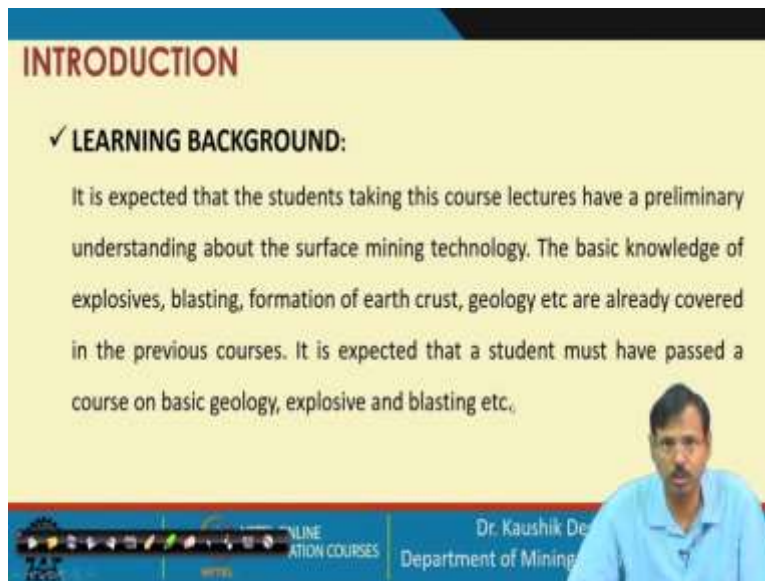


Surface Mining Technology
Professor Kaushik Dey
Department of Mining Engineering
Indian Institute of Technology, Kharagpur
Lecture – 56
Stability of Bench Slopes – I

Let me welcome you to the 56th lecture of NPTEL online certification course Surface Mining Technology. These are the lectures related to stability of bench slopes; there will be 3 lectures on this. This is the first lecture, in which we will introduce you to the bench slope; and we will discuss about the planar failure, which is one type of failure occurred in the bench slope.

(Refer Slide Time: 00:48)



INTRODUCTION

✓ **LEARNING BACKGROUND:**

It is expected that the students taking this course lectures have a preliminary understanding about the surface mining technology. The basic knowledge of explosives, blasting, formation of earth crust, geology etc are already covered in the previous courses. It is expected that a student must have passed a course on basic geology, explosive and blasting etc.

Dr. Kaushik Dey
Department of Mining Engineering

NPTEL ONLINE CERTIFICATION COURSES

INTRODUCTION

✓ Learning Objectives of This Course:

- To know the different unit operations associated with surface mining.
- Methods of surface mining.
- Deployment of machineries in surface mining.
- Productivity analysis of surface mining.
- Safety and environmental control of surface mining operations.
- Special methods of surface mining.



INTRODUCTION

✓ LEARNING OUTCOMES:

It is expected that the students taking this course lectures will be able to envisage the surface mining operation and its technological nitty-gritty. It is expected that a student will be able to design the drilling and blasting rounds for surface blasting, will be able to choose, deploy and design the mine machineries for a set production target. The desired safety and environmental requirements will also be addressed.



But, before that going into the details of this, let us look once again into the learning background required for surface mining technology course. The set learning objectives for the surface mining technology course, and expected learning outcomes.

(Refer Slide Time: 01:06)

INTRODUCTION

✓ **SOME TEXT BOOKS AND REFERENCES**

1. Mishra G. B., 1978, Surface Mining, Dhanbad Publishers
2. Das S. K., 1998, Surface Mining Technology, Lovely Prakashan
3. Deshmukh R. T., 1996, Opencast Mining, M. Publications, Nagpur,.
4. De Amithosh, 1995, Latest Development of Heavy Earth Moving Machinery, Annapurna Publishers
5. Hartman H. L., 2002, Introductory Mining Engineering, Publisher John Willey and sons

