Rock Mechanics and Tunneling
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Lecture No. 02
Rock Engineering Application Areas (Continued) and Discontinuities in rock

Hello everyone, I welcome all of you to our second lecture of Rock Mechanics and Tunneling. In our previous class, we have discussed about the learning objectives of this course, then we have also discussed about the reference books, then I have discussed about our weekly plans briefly and also we have discussed about what is rock mechanics?

Then what are the differences between soil and rock? and why we are learning separately this course when we have the knowledge of soil mechanics? So, those are the things we have discussed in our previous class and I just have started discussing about this rock engineering application areas. So, we will proceed with these today.

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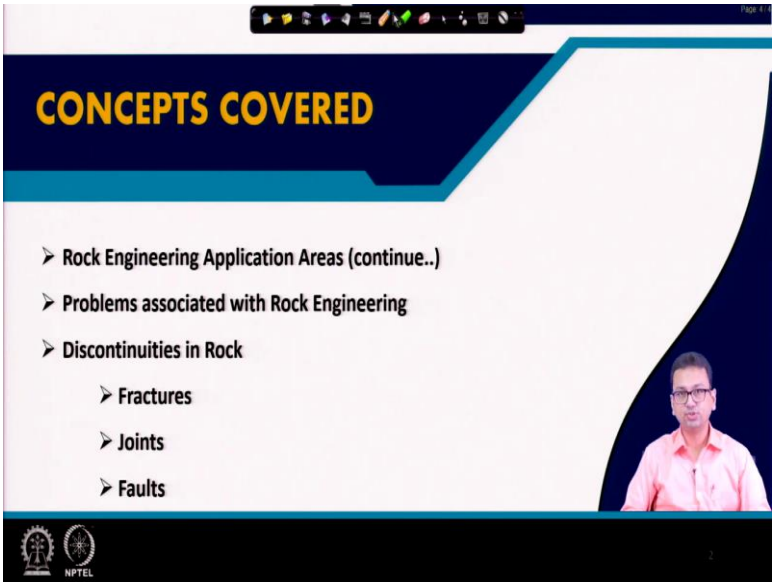

So, we will continue with rock engineering application areas and then I will discuss about the problems associated with rock engineering, somewhat I have discussed and you have got some idea what are the possible problems associated with rock engineering project. So, anyway we will discuss them more formally.

And then, we will enter into the very important topic that is discontinuities in rock. Today I will try to cover the fractures, joints, and faults. I need maybe some time in our next lecture also to complete the part of the discussion related to faults. It will be over probably in our next lecture, but I will start the discussion today. So, let us begin.

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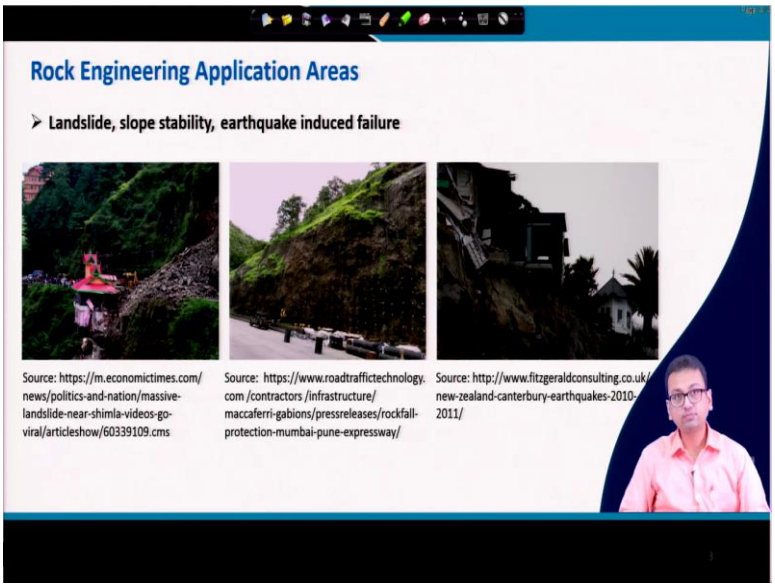

So, as I have stated in our previous lecture that the rock engineering is an interdisciplinary area; we see that there are like civil engineering, mining engineering and petroleum engineering everywhere in all, mainly in these engineering divisions and as well as geology and geophysics, there we see the applications of rock engineering very much.

So, just here I will show you some of the typical structures or application areas where we can use our knowledge. So, with some pictures, I will show you like, this is a landslide. So, here if we find that if some landslide occurs, then the restoring of that area means the disaster management becomes very much important.

So, if you have the knowledge of rock engineering means, as I have told you, we will discuss about how to improve the response of rock mass. So, if you know that, you should be in a position to restore that location and can help the people over there. So, you have chance of contributing there, if there are some landslide occurs.

Then before landslide if you can actually applying your knowledge of rock engineering, if you can analyse the stability of the slope, then, if you find that the maybe if earthquake occurs, then that slope may be susceptible to failure. In that case, you may again apply your knowledge and you can improve the response by using maybe the rock bolts, rock anchors or maybe the steel mats which you can place over there.

You can design that accordingly or you can use grouting. So, you have to stabilize that rock mass, so that the slope should not fail in future if earthquake comes there. Likewise, related to this only like earthquake induced failures, you can see in this figure, this picture that a

building is there. It is constructed over the rock mass only, so, there is slope failure as well as the foundation also has failed.

