Rock Mechanics and Tunneling
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Lecture No. 01
Objective, scope and associated problems

Hello everyone, I welcome all of you to the course, Rock Mechanics and Tunneling.

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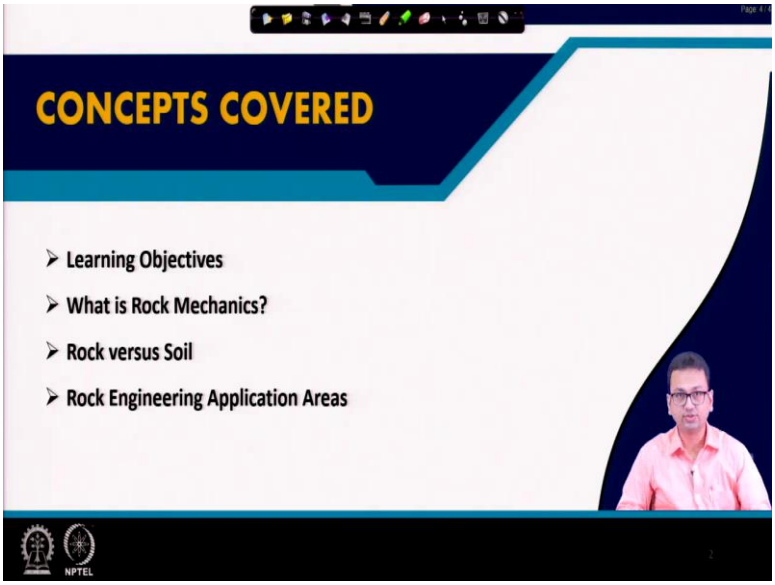

Today, we will start discussing about the learning objective first and then we will discuss about what is the rock mechanics? And finally, we will discuss about the difference between the rock and soil. So, first we will discuss about the learning objectives little bit in detail. At the end, I will start discussing about the rock mechanics application areas which will be continued in our next lecture.

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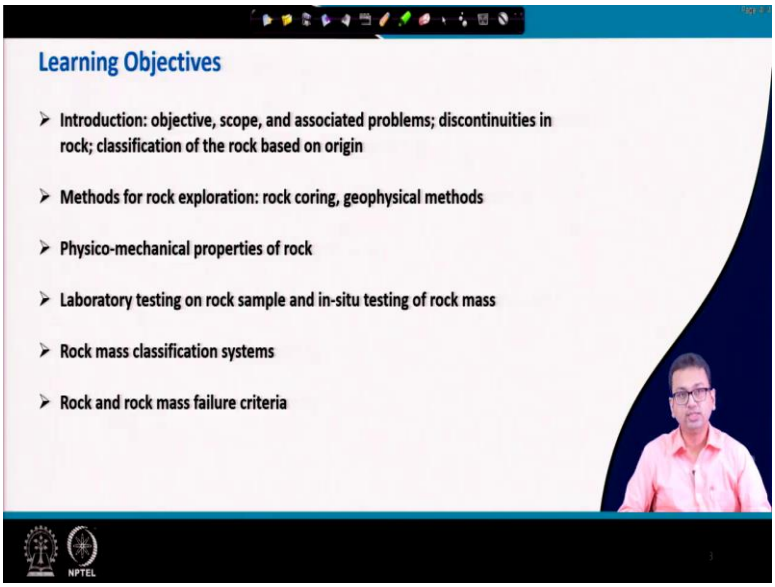

In your undergraduate level, you must have studied soil mechanics. However, the behaviour of rock is quite different from the behavior of soil under loading condition. Because, rock is highly heterogeneous and anisotropic material and the discontinuities present in rock mass and the orientation of those discontinuities play a huge role in this regard.

So, in this course, we will have a detailed discussion on the discontinuities in rock mass. Under this section, we will discuss about different types of discontinuities, such as fracture, joints, faults, folds, bedding planes, and we will also discuss about some terminologies like, strike, dip direction, dip. Then, the next topic will be the classification of rock based on its origin. Though, you know about the igneous rock, metamorphic rock, and sedimentary rock.