Dr. Kaushik Dey
Department of Mining Engineering

INTRODUCTION

✓ **SOME TEXT BOOKS AND REFERENCES**

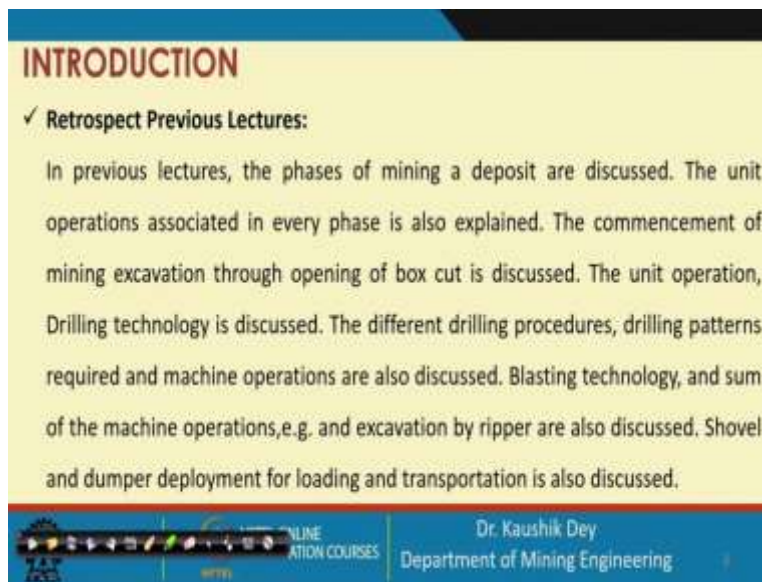
6. Peter Darling, 2011, SME Hand book, SME Publication
7. Rzhovsky, V. V., (1983), Opencast Mining Unit. Operation, Mir publications
8. Rzhovsky, V. V., (1985), Opencast Mining Technology and Integrated Mechanisations, Mir publications

Brown of slope stability manuals

Dr. Kaushik Dey
Department of Mining Engineering

And these are some of the text and reference books; this particular topic slope stability can be looked into the other various books available Brady and Brown, a book on slope stability is very famous. Apart from that, there are other slope stability books available, even if slope stability manuals are also there. So, these books are very common and can be used for further study.

(Refer Slide Time: 01:55)

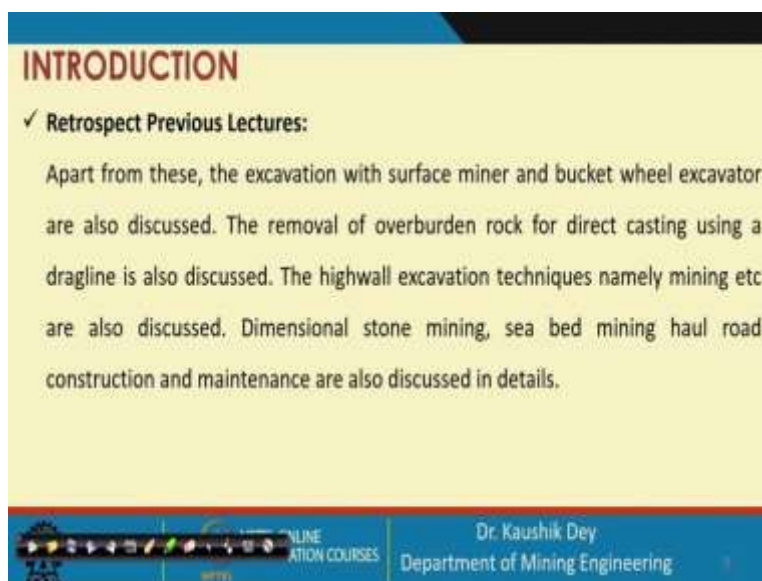


INTRODUCTION

✓ **Retrospect Previous Lectures:**

In previous lectures, the phases of mining a deposit are discussed. The unit operations associated in every phase is also explained. The commencement of mining excavation through opening of box cut is discussed. The unit operation, Drilling technology is discussed. The different drilling procedures, drilling patterns required and machine operations are also discussed. Blasting technology, and sum of the machine operations, e.g. and excavation by ripper are also discussed. Shovel and dumper deployment for loading and transportation is also discussed.

Dr. Kaushik Dey
Department of Mining Engineering



INTRODUCTION

✓ **Retrospect Previous Lectures:**

Apart from these, the excavation with surface miner and bucket wheel excavator are also discussed. The removal of overburden rock for direct casting using a dragline is also discussed. The highwall excavation techniques namely mining etc are also discussed. Dimensional stone mining, sea bed mining haul road construction and maintenance are also discussed in details.

Dr. Kaushik Dey
Department of Mining Engineering

And let us retrospect our previous lectures; we have almost at the end of the syllabus. So far, we have covered the status of the surface mining worldwide. We have covered the phases of mining a deposit; we have covered commencement of surface mining using box cut. We have covered the drilling technology, blasting technology; we have covered excavation by ripper, we have covered the handling of fragmented rock mass by shovel and excavators. And transportation of the same using a dumper or other mode of transportation system. We have covered excavation with surface miner; we have covered excavation with dragline and direct casting of the material.

We have covered the excavation with bucket wheel excavator; we have covered other auxiliary operations required in the surface mining. We have covered the haul road construction and maintenance, we have covered dimensional stone mining, we have covered sea bed mining; and haul road construction also we have discussed, highwall mining is also discussed. So, these are mostly the topics we have covered during this course of surface mining technology. And this is before except the closure of the mine, the last topic we are discussing here, the slope stability.

(Refer Slide Time: 03:26)

INTRODUCTION

✓ **Learning Objectives of This Lecture:**

- To understand the necessity of stabilization of pit slope.
- To understand the different types of slopes
- To understand the possible slope failures
- To learn slope stability analysis.