So, if you take into account the effect of earthquake while designing the structure, then obviously, if this type of disaster occurs, the failure associated with it can be prevented actually. So, your knowledge of rock engineering can be applied there also.

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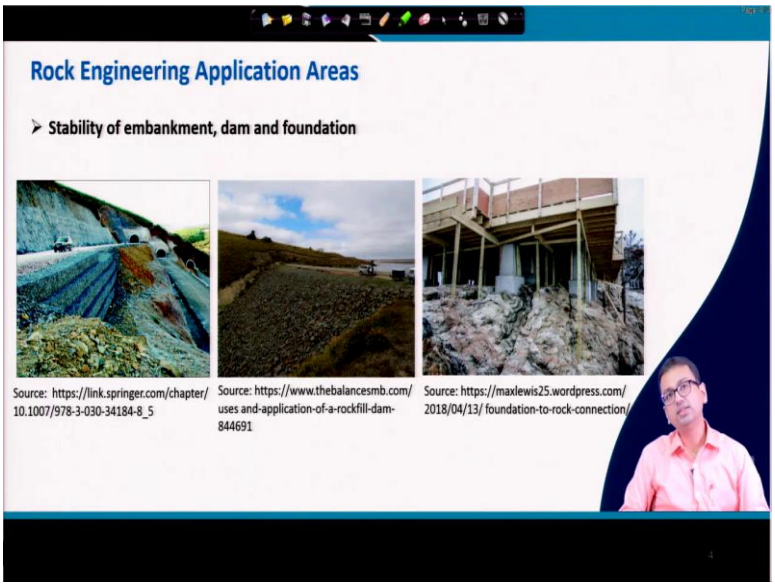

Then again stability of embankment, dam, and foundations, like this is an embankment, the dam may be constructed over rock mass and also the foundation can be constructed on rock mass. So, here also, for designing these structures, you can apply your knowledge of rock engineering.

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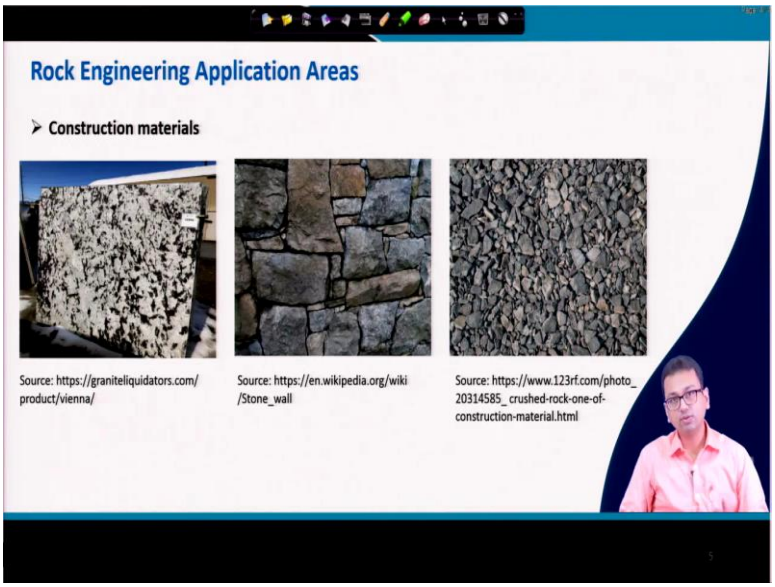

Then as construction material, so let us see some of the pictures. You see if you want to construct suppose Taj Mahal that is made of white marble; so, the construction material is itself the rock mass. Likewise, this second picture you can see that a stone wall; so, these are the nothing but the rock pieces.

And these are the stone chips that are also we can get from rock only and the stone chips are essential component of concrete mix. So, these are the construction materials. Your knowledge can be useful regarding the selection of construction materials.

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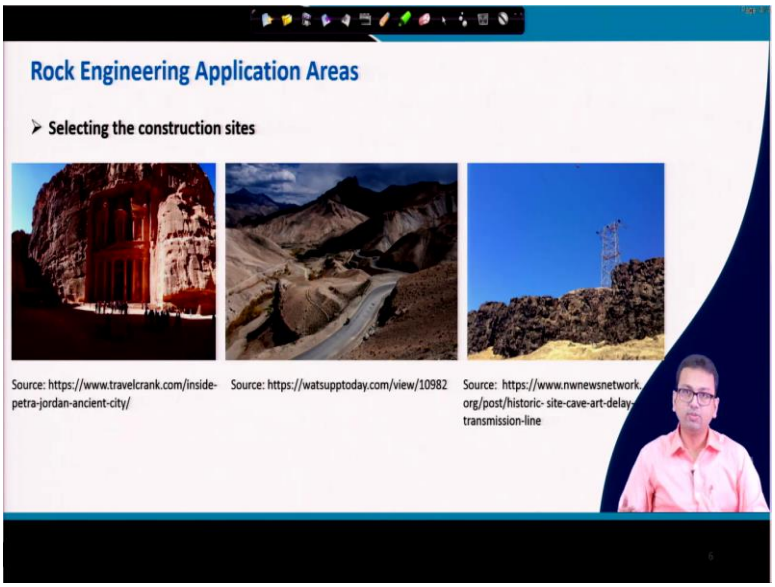

Then, another may be selecting the construction sites. So, you see a massive rock structure is over there, and then a roadway or a tower is present there. So, if you consider over here, you

see it is a huge structure. Now, obviously, in order to build this type of structure, the rock mass over which it would be constructed, should have good amount of strength.

