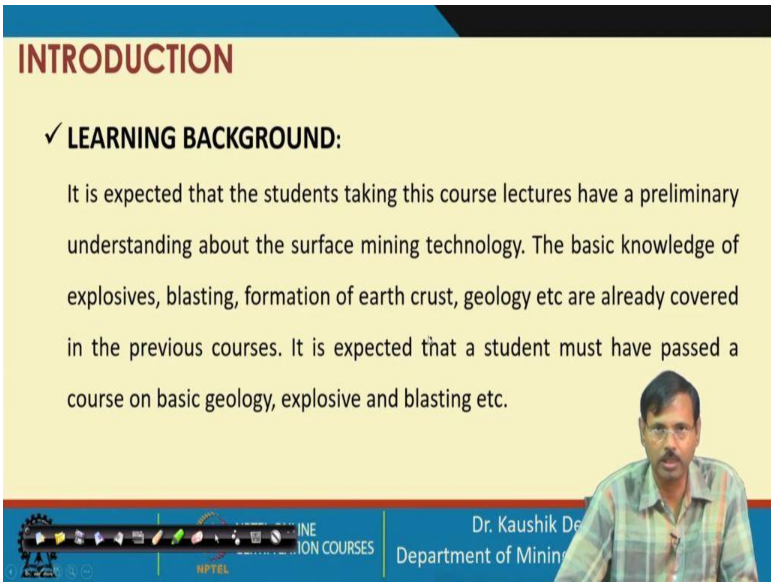
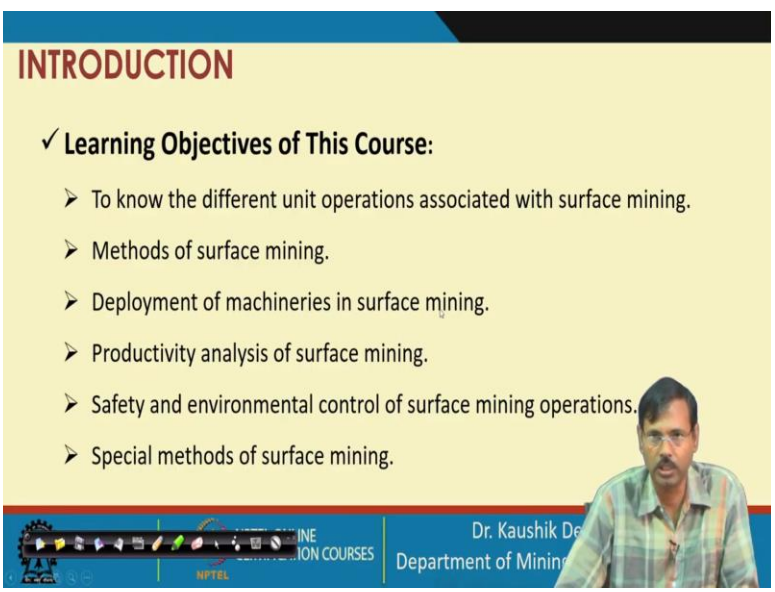
Surface Mining Technology
Professor. Kaushik Dey
Department of Mining Engineering
Indian Institute of Technology, Kharagpur
Lecture No. 41
Highwall Mining – III

Let me welcome you to the forty first lecture of NPTEL online certification course surface mining technology. This is the third and final lecture on the highwall mining; and in this lecture will basically discuss about designing a highwall mine face.

(Refer Slide Time: 00:44)