ONLINE EDUCATION COURSES WITB

Dr. Kaushik Dev
Department of Mining

The set objectives for the lectures pertaining to slope stability are set as, to understand the necessity of stabilization of pit slope, to understand the different types of slopes, to understand the possible slope failures, and to learn the slope stability analysis.

(Refer Slide Time: 03:47)

The slide features a blue header with the title "Slope and its stability" in white. Below the title, the text is as follows:

Stability of slopes, natural or artificial, in soils and rocks is a matter of interest as well as concern to mining and civil engineers, engineering geologists, and environmental engineers/scientists/managers.

Natural slopes are those slopes that have been formed by the various actions of natural agencies, and may be classified broadly into two groups by referring to the state of activity – active slopes and inactive slopes.

Active slopes are those slopes that are either moving presently or not moving currently but have moved within the last seasonal cycle.


In the bottom right corner, there is a video inset showing a man in a light blue shirt. The bottom of the slide has a blue footer with the text "ONLINE EDUCATION COURSES" and "Dr. Kaushik Dev" followed by "Department of Mining".

So, first let us understand what is slope, or what we understand by meaning of stability of slope. The slope is basically characterized as natural slope, and it is of two types; active slope and inactive slope. Slope can be natural or artificial; generally in solid soils and rocks is a matter of interest as well known concern of mining and civil engineers. We are discussing about the slopes. Natural slopes are slopes, which are formed by the various actions of natural agencies, which maybe the flow of the wind; which maybe the flow of the water. And these are classified in active and inactive slope, where active slope is the slope that are moving presently or not moving currently; but have moved within last seasonal cycle, is considered as the active slope. That means if it is a hilly terrain, and there was some movement of the terrain, with in the near past; then that is considered as the active slope.

(Refer Slide Time: 05:07)

Slope and its stability

Courtesy: Prof. Phalguni Sen



Inactive slopes are those slopes where there is no evidence of movement within the last seasonal cycle. These slopes may be in dormant state presently, that is, the failure causes are still present and a movement may take place again, or they might have been stabilized, that is, the factors likely to cause a failure have been removed, naturally or by human activity.

Artificial slopes are the slopes that have been formed as result of human activities. These may also be termed as man-made slopes. These may be subdivided into three main categories – excavation or cut slopes, embankments including earthen dams and spoil or waste heaps.

Dr. Kaushik Dey
Department of Mining Engineering

ONLINE EDUCATION COURSES

Slope and its stability

Courtesy: Prof. Phalguni Sen

Inactive slopes are those slopes where there is no evidence of movement within the last seasonal cycle. These slopes may be in dormant state presently, that is, the failure causes are still present and a movement may take place again, or they might have been stabilized, that is, the factors likely to cause a failure have been removed, naturally or by human activity.

Artificial slopes are the slopes that have been formed as result of human activities. These may also be termed as man-made slopes. These may be subdivided into three main categories – excavation or cut slopes, embankments including earthen dams and spoil or waste heaps.

Dr. Kaushik Dey
Department of Mining Engineering

ONLINE EDUCATION COURSES

Slope and its stability



Inactive slopes are those slopes where there is no evidence of movement within the last seasonal cycle. These slopes may be in dormant state presently, that is, the failure causes are still present and a movement may take place again, or they might have been stabilized, that is, the factors likely to cause a failure have been removed, naturally or by human activity.

Artificial slopes are the slopes that have been formed as result of human activities. These may also be termed as man-made slopes. These may be subdivided into three main categories – excavation cut slopes, embankments including earthen dams and spoil or waste heaps.



Slope and its stability

Courtesy: Prof. Bhagwati Sen

Inactive slopes are those slopes where there is no evidence of movement within the last seasonal cycle. These slopes may be in dormant state presently, that is, the failure causes are still present and a movement may take place again, or they might have been stabilized, that is, the factors likely to cause a failure have been removed, naturally or by human activity.

Artificial slopes are the slopes that have been formed as result of human activities. These may also be termed as man-made slopes. These may be subdivided into three main categories – excavation or cut slopes, embankments including earthen dams and spoil or waste heaps.



If there is no such movement in the near past; that is called the inactive slope. And we are very much concerned about these natural slopes, which are active; especially, stabilization of that work and the safety of the nearby passers, nearby dwellings are required. But, in mining we are creating the artificial slopes. Natural slopes are available with some hilly terrain, where the mining is being carried out in the hills; there are natural slopes existing.

But, apart from that, in mine, we create the artificial slopes also; because we have dugged out the ground. And the slopes are being created as this is the earlier position. But, with the mining, we have excavated like this; so the slopes are new slopes generated. So, new slopes are generated like this. So, that is why we are creating artificial slopes at this position, which is very very

important; these are the man-made slopes. And this is categorized as the excavation, or cut slopes, embankments, earthen dams, and spoils or waste heaps. So, artificially we have carried out slopes in three way.