Likewise, this is the roadway; now for constructing the roadway you must have to check the load carrying capacity of the rock mass over there because maybe heavy trucks may move over this road. So, if required you may have to improve the response by applying your knowledge of those grouting. Because of the loading of the vehicles if the slope becomes unstable, so in order to make it stable, you can apply like rock anchoring, bolting all those things you can do obviously.

Likewise, this electrical transmission tower is constructed over here and you can see the rock mass, several discontinuities present over there and they are also haphazardly oriented. So, it is expected probably that the strength of this one may be quite less, but if your structure is not so heavy, probably the rock mass will be able to withstand that load, but if it is not and if you are compelled to construct your structure over a weak rock strata, then you may have to improve the strength characteristics of the rock mass there.

So; or if possible select a different location if it permits, then only; if it is fixed then you have to construct a structure at that particular location, then you cannot do anything, but if you have the luxury to choose another location, then obviously you may try to find a location where the strength of the rock mass is better maybe. But depending on how much load is coming and availability of land; all these things based on that you can select a suitable location.

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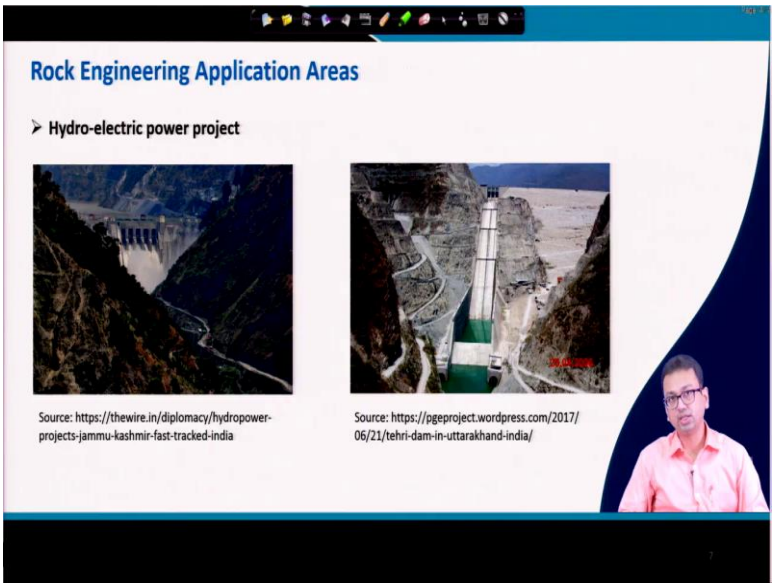

Then hydroelectric power project, this is actually one of the very important civil engineering structure and they are mostly constructed in the hilly terrain, so like the right side picture is of the Tehri dam in Uttarakhand. So, for designing hydroelectric power projects, where you have to construct huge dam, there your knowledge of rock engineering will become very essential actually.

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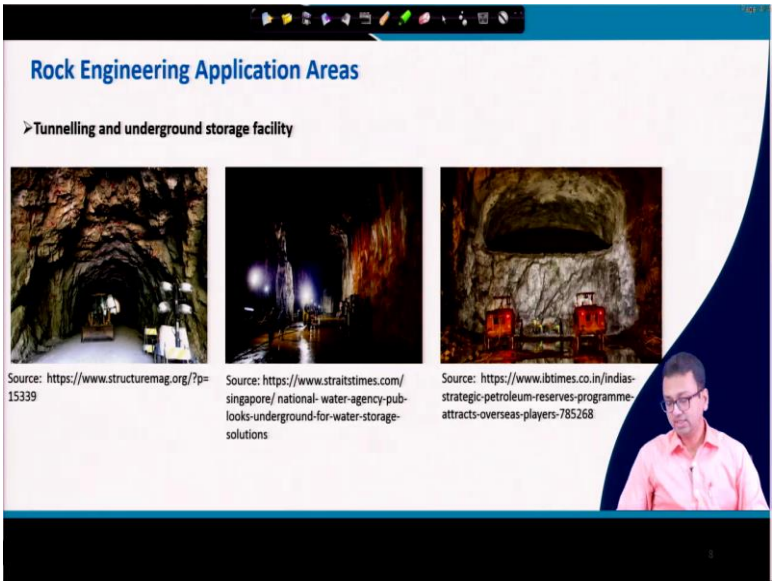

Then the tunneling and underground storage facilities as I have told you that for both civil and mining engineers, they are very important. For civil engineers, for transportation purposes, nowadays most of the cities are getting metro rail.

So, tunneling is becoming quite normal affair nowadays. And for mining engineers over the years they are creating tunnels to reach up to ores or minerals. Suppose, a coal block is there at a particular depth at a particular region, then you may have to first go for a vertical excavation then maybe a horizontal excavation i.e. the tunnel you may have to create.

So, your knowledge will be useful for designing tunnels. As well as the how the tunnel will be constructed you see it is a tunnel construction is in process, the upper part is excavated then gradually in sequence these rocks will also be taken out.

Other than that there are other equipments are also there, TBM - Tunnel Boring Machines are there, we will discuss about that later. But however, you should have a good knowledge of rock mechanics in order to design the tunnels or underground other storage facilities or vertical excavations, all these things.