INTRODUCTION

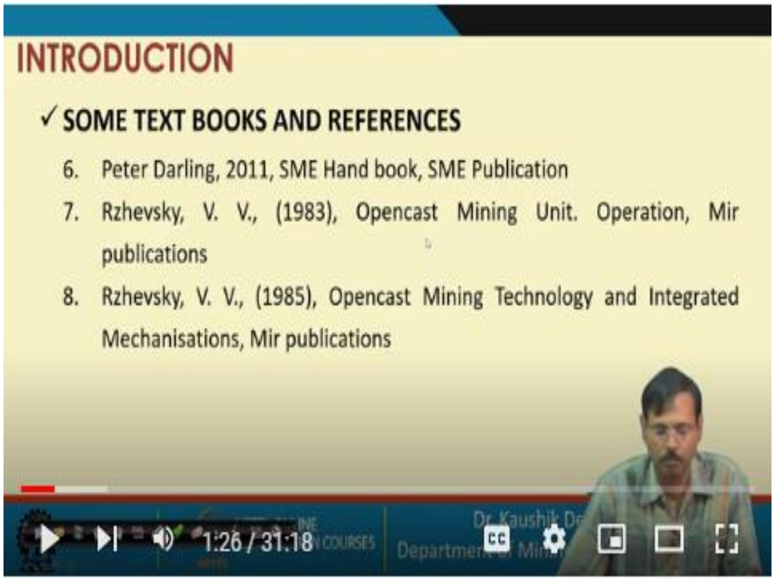
✓ **LEARNING OUTCOMES:**

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 abled 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 and environmental requirements will also be addressed.

INTRODUCTION

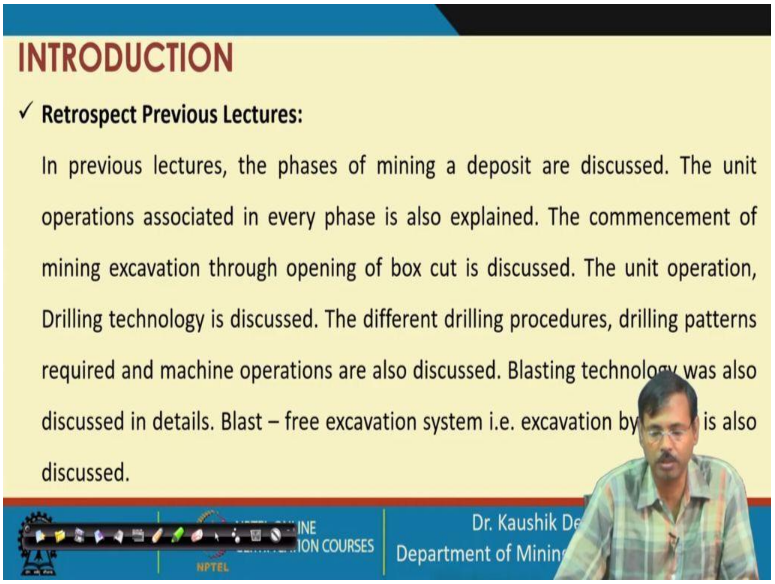
✓ **SOME TEXT BOOKS AND REFERENCES**

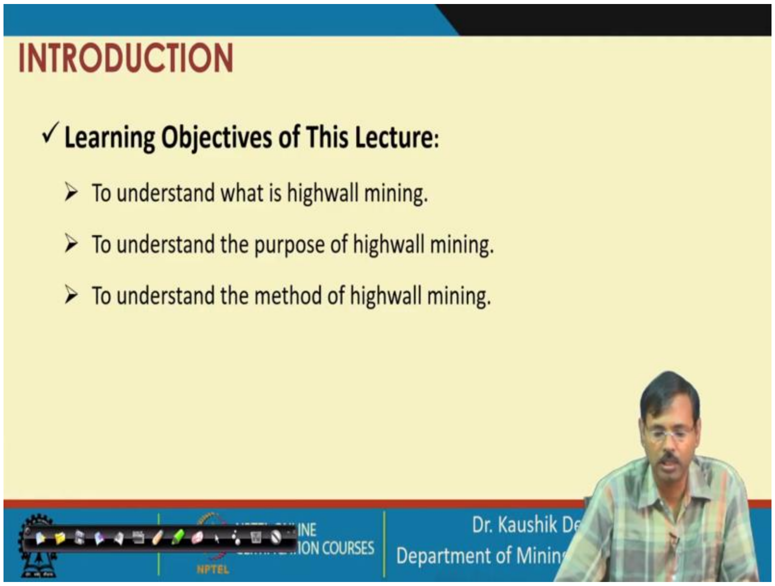
1. Mishra G. B., 1978, Surface Mining, Dhanbad Publishers
2. Das S. K., 1998, Surface Mining Technology, Lovely Prakashan
3. Deshmukh R. T., 1996, Opencast Mining, M. Publications, Nagpur,.
4. De Amithosh, 1995, Latest Development of Heavy Earth Moving Machinery, Annapurna Publishers
5. Hartman H. L.,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



But, before that let us have once look into the learning background required for surface mining technology course in NPTEL. This is the learning objectives set for the surface mining technology course. And these are the learning outcomes expected from the participants of the surface mining technology course; and these are some of the text and reference books. Most of the part of the Highwall is taken from the websites, because this is a new technology, and not available in these books. And these are few more text and reference books.