First is that we cut this, as we have shown the earlier diagram; and this is one possibilities. Second possibility is that this is a natural ground; we are depositing something. These are often carried out for some water movement or making some cannels at these positions. So, or by constructing the roads, say roads are made here; so these are the embankment constructed. And because of that some slopes are generated at this position; so these are called the embankment. And often we do not do anything of this; we are just allowing the dumping of the materials like this. And that is creating the slope; that is the waste dump or waste heap slopes are often created. So, these are the main artificial slopes which are created.

(Refer Slide Time: 07:56)

Slope and its stability Copyright: Prof. Phalguni Sen

Surface Mine Slopes

The formation of slopes in a surface mine is basic to the mining operation. The slopes are made by excavating benches in order to extract the ore body and by dumping the excavated waste rock / overburden. The surface mine slopes may be categorised broadly into two groups:

Highwall slopes (face / front slopes, side slopes and back slopes) are the slopes that are formed by excavation in in-situ rock mass or soil.

Dump slopes are the slopes that are formed by dumping the excavated broken materials (soil or soil-like material such as excavated overburden, waste rock, fills, tailings etc.) If the dump is formed outside the pit limits it is called an external dump, and if it is made within the mined out area within the pit limit it is known as backfilled / internal dump.

MINING ENGINEERING COURSES **Dr. Kaushik Dey**
Department of Mining Engineering

But, here we are basically considering the mining slopes. In mines, in general, we do not make the embankment; so we are concerned about that cut slopes or the overburden dump slopes. So, basically, these are the two types of slopes we are forming. The first one by cutting the benches, we are creating the depth; and that is why the slopes are created. So, that is called cut slopes and the second one is the dump slope, as we are dumping the overburden; that is creating the dump slopes. Often these are internal overburden dumping also; but that is also having the dump slopes.

(Refer Slide Time: 08:37)

Slope and its stability Courtesy: Prof. Phalgun Sen

Highwall Slopes

Bench slope is the slope of the line joining the bench toe and the bench crest.

Berm (or Inter-ramp) slope is the slope of the line joining the crest and the toe of a berm (group of benches) between ramps in an open pit. The berm / inter-ramp slope is a function of bench slope, bench height, bench width and the number of benches in a berm.

Overall pit slope is the slope of the line joining the crest and the toe of the pit. The maximum achievable overall pit slope angle is the function of the berm slope, the number of benches in a berm, number of berms and the width of berms (wide benches containing haulage roads).

Dr. Kaushik Dey
Department of Mining Engg.

Bench slopes are classified in three way; one is the individual slope of a bench, where the crest and toes are joint. And the angle of that is representing the bench slope. Theoretically, all the active benches are having a bench slope of 90 degree; but we try to keep it as as steep as possible, so that the excavation can be carried out properly. The burden of the blasting should be same as the crest and as the toe also. In that consideration we will try to make the slope as high as possible, and theoretically it is 90 degree, we try to maintain.

Berm slope is the slope that the line joining the crest and the toe of a berm; that is the group of benches is called the berm slope; or it is also called inter-ramp slope. The berm or inter-ramp slope is a function of bench slope, bench height and bench width in that number of benches. This is in general carried out, where say overburden having some number of benches; those are considered as a group.

Then, there is the ore body. We are keeping some width between this overburden benches and the ore body; so that is creating a group of benches in the ore body, a group of benches in the overburden. And by that way we are maintaining that called as inter inter-ramp slope or the berm slope. And overall pit slope is the speed slope considering all the benches; and we are in this case considering the crest of the top most or the surface, topmost bench or that surface; and the toe of the bottom most bench or the pit. So, in consideration of that one whatever slope angle is obtained; that is called overall pit slope angle.

(Refer Slide Time: 10:41)

Slope and its stability Courtesy: Prof. Pabipal Sen

H – Bench Height BH – Berm Height W – Bench Width
BW – Berm Width α – Bench Face Slope β – Berm Slope
 γ – Overall Pit Slope

Elements of Highwall Slope

ONLINE EDUCATION COURSES Dr. Kaushik Dey
Department of Mining Engg.