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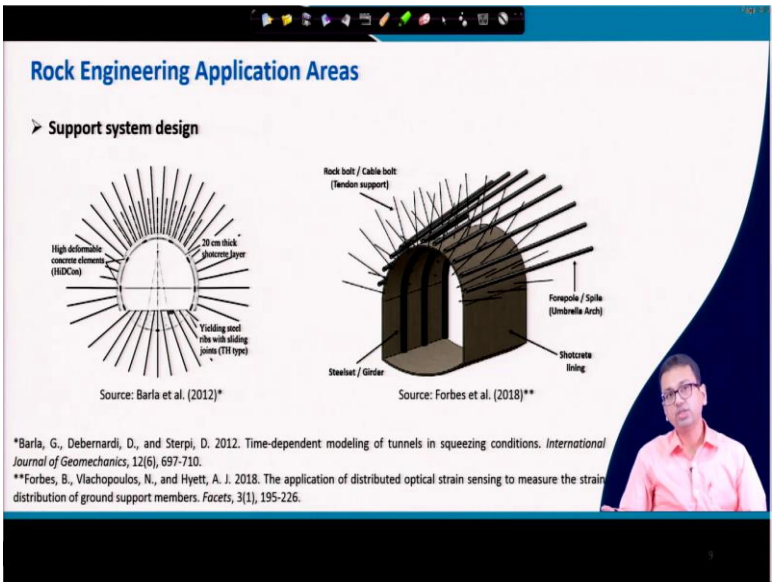

Now, supports system design. Suppose, if we see these two pictures, these are for tunnels. You may find that after carrying out the numerical analysis, the tunnel is not stable enough means under the loading, whatever loading will come there, because of the loading it may fail or if some earthquake comes it may very easily collapse.

In that case, you may have to design the support systems like you can see over here the shotcreting, this is very common thing in case of stabilizing the spaces, the sides of these tunnels. Then, you can see the rock bolts are also used over here. And apart from that precast concrete liner is also used. So, there are several things that we will learn later.

But anyway, for tunnel construction and stabilization of slope, the knowledge regarding support system design becomes very essential. So, the knowledge of rock engineering will help you to design the support system. So, I think that this part is ending.

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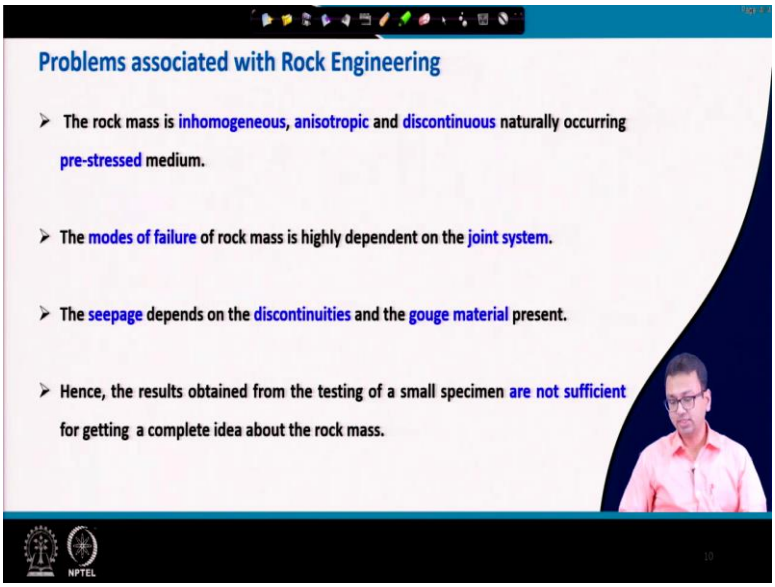

Now we will discuss about some of the problems associated with rock engineering. So, again, I have stated it earlier, but in a formal way it is written here, the rock mass is inhomogeneous, anisotropic and discontinuous naturally occurring pre-stressed medium.

So, you see, it is inhomogeneous, anisotropic and discontinuous as well as pre-stressed medium. So, obviously, we can understand it is a very complex thing and designing a structure on this type of rock mass or in this type of rock where within a few meters your properties of the rocks or strength characteristics of the rock changes very drastically.

So, in that situation, designing a structure is really challenging task and the design may be particular site specific also depending on these all these uncertainties. So, it is a challenging job obviously.

Then, because of this presence of these discontinuities, the modes of failures rock mass are highly dependent on these things as I have stated earlier, joint system. So, that is one of the important things. So, again maybe at a particular location, the orientation of the joints or the discontinuities is maybe of some pattern and maybe after within maybe 10 meters it is different.

So, if you want to construct a massive structure, you need to take care of all those things, when you will design a foundation, a big foundation, maybe a portion of the foundation may

be over a good rock mass having good load carrying capacity, but maybe the other portion of the same foundation may be over a weak rock mass, so where several discontinuities are present so that we need to keep in our mind.

So, the designing becomes obviously quite challenging. Likewise, the seepage in rock depends on the discontinuities as well as the gouge material or the infill material present there. So, in those discontinuities, the water may present or maybe the cohesive material may present or maybe cohesionless material maybe there.

So, the seepage depends on the discontinuities and the infill materials present and already you have that idea that in case of soil you must have noticed that the stability of slope depends highly on seepage. So, here also seepage plays an important role. So, regarding seepage this is the difficulty.

So, what we can say that the results obtained from the testing of small specimen are not sufficient for getting a complete idea about the rock mass. So, you must have to perform some of the in-situ testing also. By combining the laboratory test on small specimen and the information gathered from the field in-situ testing, you will get a good idea and based on that you will be able to design your structure.