(Refer Slide Time: 01:31)





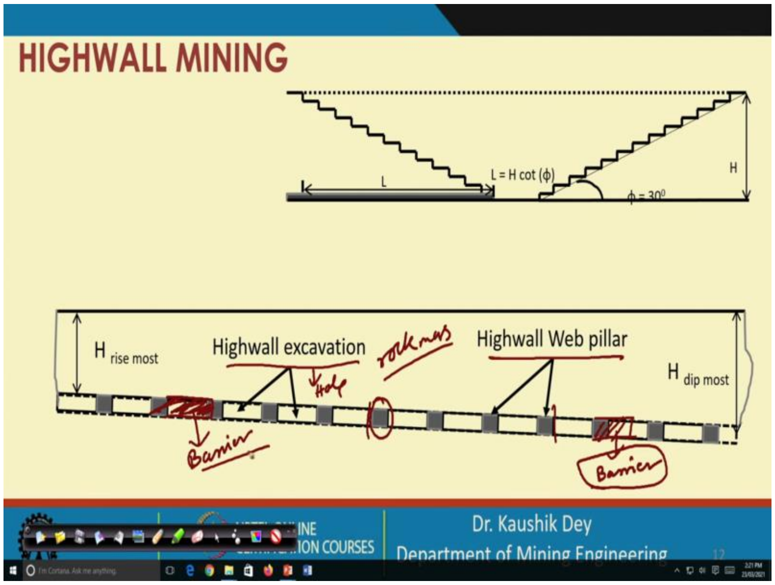
And let us retrospect once again so far whatever we have covered. So, far we have covered the phases of mining a deposit. We have covered the unit operations associated with every phase; we have covered the commencement of surface mining using opening through box cut. We have covered the drilling technology, which is required for positioning the charging the positioning the holes for charging the explosive.

Then, we have covered the blasting technology, blast designing in details; blast free technology like excavation by ripper is also discussed. And after that we have discussed the material handling or the handling of the fragmented rocks by the shovel or excavators, followed by we have discussed the transportation system in surface mines. We mainly emphasize on the dumper transportation system and shovel dumper combinations.

After that, we have discussed the excavation by surface miner. Then excavation and casting of the overburden material by dragline; and after that we are following the lectures pertaining to highwall mining, which is a new technology. So, in the last two lectures of highwall mining, we have covered major part that is the mining method, types of highwall mining, all these are discussed.

And the learning objective sets for the lectures pertaining to highwall mining to understand the highwall mining, understand the purpose of firewall mining, and understand the methods of highwall mining. But along with that, we will learn something related to how to design a highwall face.

(Refer Slide Time: 03:24)



So, we know the terminology is important in this case, because we have to design. So, if this is the slope angle, and this is the seam, we have to find out how the stability has to be given. And we know here, basically the overburdened rock mass, this rock mass; the load of this rock mass is basically taken by these pillars, which are called web pillar. And the excavations are made, which is called highwall excavation, or also called hole.

And after say few pillars, in general we kept a large pillar; that is also called barrier pillar, which is not shown in this figure. So, we provide a barrier pillar, so there may be one barrier pillar at this position. So, this is another barrier pillar. So there are few web pillars, and there are few barrier pillars; and all together they are supporting the top rock mass which is basically the highwall. So, this is the concept in general adopted in a highwall mining.

(Refer Slide Time: 04:53)

Let us look once into the how the highwall mining carried out. So, these are the highwall mining carried out, you can see the holes are there; this is the highwall miner is cutting. And these are the pusher beams, which is pushing the cutter head; and you can see this is the highwall mining. This is the pusher beam and this is the discharge conveyor discharging the cut material; so, these are the pusher beams kept at this position.