We will revisit those things little bit. And then, we will proceed to the next module that is on methods for rock exploration. Under that we will discuss about the rock coring and logging methods. And also to some extent, we will discuss about the geophysical methods.

Then, we will spend a good amount of time on physico-mechanical properties of rock. We will understand how the ultimate behaviour is dependent on the physical and mechanical properties of the rock mass. So, we have to understand about different physico-mechanical properties of rock. And these will be followed by the discussion about the laboratory testing on rock samples and the in-situ testing of rock mass.

As I have mentioned earlier that the rock mass is highly heterogeneous, anisotropic, and discontinuities are also present in the rock matrix. So, the laboratory tests on an intact rock

sample may not give us a complete idea about the behavior of rock mass at that particular site where we are planning to construct any structure.

So, for very big projects, it becomes almost essential to perform the in-situ testing also. So, that we can gather more data and we can ultimately predict the overall behavior of rock mass in that region. After the completion of laboratory and in-situ testing methods, we will discuss about the rock mass classification systems. It is very important because depending on the requirements, there are different classifications systems present in the rock mechanics.

Some of them are rock quality designation (RQD) system, rock mass rating (RMR) system, geological strength index (GSI) system. Few other classifications systems are there which we will discuss in this module. This module will be followed by the discussion on the rock and rock mass failure criteria. This is extremely important, because if we want to ultimately simulate or design a structure.

And if you want to check its possible displacement or if we have to construct a foundation, how much settlement it will undergo when subjected to different type of loading or how much ultimate load it can take, in order to find out that we have to go for numerical modelling, then the failure criteria what we are choosing will play an important role, in fact, very important role.

So, that is why our target will be to use the most appropriate failure criteria. So, for that purpose, we will spend a good amount of time in learning the rock mass failure criteria. So, we will discuss about the well-known Mohr-Coulomb yield criteria which are mostly applicable for soil. Though, we will discuss about it in detail because the Mohr-Coulomb yield criteria can be used for rock also.

Other than that we will discuss about the Drucker-Prager yield criteria and finally, we will discuss in detail about the most appropriate failure criteria i.e. the Hoek-Brown yield criterion.

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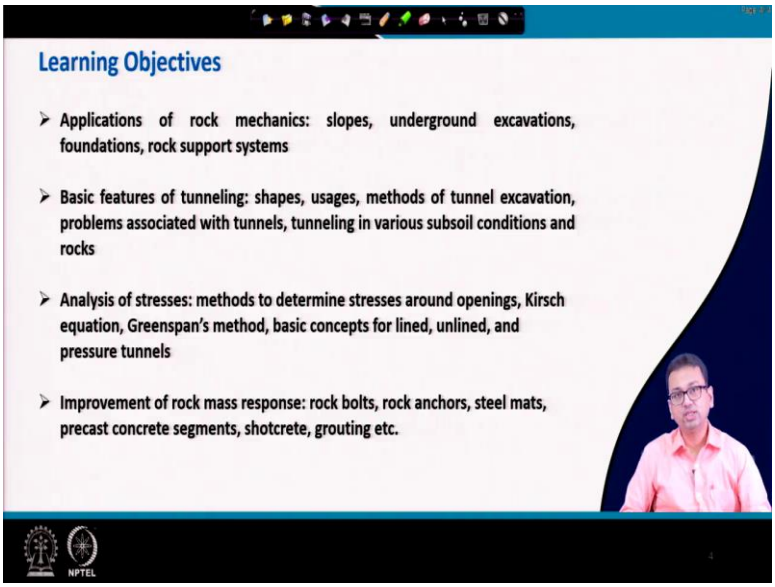

After having this much background, we will start discussing about the applications of rock mechanics. So, the potential areas will be slopes, underground excavations, foundations and rock support systems. We will cover these topics. We will spend a good amount of time for slope stability analysis as the slope stability analysis for rock is quite different from the slope stability analysis for soil, because of the presence of different discontinuities. The techniques or modes of failures are also different.