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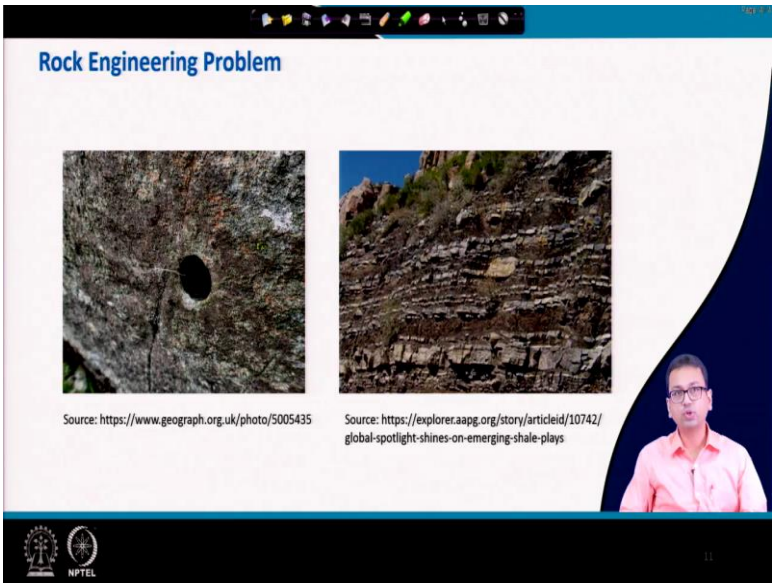

So, these are some pictures as you can see, it is highly heterogeneous. See in the pictures only you can see so many discontinuities are present there. So, it is, that is why it becomes challenging.

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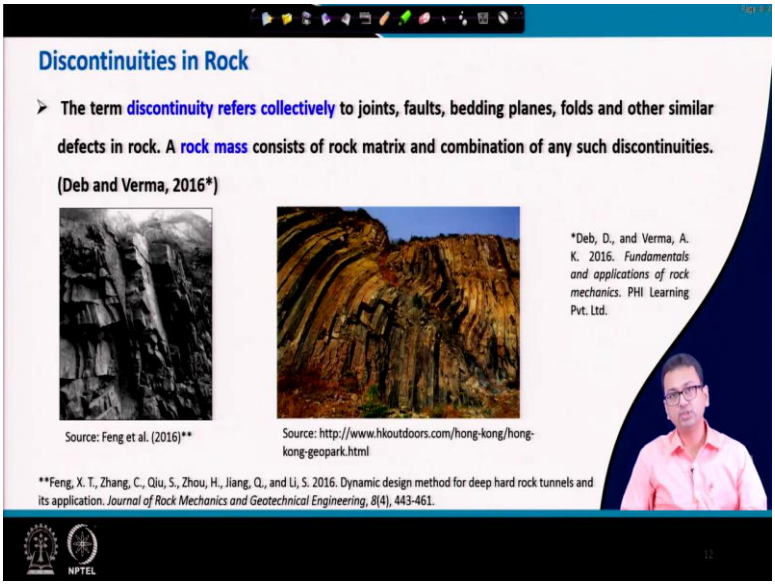

Now, our next topic that is discontinuities is in rock, this is very important. This part of our discussion basically for this part, I have referred primarily the book of Deb and Verma, but anyway I am discussing the things here. So, the term discontinuity refers collectively to joints, faults, bedding planes, folds and other similar defects in rock.

The term discontinuity refers collectively to joints, faults, bedding planes, folds and other similar defects in rock and a rock mass consists of basically rock matrix and combination of

all such discontinuities. So, I have stated this earlier also same thing that is written over here. So, you can see from these two diagrams that the discontinuities are very much visible.

And orientations of the discontinuities are different. Here we can see a particular pattern, again here another pattern, here different patterns we can see. Thus the orientations of the discontinuities are different. So, we must have solid knowledge about the discontinuities in rock.

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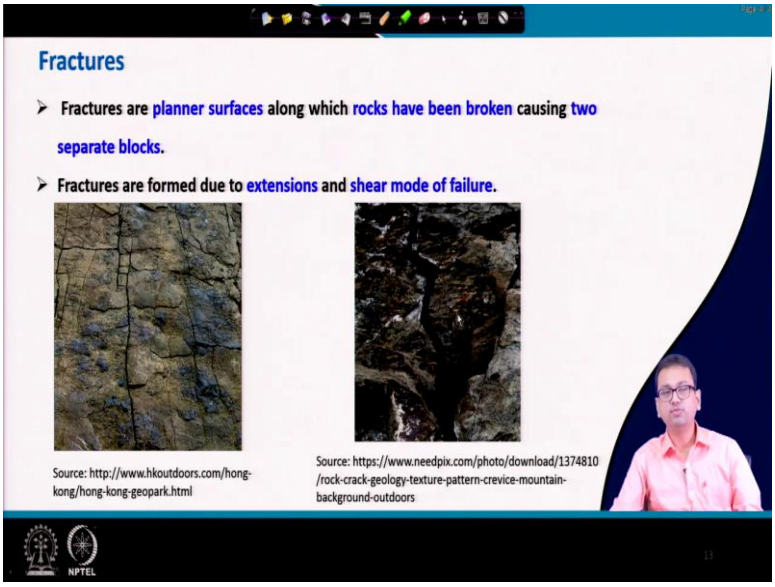

So first we will discuss about the fractures. So, fractures are planar surfaces along which rocks have been broken causing two separate blocks and fractures are formed due to the extensions and shear mode of failure. So, let us see these two pictures, then I will again get back to the things what I have written. You see, you can clearly see a fracture and because of that the two blocks are separated here.