So, the highwall miner is operating here. Actually the position required for highwall mining is not significantly high. In a small position, the highwall miner can work; and this is how a pusher beam is placed. This cutter head, and for extra low, medium, high seam different types of cutters head are available. And up to 4.5 meter can be excavated by the cutter head; these are all caterpillar highwall miner.

And this is the propelling of the highwall miner towards the face, which is a four crawler machine; and these are the basic dimensions of the machines. This is fully automated control units available; all those controlling cables, power cables are taken from this. And this is the anchoring system, how the machine is anchored with the floor; so, by this way, the machine is anchored with the floors.

So, after pushing it, machine cannot be revert back, because it is tightly anchored into the floor. Now, the pusher beam is pushed forward, and the cutter head is having a constant thrust from the machine. So, this is the pusher beam pushed; and all pusher beams having the auger fitted with this.

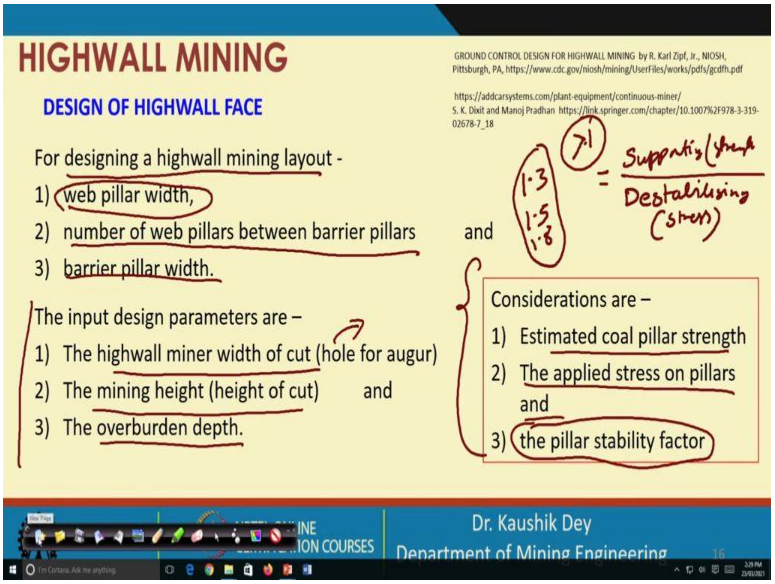
So that the material cut by the miner can be thrown back by this augers. So, these are the augers, which takes the material and throw the material in the backside. And by this way, this pusher beams are attached to each other with these clamps. This is the primary conveyor, discharging the material to the secondary discharge conveyor; discharge conveyor is making the heap and heap is taken by the wheel loader.

Approximately 300 meter can be excavated by the highwall miner; highwall miner can operate on electrical power also; and that is much more energy efficient. These are the control units and the controlling is soft controlling. So, now let us look into the another video is available, how the holes are carried out or excavations are carried out.

(Refer Slide Time: 09:28)

So, this is how excavations along with the pusher beam is pushing; and this is the speed of the movement. So, the performance of the highwall miner can be controlled with this; this is how the roof rocks are fractured, roof rocks are falling onto the cutter. Now, let us go for designing this one.

(Refer Slide Time: 10:47)