So, we have to discuss this in detail and other than that, the underground excavation, foundation and rock support system, we will discuss in detail as much as possible by solving some problems because I believe that if we solve some of the problems, your concept will get even clearer. So, we will solve few numerical problems. Then we will enter into the tunneling section.

So, as you know that course name is Rock Mechanics and Tunneling. So, we will spend a good amount of time or dedicate a good amount of time for understanding the different things related to tunnels such as first, like basic features of tunneling, such as the shapes, different shapes of tunnel, we will discuss about that, usages, and then the methods of tunnel excavation which is very important. Then the problems associated with tunnels, tunneling in various subsoil conditions, and rocks. These things, we will discuss in detail.

And in this part of our lecture, maybe I will refer some of the recent research papers also, where researchers have done numerical modelling to simulate these various subsoil conditions or rocks or different rock conditions, where the tunneling can be done or subjected

to different loading conditions, how the stability of the tunnel will change, or how the tunnel will behave that we will try to understand by referring some of the latest research papers.

Then, we will also discuss in detail, about the analysis of stresses; means if you create opening like excavation tunnel, then in surrounding areas how the stresses will behave, and after constructing the tunnel, how the stresses will change in the surrounding rock mass that we will try to understand.

So, the methods to determine stresses around openings, we will discuss about them. We will discuss about Kirsch equation, Greenspan's method and also basic concepts of lined, unlined and pressure tunnel. So, here also I will try to refer some of the recently published research papers.

And after that, at the end, we will discuss about the improvements of rock mass response. We may have to construct a particular structure at a particular location. Now, suppose if we have to construct a foundation for a big structure, so obviously a huge load will come and if the rock mass over which we have to construct if that is not good enough, then what is the way?

So, in that case we may have to improve that response of that rock mass. There are different techniques available like grouting is there, as I am telling about the foundation, now if it is for a slope suppose, slope stability issue is there, if we find that may be a slope is susceptible to failure due to earthquake, then we may have to go for some techniques like rock bolting, rock anchoring or we can apply steel mats, we can do all these things.

Or if it is a tunnel, a tunnel may not be stable in its own, so we may have to provide some liners there and we may have to go for rock bolting and we may have to improve the surrounding rock mass by applying the grouting or shotcreting which is also very common in case of stabilizing tunnel. So, these are the things we will try to discuss in detail.

And hopefully, at the end of this course, you will be able to design the structures ‘with’ rock or ‘in’ rock or ‘on’ the rock mass quite confidently.

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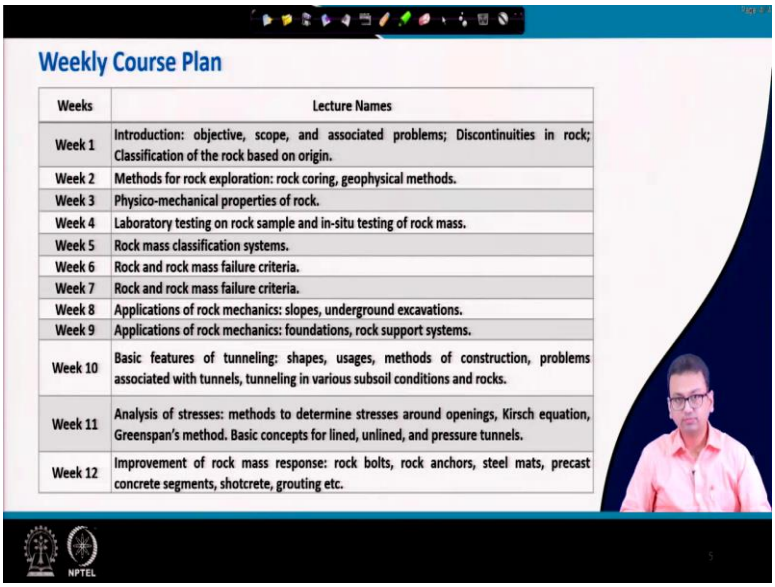