Slope and its stability Courtesy: Prof. Pabipal Sen

H – Bench Height BH – Berm Height W – Bench Width
BW – Berm Width α – Bench Face Slope β – Berm Slope
 γ – Overall Pit Slope

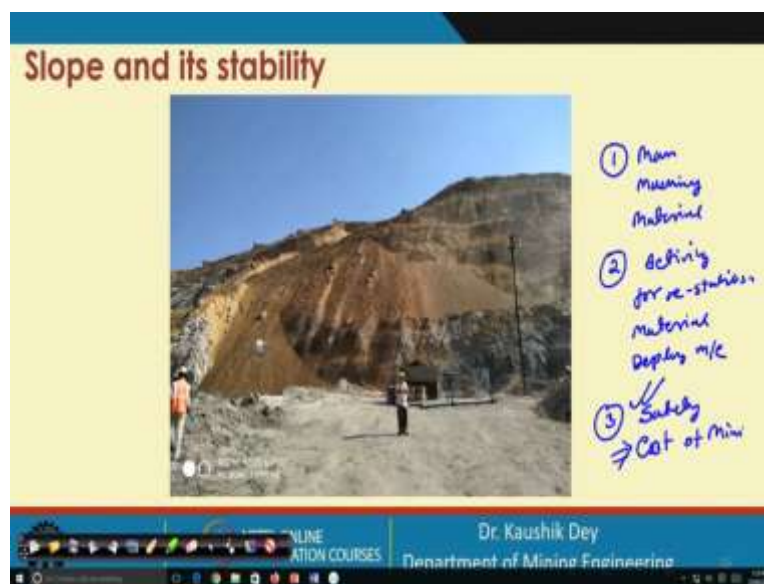
Elements of Highwall Slope

ONLINE EDUCATION COURSES Dr. Kaushik Dey
Department of Mining Engg.

So, when we are presenting it in a pictorial form, it can be seen. This is a bench slope, this is a berm slope, and this is a pit slope or overall pit slope. But, the bench slopes, there are many bench slopes; these slopes maybe different. Similarly, there are many berm slopes; these berm slopes angle maybe different, depending on the type of benches and etcetera. So, we can tell that this maybe B1, B2, B3; and these are the individual benches, maybe alpha1, alpha2 or something like that. But, overall pit slopes remain same; these are the individual bench width. These are the individual bench width, and these are the bench height; these are the berm width, this is bench width. Let me write completely.

This is bench height, this is berm width, and this is berm height; and this is overall pit height, pit depth, so this is the general terminology. And we can understand this generally, whenever a mining is carried out as any mine is progressing. In general, a mine is progressing in this direction; in these places, we are having the operating benches. But, these are the side walls, where in general, we reach up to the pit depth; and this wall is are called highwall. And the slope stability we are concerned about in this highwall especially, because those are very steep in nature.

(Refer Slide Time: 13:59)



So, this is one photograph of a slope failure; it can be seen how this slope is failed, this portion, how the slope is failed. And it is very understood that the failure of slope may result in the loss of man, machinery, material. Apart from that it involves in the activity for re-stabilization, material handling, deployment of machines. So, these are unwanted because it is a threat to the safety; it increases the cost of mining significantly.

So, these are the main drawbacks, so the slope stability is very very important. Considering this one very first requirement for this it is essentially required. Apart from that, these are very costly operations also, if million tons of million-meter cubes of materials are sliding down. Then, that is creating a problem, and the re-handling cost of this million-meter cube of material is becoming a very costly operation.

(Refer Slide Time: 15:59)

Slope and its stability

- Slope stability of any slope whether overburden slope or pit slope is the potential of slopes to withstand any movement due to imbalance of forces which were in equilibrium
- Stability is determined by checking the balance between stresses acting on the slopes to strength of the slopes
- Before mining, (generally) the ground remains in stable equilibrium condition; mining disturbs the equilibrium of stresses and hence stability needs to be accessed to check whether the slopes are stable or not
- The field of stability of slopes, whether pit slope or dump slope, encompasses static and dynamic stability analysis of the slopes

Image Source: <https://www.google.com/search?q=slope+stability+condition+compaction>

Dr. Kaushik Dey
Department of Mining Engineering

So, slope stability: stability of any slope whether overburden slope or pit slope, is the potential of slopes to withstand any movement due to imbalance of forces, which were in equilibrium. So, suppose whether it will be moving in this side or not, that is depending on the changes in the forces acting on this. And that is why whatever the shear force is coming at this position; that is depending on the shear strength of this one. That is frictional forces depending on the normal force, which we are providing; so, weight of the material is also important. Safety is determined by checking the balance between the stress acting on this.

Before mining, the ground remains in stable equilibrium condition; mining disturbs the equilibrium. And that is why this stress are being induced, and the static and dynamic stability analysis should be carried out, for the pit slopes and dump slopes; while, the mining is being carried out to ascertain the stability of the place.

(Refer Slide Time: 17:16)

What controls the stability of slope

Stability of any engineered slopes depends on various parameters

- Slope angle is an important properties for the stability of slopes
- Material properties (s , c , ϕ)
- Geological properties (Discontinuities \rightarrow oriented \rightarrow Properties)
- Hydrogeological factors \rightarrow water

The slide includes a diagram of a slope with a failure surface and another diagram showing a road cut with labels: 'Steep cut slope', 'Removed material', 'Road surface', 'Removed material used as fill', and 'Steep filled slope'. Handwritten notes in blue and red ink are present on the slide, including a checkmark next to 'Slope angle' and a circle around 'Hydrogeological factors'.