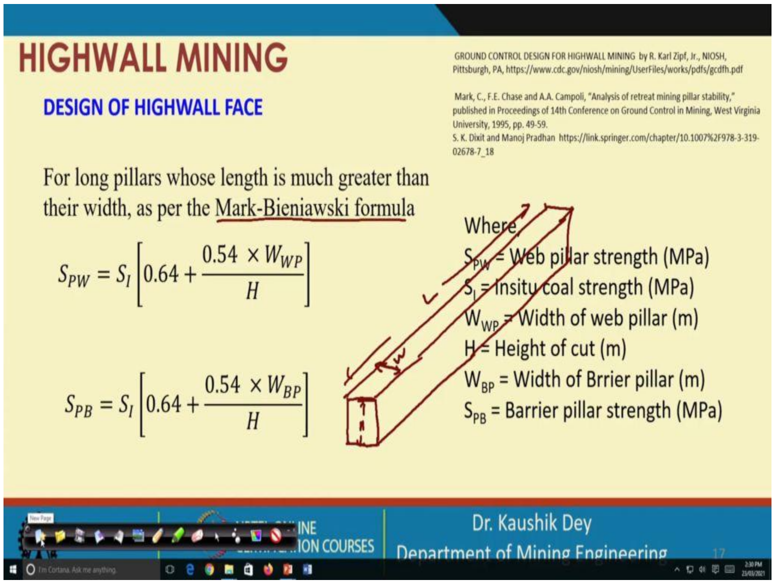


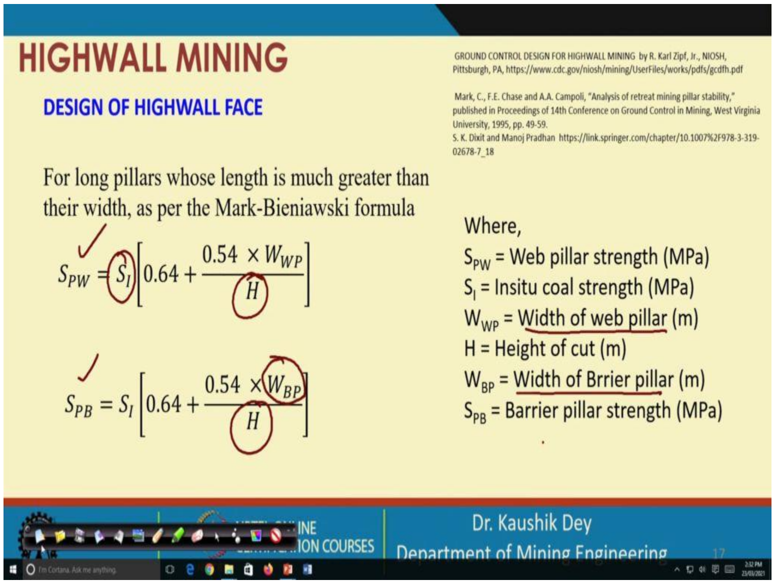
For designing a high wall face, the requirement is that desig the highwall mining layout; that is the web pillar width, number of pillars in between the barrier pillars, and the barrier pillar width. So, this is the requirement of a designing a highwall mining layout; and the design parameters, which are required for determining this, the highwall miner width of cut for auger. That is the diameter of the auger, mining height that is the height of cut; and the overburden cover depth that is required the supporting.

And what the estimations are made? The estimations are made that strength of the coal pillar, which is acting as the web pillar and the barrier pillar; we have to estimate the strength of that. And what is the apply stress coming on to the coal pillar; that has to be considered, or that has to be a designed estimate. And we have to consider a safety factor; that is the pillar stability factor, so that the supporting force that is strength must be higher than the destabilizing force, that is the stress.

And what this ratio you are expecting, that is the considerations, where whether we are considering 1.3 is sufficient or 1.5 is required, or 1.8 is required; this is the essential understanding. But there is no doubt on this, this must be greater than one, so, this is the design considerations in, so, let us go by one by one.

(Refer Slide Time: 13:07)





This is one particular concept, in which the Mark-Bieniawski formula can be used, which is valid for the long pillar of whose length is much greater than the width. So, if there is a pillar, whose length is significantly greater than its width. So, in that case, this formula, this is the width, this is the length, and this is the height. In that case, this Mark-Bieniawski formula is applicable.

And here, the formula utilized is:

$$S_{PW} = S_I \left[0.64 + \frac{0.54 \times W_{WP}}{H}\right]$$

where S_{PW} is the web pillar strength. S_I is the insitu coal strength, W_{WP} is the width of the web pillar, and H is the height of the cut. So, in that case, the web pillar strength can be determined using this formula; similarly, for the barrier pillar.