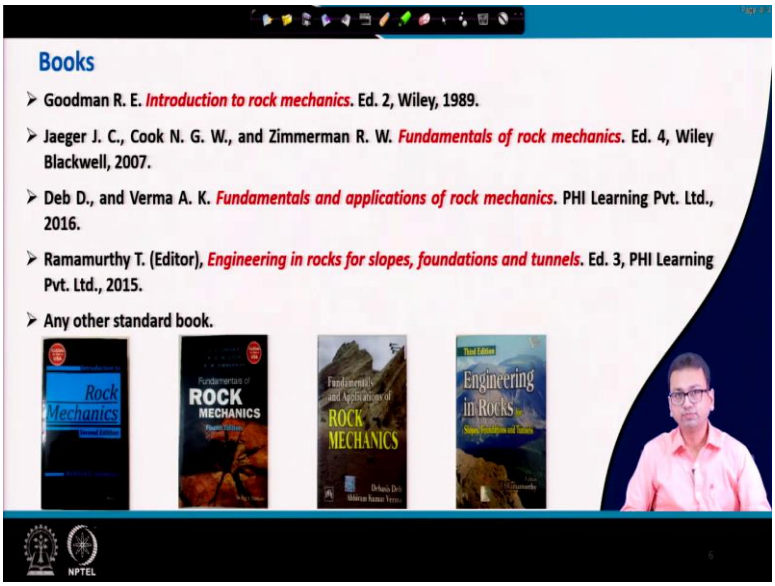

Now, this is the tentative weekly course plan. So, the same topics are written here only and they are divided into 12 weeks. So, that is it here. Then, important thing is what the books are, we should refer. So, here I have listed the names of four books, but it is not like that I will strictly follow these four books only as I have stated that I may follow some of the recent research papers or even old research papers also.

But for you, it is better to have one or two books with you so that you can refer those books whenever required. Apart from, so first let me show you the four books that I have listed here. The first one is the 'Introduction to Rock Mechanics' by Goodman, this is a quite old book and very renowned book throughout the world, thus the book is referred. Then, another

book is on ‘Fundamentals of rock mechanics’. This is by Jaeger, Cook and Zimmerman. This is also a very good book.

Next one is the ‘Fundamentals and applications of rock mechanics’ by processor Debasis Deb and processor A. K. Verma. This is also a very good book. In this book, there are several example problems and several exercise problems are also given. So, you can solve those exercise problems also to become even more confident.

And there is an another book, the name is ‘Engineering in rocks for slopes, foundations and tunnels’ by Professor T. Ramamurthy, this book is also very good, you can follow this book also. And apart from these four books, any other standard book you can follow there are several other books also available, you can follow any of them.

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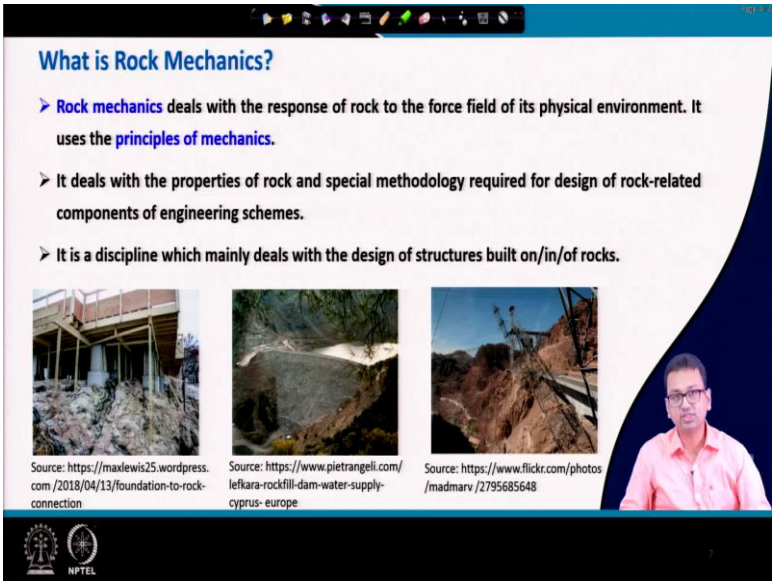

So, with this much of background, let us now move to the topic - rock mechanics and why we need to learn this subject. As just few minutes back, I have stated the behavior of rock under loading is quite different from the behaviour of soil under loading because of the presence of discontinuities and because of it, rock is very much heterogeneous and anisotropic and it shows different behavior than soil.