Dr. Kaushik Dey
Department of Mining Engineering

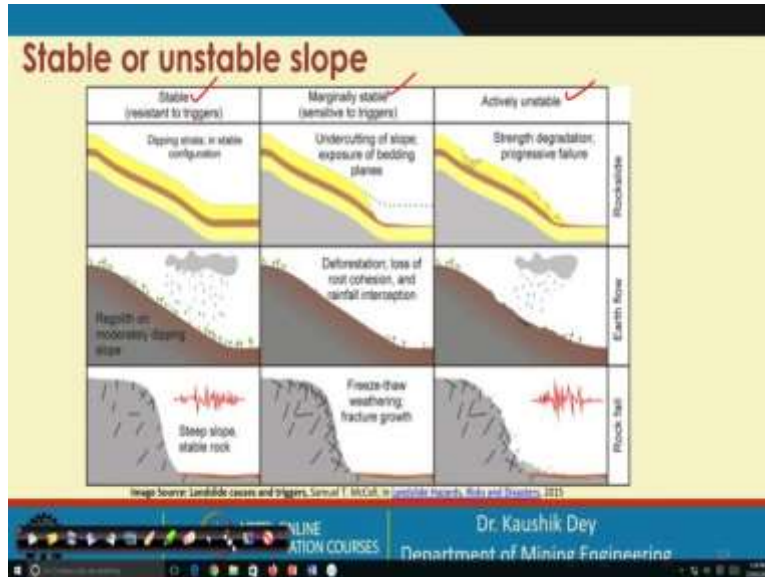
So, let us look what are the influential factors; that is controlling the stability of a slope. Slope angle is very very important; that means if we are having a bench, this may not be stable. But, instead of if we are having a bench, this angle maybe stable, because it is much of reduced inclination; so, the slope angle is very one. Second is the material properties- if the material here is very strong, then it can withstand this one. But, if it not much that strong, then it cannot withstand. In this material property, the major material property is the strength of the rock; especially, the shear strength, the cohesion, the friction angle all these are important in this case.

Next, is the geological property; that means if we are having some discontinuity plane; let us draw it in different color. Say, if we are having some discontinuity planes like this; this, then this allows the falling of this discontinuity planes, but material over this. But if we are having a discontinuity plane like this, this is stable enough; and this will not allow the fall of material along that discontinuity plane in this direction. So, the orientations, discontinuity plane and their orientations, and their properties; these are some important parameters and needs to be considered, while we are considering the stability of a slope.

And finally, the hydrogeological factors, that is the in-situ water, surface waters, what are the stress coming on to this mass rock mass, which is tending to falling from the slope. And what is the saturation, increase in the weight of the rock mass because of the saturation of the water; so,

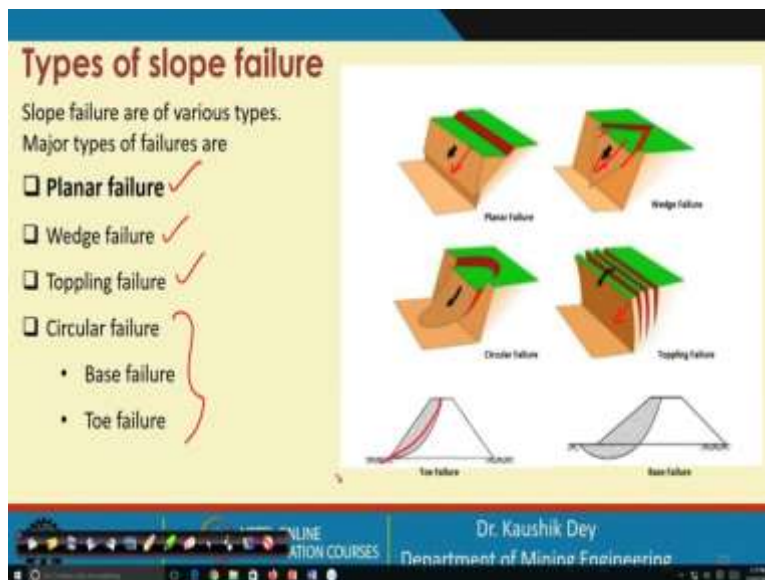
these two are the factors. That is the factors pertaining to water needs to be considered in this as the hydrogeological factor, which are influencing the stability of one slope.

(Refer Slide Time: 19:58)



Now, these are the different considerations, whether a slope is stable or marginally stable, or it is an active one. And what are the different factors, which are affecting these things are basically shown in this figure.