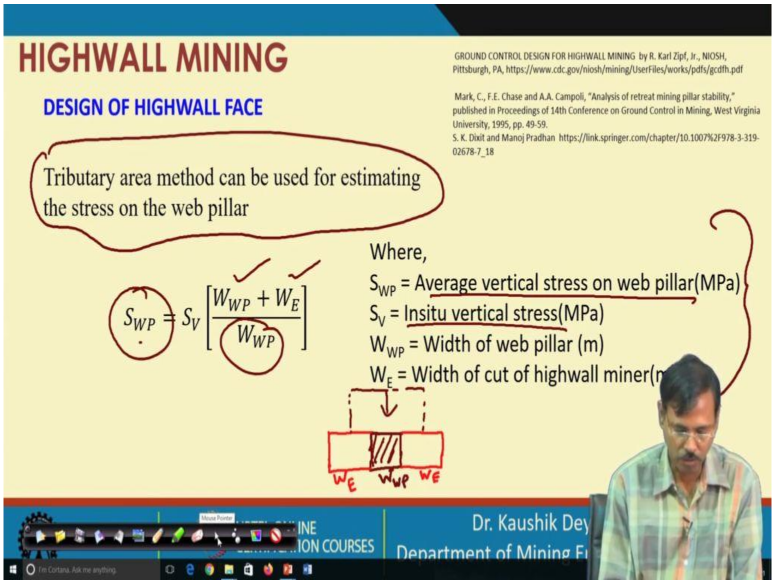
The same formula is useful for the barrier pillar,

$$S_{PB} = S_I \left[0.64 + \frac{0.54 \times W_{BP}}{H}\right]$$

where S_{PB} the strength is called barrier pillar strength is. S_I is the insitu coal, because barrier pillar is also made of coal. So, this is insitu coal strength, and the W_{BP} is the width of the barrier pillar, and H is the height of excavation is considered. So, these are the two strength parameters, which are considered in this case. And from by this width of web pillar is and width of barrier pillar, we have to take it initially; and then from there we have to establish the strength.

So, first we have to iterate it, we will consider whether the width of the web pillar is 3 meter, or 4 meter or 2 meter; or width of the barrier pillar is 8 meter, we will consider this. S_I is known to us, insitu coal strength; and H is already our designated the highwall miner cutting height. From there we find out the strength of the pillars like this.

(Refer Slide Time: 16:18)

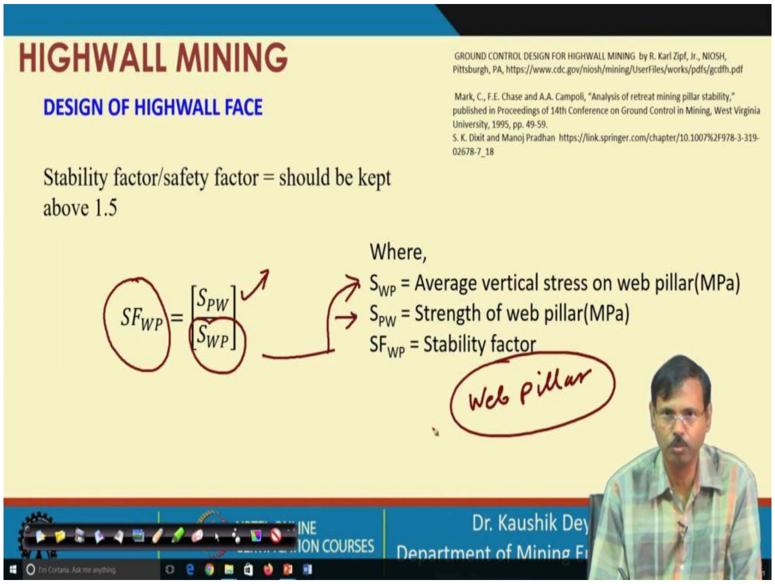


And after completion of this one, we have to find out the average stress coming on to the web pillar. So, what is the formula for this? This is actually, we use tributary area method, in which we are estimating the how much load is coming on to the pillar. So, where S_{WP} is the stress, S_V is the insitu vertical stress; often we consider the weight of the material. And this is width of the web pillar, and this is width of the cut.

So, that means if we are considering this is the width of the pillar W; then it is having one adjacent cut at this position. So, this is W_E this is W_E, and this is W_{WP}. So, in tributary area method, we are considering the load of this one is coming on to the pillar; so the stress of this oe is that is the load. That is vertical stress and that is multiplied with the area that is we are considering this is the length.