So, what may be stated is “Rock mechanics deals with the response of rock to the force field of its physical environment and it uses the principles of mechanics.” So, let me read it once again, “Rock mechanics deals with the response of rock to the force field of its physical environment; it uses the principles of mechanics.” So, it is quite self-explanatory.

So, next what we can say is “It deals with the properties of rock and special methodology required for design of rock related components of engineering schemes.” So, again this is also quite self-explanatory. So, it deals with the properties of the rock and special methodology required for design of rock related components of engineering schemes.

Also, it may also be stated that rock mechanics is a discipline which mainly deals with the design of structures built ‘on’ rock or built ‘in’ rock or built ‘of’ rocks. So, why have I written ‘on’, ‘in’ and ‘of’? If you consider a foundation, the foundation is constructed over the rock mass, so the foundation of this building is being constructed on the rock.

So, that is why ‘on’. Likewise, this dam is constructed in hilly terrain and it is also on the rock mass. Likewise, this is a bridge, bridge abutment, you can see this is also over the rock mass; not only that, the transmission towers which can be noticed here, the foundations of this transmission towers are also over the rock mass. So, these are the cases where structures are built on the rock.

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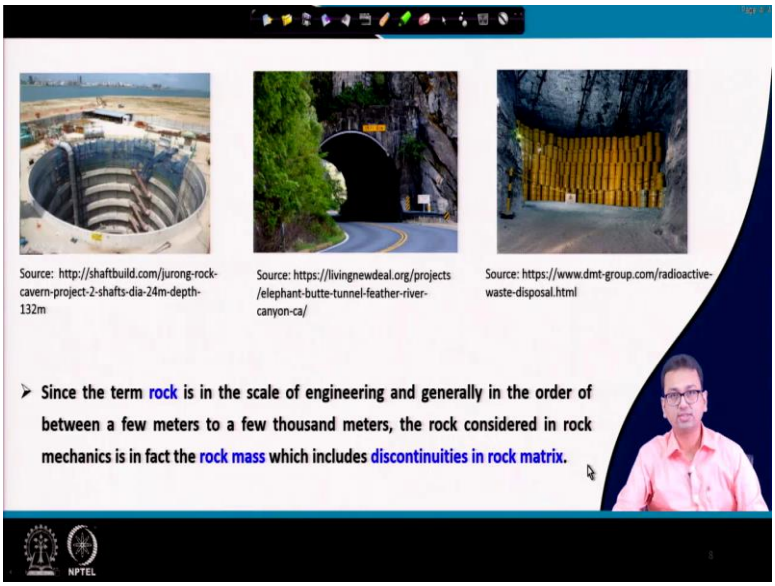

Then, you see the excavation, it is an excavation, a shaft is being constructed here and a vertical excavation. So, it is in the rock. Also a tunnel, this tunnel is in the rock, this is the rock mass and here the tunnel is created. So, you can clearly notice that the rock mass here contain several discontinuities. So, they actually play a major role, when we analyse the stability of this tunnel. And accordingly we need to design this tunnel depending on the presence of these discontinuities and orientation of these discontinuities.

Here, this is an underground storage facility in rock. So, this is also another commonly built structure that we construct inside the rock mass. Other than that, you can see, ancient temples are constructed with the rock. One of the very common examples is 'Taj Mahal' which is made of white marble, so that is nothing but rock only.

Apart from that, one comment is there you see since the term 'rock' is in the scale of engineering and generally in the order of between a few meters to few thousand meters. So, few meters means, if you consider a foundation that may be 2 × 2 m or 5 × 5 m foundation. On the other hand, if you construct a tunnel that may be a length of few thousand meters. So, again let me say this one from the beginning.