From these two pictures you can see that the fractures are clearly visible. So, what is stated here, fractures are planar surfaces along which rocks have been broken causing two separate blocks. So, you can clearly see that two separate blocks are created and it is also stated the fractures are formed due to the extensions and shear mode of failure.

So, it may be like the extension or shearing has occurred between means over here so, shearing has occurred and this kind of failure has occurred or similarly here because of shearing it may have developed or because of the tensile force. So, that can also be the reason means, that tension, because of tension also this type of defects may develop.

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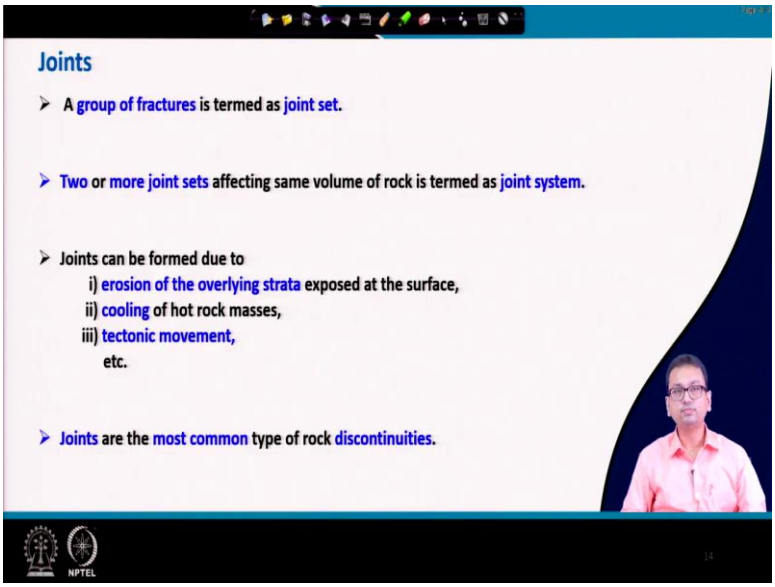

Now, joints – actually a group of fractures is termed as joint set. A group of fractures is termed as joint set and similarly, another term is important that is joint system. What is that? two or more joint sets affecting same volume of rock is termed as joint system. Now, joints can be formed due to different activities like first one is erosion of the overlying strata exposed at the surface.

That is one of the common reasons, then cooling of the hot rock masses. So, you can understand because of the cooling of hot rock mass, this type of joints may develop. And tectonic movements that is also possible for creating joints, etcetera. And another thing is that joints are the most common type of rock discontinuities. So, that we have to keep in our mind.

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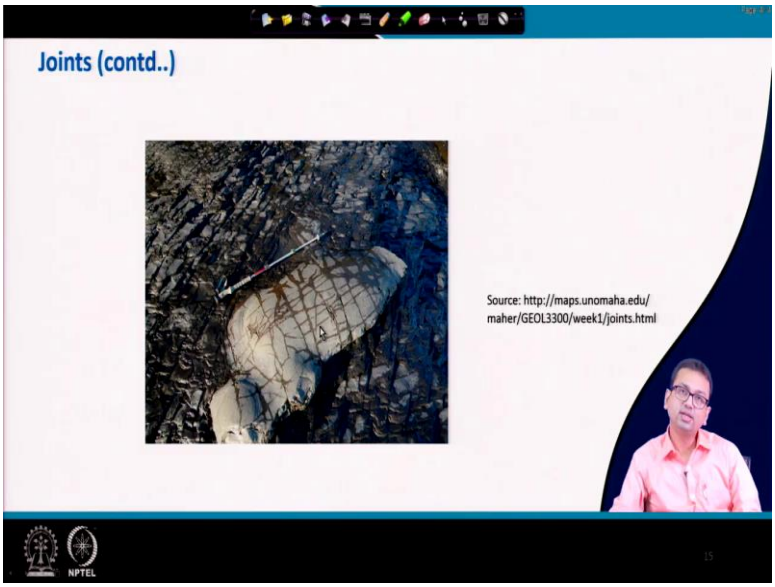

In this picture we can see, these are parallel lines, this is a joint set and again there you can see another pattern that is another joint set. So, overall it is creating a joint system. So, that is just pictorially shown over here.