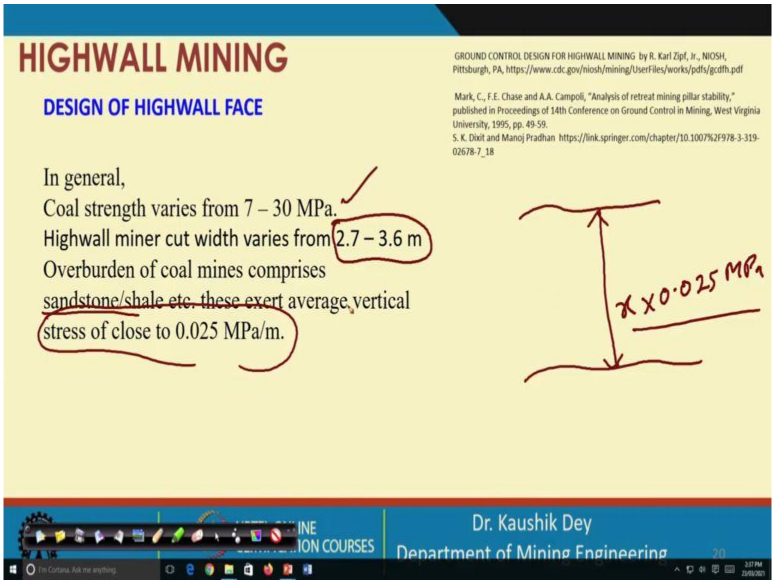
So, W_{WP} plus W_E, this is the stress acting on this; and this is the load or length which is taking that load. So, this is the tributary area method; we are taking the calculating the stress considering this. Now, with these considerations, we are finding out the stress coming on this; and then we can find out the safety factor.

(Refer Slide Time: 18:51)



Now, the safety factor, now the safety factor: this one is the strength, which we have obtained from the Mark-Bieniawski formula; divided by the stress which has come from the tributary area method. So, this is the safety factor or we can say stability factor for the web pillar. So, applications of these are very easy; this formula very simple formula; and that can be easily used for this designing purpose.

(Refer Slide Time: 19:38)

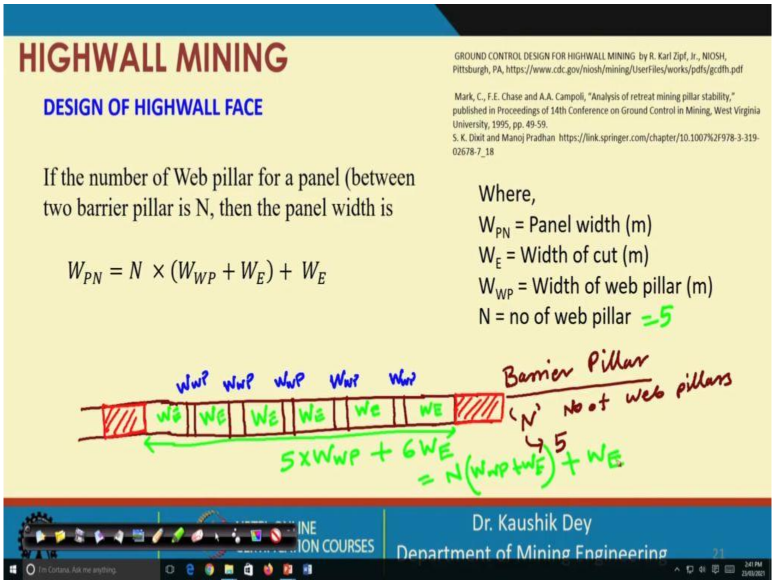


And in that some of the general information's, coal strength are varying from 7 to 30 MPa; in some of the Indian coals it is up to 40 MPa also: that is the compressive. Highwall miner can commercially available to cut 2.7 to 3.6 meter width; and overburden of the coal rock. In general comprises sandstone/shale, maybe fine grains coarse grain sandstone; some of the mixing of this gray shale all these are available.

And generally, as considering the density it has been found the stress they are exerting is close to 0.25 Mega Pascal per meter of depth. So, that means if we know the height, depth of cover; we can assume that if it is x, the vertical stress coming on to this is x into 0.025 Mega Pascal can be considered.