Since the rock, term rock is in the scale of engineering and generally in the order of between a few meters to a few thousand meters, the rock considered in rock mechanics is in fact the rock mass which includes discontinuities in rock matrix. Just now, what I have stated that when you construct a tunnel, you need to take into account the effects of these discontinuities, presence of the discontinuities and the orientations of these discontinuities. So, we have to think about the rock mass, which includes discontinuities in the rock matrix.

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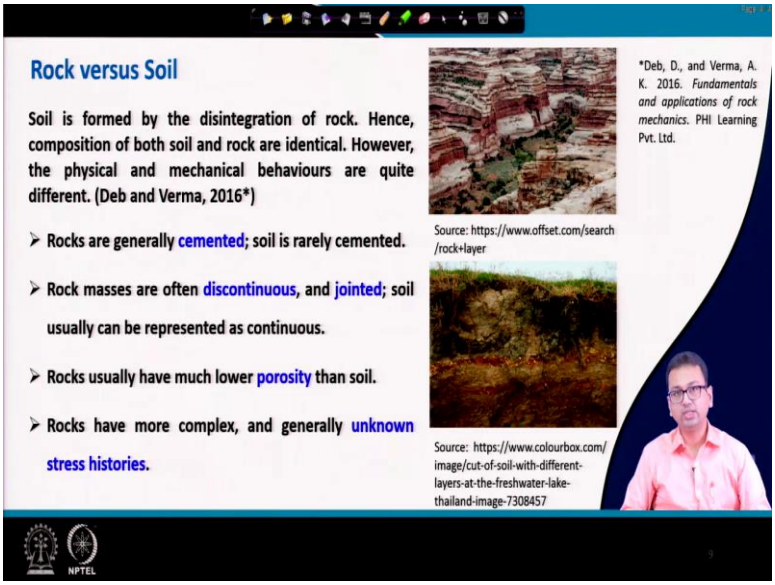

Now, we will briefly discuss about the differences between rock and soil. Here, I have listed some of them, but, definitely if you think you can also find out few more differences. So, let us see what I have written here. So, the soil is formed by the disintegration of rock that we know. So, since soil is formed by the disintegration of rock, the composition of both soil and rock are identical.

However, both these physical and mechanical behaviours are quite different. And why it is different, because, as I have stated that rock is more anisotropic and heterogeneous as compared to soil and most importantly, we see a lot of discontinuities present in rock mass and because of the presence of those discontinuities and orientations of those discontinuities, the strength also differs from case to case.

So, that is why, though the composition of both soil and rock are identical, but physical and mechanical properties are different and that is why we are learning separately this subject rock mechanics and tunneling. So, some of the points are listed here. Rocks are generally cemented; whereas, soil is rarely cemented, that is obvious as you can understand from your own experience also.

If you take some amount of sand in your hand, they are basically not at all cemented; they are separate particles. Rock masses are often discontinuous, as I have stated, they are discontinuous and jointed; whereas, soil usually can be represented as continuous. So, though obviously, in soil also particles are there, but when we go for numerical modelling, we can generally consider the soil as a continuum body.

Whereas, truly speaking, if you want to analyse a rock mass, then we should take into account the discontinuities and joints whatever present there. So, we will discuss about these things in detail and whether we can use continuum model for rock also that we will discuss in detail.

So, next point is rocks usually have much lower porosity than soil. And that also we will see later when we will discuss about the physico-mechanical property, under physical property we will discuss briefly about the porosity. But here this statement can be made that generally rocks have much lower porosity than soil. And also it can be stated that rocks have more complex and generally, unknown stress histories.

Rock is complex because of the presence of these discontinuities, heterogeneity and anisotropy and generally having unknown stress histories, why it is stated is you see rocks are there for millions of years. So, at a particular location may be a few millions years ago, may be what that some other rock mass was there over the period because of weathering.

May be that layer has vanished from that location because of weathering and so, therefore, the stress history of the rock mass becomes quite unknown to us, because it is very old material. So, these are the some of the differences.