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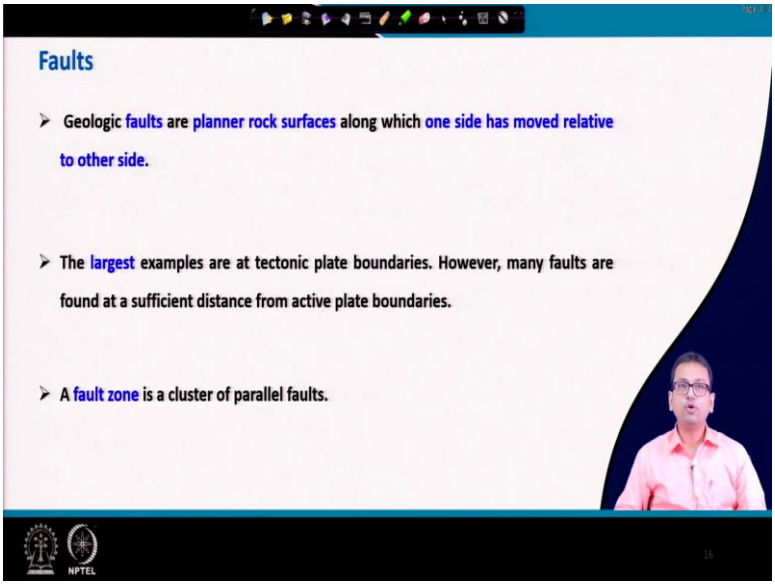

Now, geologic faults are planar rock surfaces along which one side has moved relative to the other side. Geologic faults are the planar rock surfaces along which one side has moved relative to the other side. Also, we can say that the largest examples are at the tectonic plate boundaries.

Tectonic plate boundaries, they are very large and clearly visible. However, many faults are found at a sufficient distance from active plate boundaries also. And another term fault zone, a fault zone is a cluster of parallel faults.

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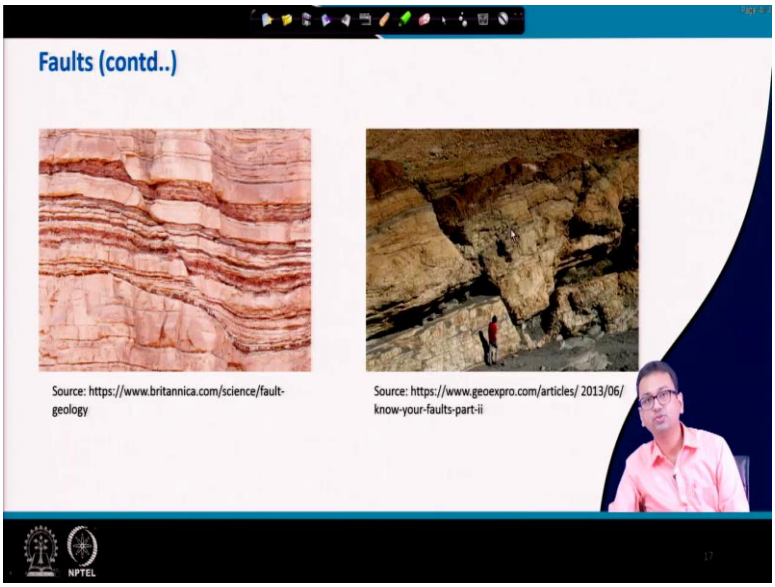

Now, you see this is a nice picture, you can see there is this line is going here it has become discontinuous at lower level it has come. Similarly, all these lines in the right side are at lower level. So, you see this line is nothing but a fault line. So, what was stated there, what is fault? Geologic faults are planar rock surfaces along which one side has moved relative to the other.

So, there is a relative movement we can see. So, fault we can clearly notice. Similarly, here, this picture is also clearly showing us the presence of faults. So, you see the relative movements have occurred between this block and this block as well as this block. So, faults are clearly visible right here.

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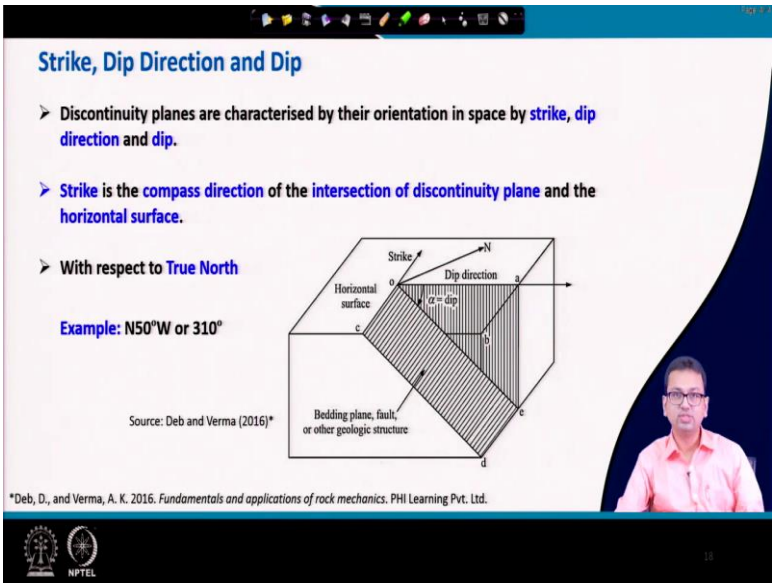

Now, before further continuing with these faults, let us discuss about three essential parameters - they are strike, dip direction and dip. They are very important as these things will be found to be useful when we will design suppose a tunnel or a foundation or any structure in rock.

So, I will briefly explain what are strike, dip direction and dip and in our next class we will further discuss about these points. So, discontinuity planes are characterized by their orientation in space by strike, dip direction and dip. Now, this picture is showing all these three things.

You can see here written strike, here dip direction, here dip, what are they? And you can also see this line is showing the north, it is in the direction of true north. So, what is strike? Strike is the compass direction of the intersection of discontinuity plane and the horizontal surface.

So, you see, this is the horizontal surface and this is the discontinuity plane, now we can see where this discontinuity plane is intersecting with the horizontal surface. So, strike is the compass direction of the intersection of discontinuity plane and the horizontal surface.