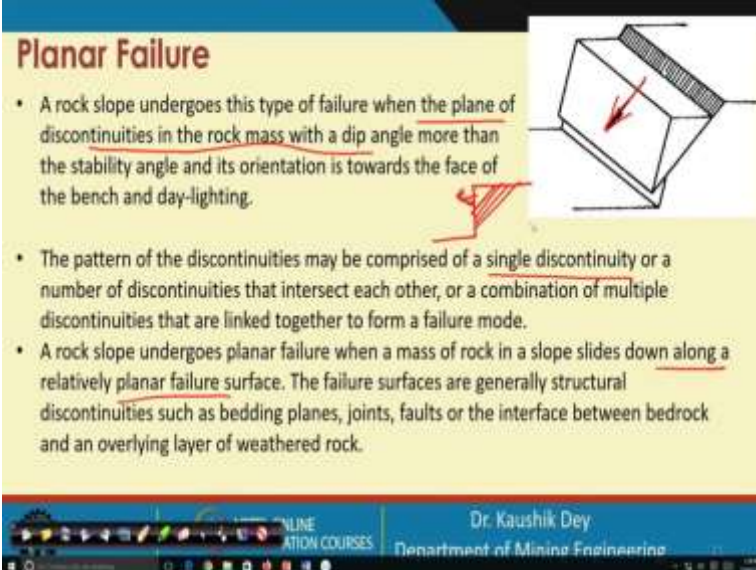
(Refer Slide Time: 20:18)



And these are the different types of failures, which we observed commonly in a mining slope. First one is the planar slope, where the plane of rock is falling down. Second one is wedge slope, where the wedges is formed by virtue of the different discontinuity planes. And then the whatever rock mass is coming within that wedge that is sliding down. Toppling failure is one kind of planar failure only, where the two sets of plane two two sets of two joint sets, or discontinuity planes are created; and the one by one, the columns are doubled down.

And circular failure is the failure, where the rock mass is slided down in soil in general. Or, very very highly fractured rock mass it is observed, where it is completely failed. The material is failed, because it is a soft material and it is not following any discontinuity planes; it is slided down as the material is highly fractured.

(Refer Slide Time: 21:25)



Planar Failure

- A rock slope undergoes this type of failure when the plane of discontinuities in the rock mass with a dip angle more than the stability angle and its orientation is towards the face of the bench and day-lighting.
- The pattern of the discontinuities may be comprised of a single discontinuity or a number of discontinuities that intersect each other, or a combination of multiple discontinuities that are linked together to form a failure mode.
- A rock slope undergoes planar failure when a mass of rock in a slope slides down along a relatively planar failure surface. The failure surfaces are generally structural discontinuities such as bedding planes, joints, faults or the interface between bedrock and an overlying layer of weathered rock.

Dr. Kaushik Dey
Department of Mine Engineering

Now, in this lecture, we will end with the planar failure; so, let us look what is planar failure. Basically, planar failure is a type of failure when the plane of discontinuities in the rock mass with a deep angle more than the stability angle. Or, you can say the angle of repose, or friction angle, and its orientation is towards the face of the bench and delighting. Then, the chances of failure of this rock mass are there; and that is called a planar failure.

So, here the important part is the discontinuity plane, its pattern is very very important. It may be continuing a single discontinuity, or it may be a set of discontinuities. Or, it may be a set of

discontinuities, it may link together also. And the rock mass is slid down along this plane. And it occurs in most of the cases, if we are failed to control the direction of our benching.

(Refer Slide Time: 22:52)

Planar Failure

Factor of safety for the sliding block is

$$FOS = \frac{Ac + w \cos \alpha \cdot \tan \phi}{w \sin \alpha}$$

w = weight of sliding block
A = area of contact of block for unit width
c = cohesion

Discontinuity plane is plane AC,
Inclination of the discontinuity plane is α
Slope angle of the rock slope is β
Slope height is H

The force that is holding the slope in position is $(A \cdot c + w \cos \alpha \cdot \tan \phi)$
The destabilizing force is $w \sin \alpha$

Handwritten notes:
 $A > \alpha > \phi$
 $FOS = \frac{\text{Destabilizing Force}}{\text{Stabilizing Force}} = 1.5$

Dr. Kaushik De
Department of Mining

So, now, if we are looking into this, if we are considering this rock mass, or in word; say this rock mass weight is w acting here. And then there are two components, sin alpha and cos alpha; this alpha is the angle of discontinuity plane with the horizontal. And it is acting at a depth of h, while the bench height is H. So, this bench angle beta is greater than the alpha, and this alpha is greater than the friction angle phi. So, if this is the considerations occurs, we are trying to find out what is the destabilizing force, and what is a stabilizing force. So, this destabilizing forces this one, which is trying to send this rock mass at this position.

