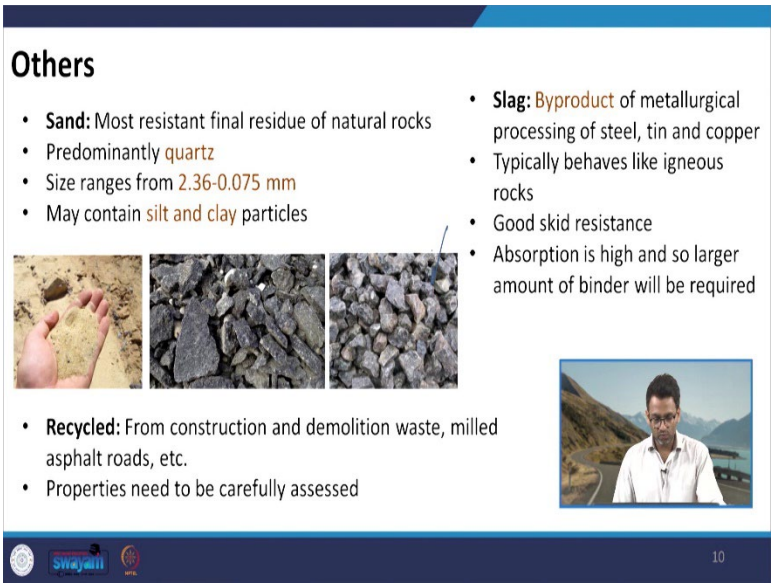

Then we have sand. Sand is the most resistant final residue of natural rock. Now, sand it contains SiO_2 which is covalently bonded and therefore is not very easy to break therefore is a very strong material. It contains predominantly quartz. The size of sands are usually finer in nature, the size ranges from typically 2.36 mm to 0.075 mm.

They may contain silt and clay particles, again, depending on the size of the entire sand material. Now, silt and clay are materials of further smaller sizes. This is an example of a sand deposit, we can have slag. Slag as I mentioned is a byproduct of metallurgical process and are obtained from manufacturing of steel, tin or copper and there can be other processes through which other forms of slag can be obtained.

They typically behave like igneous rocks, which means they are strong in nature, they have good strength. They have good skid resistance also. So, due to this characteristic they are also suitable for the veering course or the surface layer where skid resistance is desired for safety however, most of the slag material has higher water absorption.

And when we talk about the asphalt mix, for example, large higher amounts of binder may be required in comparison to the conventional aggregates if slag is used in construction. This is again an example of slag. And visually we can see it is more or less like a conventional aggregate. We can also have recycled aggregates that are obtained from construction and demolition waste, or milled asphalt roads, which is bituminous roads, etc.

And their properties need to be carefully assessed before they can be actually used in construction. We will be discussing about reclaimed asphalt pavement and there will be talk that why we say that the properties needs to be assessed carefully so that they can be used for construction. Again, this is an

example of a rap deposit, a photograph taken from a milled pavement, showing you the reclaimed asphalt pavement material here.

With this, we complete our discussion on Origin and Types of aggregates. And I hope that by now, we have familiarized ourselves with what aggregates are? How aggregates look like? What can be different types of aggregates? We have also tried to understand that aggregates can be obtained from different sources and what these different sources can be.

We have also learned that aggregates can be from have different forms such as it we can have natural aggregates, we can have manufactured or industrial aggregates, we can also have reclaimed, or aggregates obtained from demolition or construction waste. With this thank you and in the next presentation, we will proceed from here and we will try to learn about various other aspects related to mineral aggregates. Thank you.