So, this is the intersection line and orientation of this intersection line with respect to this true north will give us a strike. So, the compass direction will give us the strike. So, this angle if we measure, we will get the strike. So, let us see, suppose, as I have stated with respect true north that is only shown here.

Suppose, this angle, I am assuming as 50°. So, the strike can be written as N50°W, you see it is in the west side of this north. So, the strike of this where the discontinuity plane and the

horizontal surface are intersecting that, if I see that line the orientation of this line can be represented by N50°W west or you can write it also as from here it is 310° (as whole circle bearing). So, in both the ways we can represent it.

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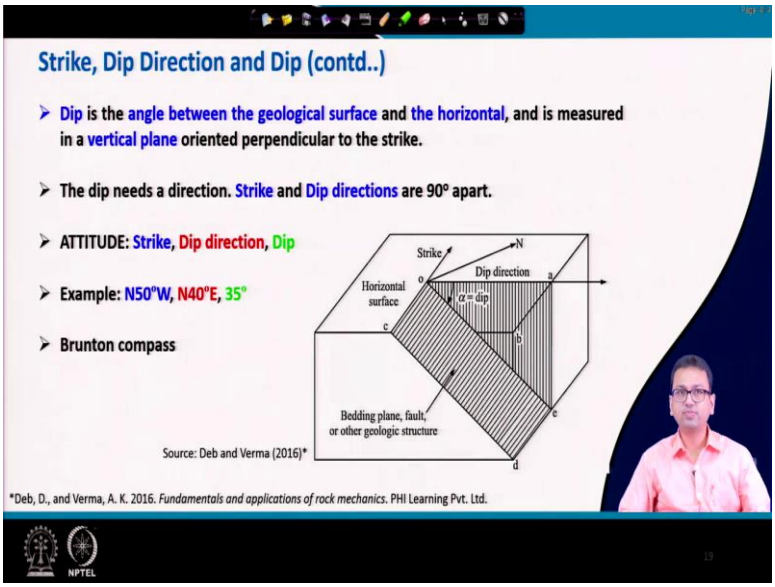

Now, what is dip and dip direction? "Dip is the angle between the geological surface and the horizontal and is measured in a vertical plane oriented perpendicular to the strike." Let me read it once again "Dip is the angle between geological surface," this is the discontinuity plane, "and the horizontal, so it is the horizontal surface and is measured in a vertical plane."

So, it is measured in a vertical plane that is 'aoe', is the vertical plane, the angle is measured here with respect to the horizontal surface and the orientation of this geological surface or discontinuity plane i.e. the angle is measured in this vertical plane. So, this is the dip angle basically. Now, this dip needs a direction and how we can find the direction? Actually the strike and dip direction are 90° apart.

That is fixed. So, if you find out the strike that what we have just now found out it is N50°W. So, from there we can easily tell what the dip direction is as the angle between dip direction and strike is 90°. So, obviously, this angle is obviously 40°.

So, what we can say this dip direction is actually N40°E. And now, one thing is, and this is the dip, the angle what we are measuring here in this vertical plane. So, now these three terms together is called as 'Attitude', if I tell you what is the Attitude? Then you should understand that I am asking for the strike, dip direction and dip in this sequence.

So, for this problem just what I have assumed like if I have consider this angle is 50°, then the dip direction will be N40°E and if I consider the dip is 35°, then the attitude can be written in this way N50°W, N40°E, and 35°. So, the blue color is indicating strike, red color is indicating dip direction and this green colour is indicating the dip angle.

So, with the help of these three quantities, you can create an image in your mind that the discontinuity plane is oriented in this manner. So, that habit should be automatically developed in you. For measuring the angle, the Brunton compass is generally used.

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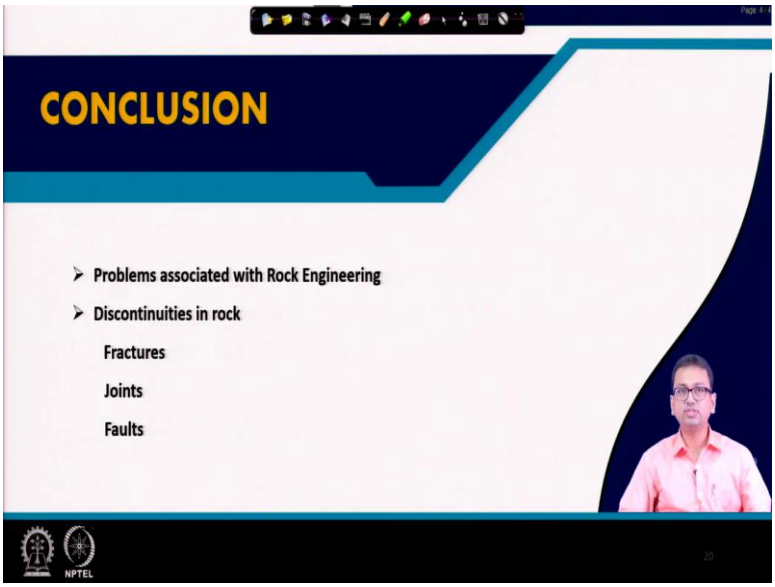

So, today we have discussed about these things – problems associated with rock engineering and also we have completed the applications of rock engineering, then discontinuities in rock, under that we have discussed about the fractures and joints and we have discussed about the faults. So, thank you. In our next class we will continue our discussion with faults.