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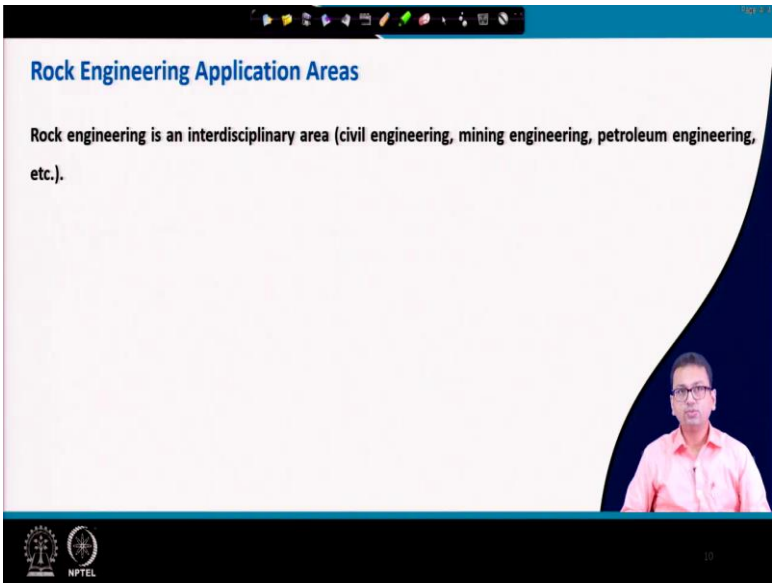

Now, next topic is the rock engineering application areas. Basically, rock engineering is an interdisciplinary area. Its application we can see in civil engineering widely, also widely in mining engineering, as well as in petroleum engineering, we can see its application; not only there, in geology and geophysics also we can see a lot of applications.

So, for example, if we consider a foundation, if we want to construct a foundation over rock mass or if we want to check the stability of a slope and if we find out that the stability is not good enough, we may have to go for some adaptation, improvement techniques. So, like if we want to construct a hydroelectric power project that may be in the hilly terrain, and where we will see mostly the rock masses.

So, the knowledge of rock engineering will help us to construct the civil engineering structure; there are many more application areas which I will discuss in our next lecture. Likewise in case of mining the underground excavations, like vertical excavation as well as horizontal excavation, and tunnel, they are very common problems.

Because may be there is a coal block located at a particular location below ground and in order to access that you may have to first construct a vertical excavation and then you will have to create a tunnel or horizontal excavation to reach up to that point. Likewise in petroleum engineering, for exploring the hydrocarbons, the petroleum engineers have to go for the vertical excavations.

So, they construct the shafts actually and for constructing that also the knowledge of rock engineering becomes quite essential.

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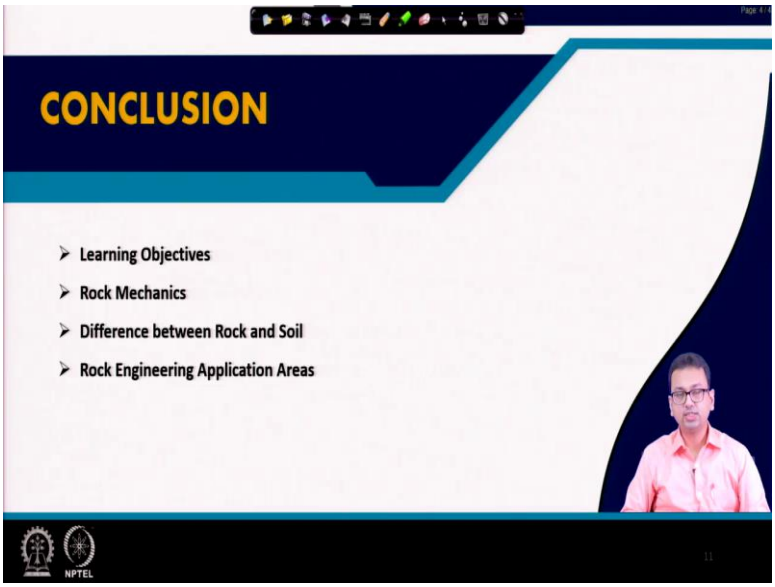

So, with this much discussion, I will conclude our today's lecture. I will start with again the rock mechanics application areas in our next lecture. Thank you!