And stabilizing force is that the frictional component which is coming; that is the mu into w sin alpha whatever is coming, that is the frictional component. So, if we are considering this along with the cohesion, then the factor of safety which is the stabilizing force, stabilizing force by the destabilizing force; or we can say the strength by the stress also. So, the stabilizing force is the cohesion plus, frictional component frictional force; and destabilizing force is the weight component of the rock mass. So, if we are considering this one, then whatever value you are getting that is considered as the; that is considered as the factor of safety.

So, for our open cast slop benches, we have to find out that this for a factor of safety should be 1.5 for a long term stability; and more than 1.2 for the short term stability we can consider. And

depending on that we have to carry out the analysis. So, planar failure analysis required the holistic joint survey, and we have to find out the material properties.

(Refer Slide Time: 25:31)

Planar Failure

- In open pit mines, planar, wedge toppling and rock fall are the common modes of failure
- Planar mode of failure are seen in stratified sedimentary and meta-sedimentary rock formations
- It generally occurs when structural discontinuities plane dips or daylight towards the pit at an angle smaller than the face angle and greater than the friction angle of the discontinuity surface
- In this type of failure, the strike of potential discontinuity surface is nearly parallel to the slope face

Dr. Kaushik Dey
Department of Mining Engineering

Generally, planar failure is observed in mostly the sedimentary deposit; because the sedimentary deposits are having clear joint sets. And the discontinuity plane dips or daylight towards the pit at an angle smaller than the face angle, and greater than the friction angle. So, the important part is that greater than the friction angle, smaller than the slope angle is well understood. But, this material will fall down, only when it is daylighting towards the face.

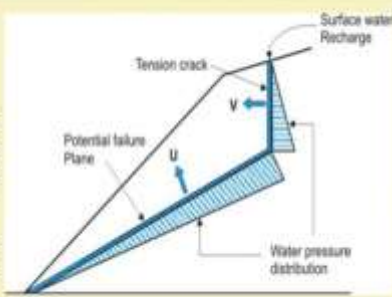
So that means, if we are having this joint set, this will fall down if it is open towards this side. But, instead this joint set will remain same, but instead of having the bench direction at this side, if we are changed our bench direction to this side. This same joint will not pose any threat to the failure of this planar failure of this rock mass. So, that is why this daylighting is very very important, if the direction is daylighting towards that one; and then only it will fail, otherwise it is not failing at this side. So, the orientation and daylighting is very very important one in the slope failure analysis.

(Refer Slide Time: 27:01)

Planar Failure

Effect of water

- Surface flow of water on upper slope will find its way easily through the tension crack to recharge the potential failure surface
- This water in tension crack will develop a water force (V) and also an uplift water force (U) which is along the potential failure surface
- This reduces the holding force or in other words increases the destabilizing force



The figure is showing the water force and its pressure distribution in slope having potential plane mode of failure

Dr. Kaushik Dey
Department of Mining Engineering


Now, there some effect of water is also there, if we are having surface water or underground water is percolating through these cracks, then the water is acting in two ways. One is that it is giving a thrust in this direction; and second is that due to the buoyancy, it is reducing the $w \cos \alpha$. So, in other turn it is reducing the frictional force; and, as well as in saturated rock mass cohesion is also becoming 0. So, basically the water in the rock slope is reducing the stability and that is why it is a threat; it is a threat to the stability of the rock mass.

(Refer Slide Time: 27:55)

Governing Factors

Stability of slopes whether natural or engineered, is concerned with the relationship between stabilizing and destabilizing forces. Some factors contributes to the stabilizing force where as some contributes to the destabilizing force

INTERNAL FACTORS	EXTERNAL FACTORS
<ul style="list-style-type: none">• Characteristics of potential failure plane• Surface drainage & Ground water condition	<ul style="list-style-type: none">• Rainfall• Seismicity• Slope Geometry



Dr. Kaushik Dey
Department of Mining Engineering

So, there are different factors which is governing the stability; these are the characteristics of the failure plane, surface drainage, ground water condition; external factor rainfall, seismicity, maybe the earthquake, slope geometries, these are some of the important factor. And the best way to control the planar failure is the change in the orientation of the bench, considered to be the best thing.

(Refer Slide Time: 28:24)

INTRODUCTION

INTERNAL FACTORS

- **Characteristics of potential failure plane**
- Surface drainage & Ground water condition

• The resisting forces along the potential failure surface is grossly defined by shear strength parameters

• Shear strength parameters are: cohesion and angle of internal friction

• When the cohesion and friction angle value is higher, then the slope is less like to fail unless the destabilizing force is not increased

• Angle of the potential failure plane with the horizontal is also important

• Higher angle then the angle of repose increases the destabilizing force

ONLINE EDUCATION COURSES

Dr. Kaushik De
Department of Mining

So, these are some of the characteristics of the planar failure, and these are should be controlled during this planar failure analysis. Thank you.