So, this is a rule of thumb, this may not be always true; but most of the coal mining cases, where the sandstone/shale etcetera are, in general, found as the overburden rock. These are the values obtained there. So, this is the design considerations for the web pillar to determine this.

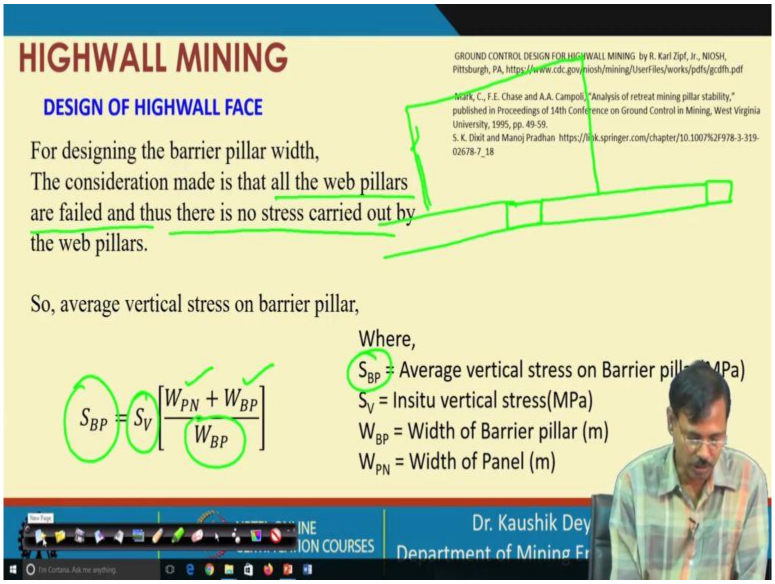
(Refer Slide Time: 21:07)



However, for the barrier pillar, the values are little bit different. The reason is that if we are considering, say our, we will keep the barrier pillar whose width we have already calculated for the strength. And we have considered we will leave a barrier pillar after N number of web pillars. So, that means if this is the coal seam we are considering, say N is equal to 5. So, we will keep 5 web pillars, say these are the web pillars, say these are the 5 web pillars. And as per our design considerations after 5 web pillars we will leave a barrier pillar. Say, let us make our barrier pillar as red; so these are the barrier pillars.

Now, our width of the web pillar is W_{WP}; and our width of excavation that W_E, so this is W_E, this is W_E. So, our panel width is this much, so this is equal to 5 into W_{WP} plus 6 into W_E. So, we can say as our N is equal to 5 as we have considered in this case; so this is N into W_{WP} plus W_E. So, this is the panel width that is the width between two consecutive barrier pillar; this is the considerations we have made in this case. Now, while this is understood, now while we are doing this, we have also considered few more things.

(Refer Slide Time: 25:11)

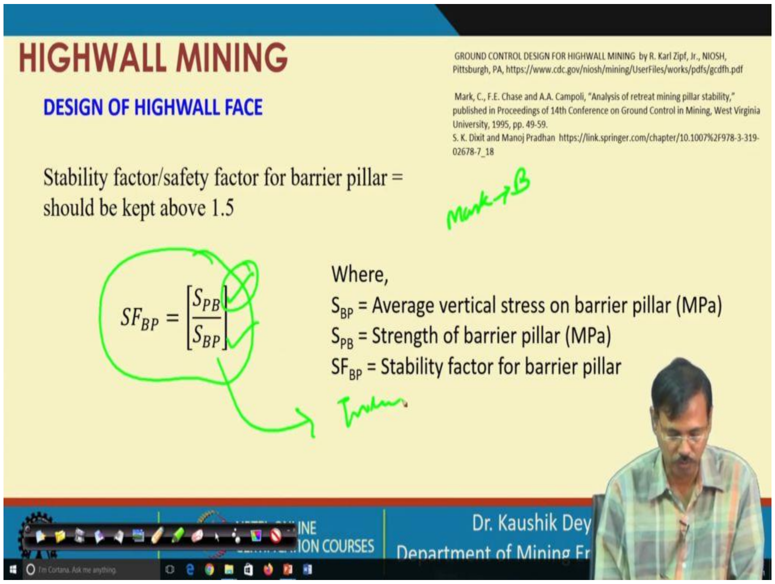


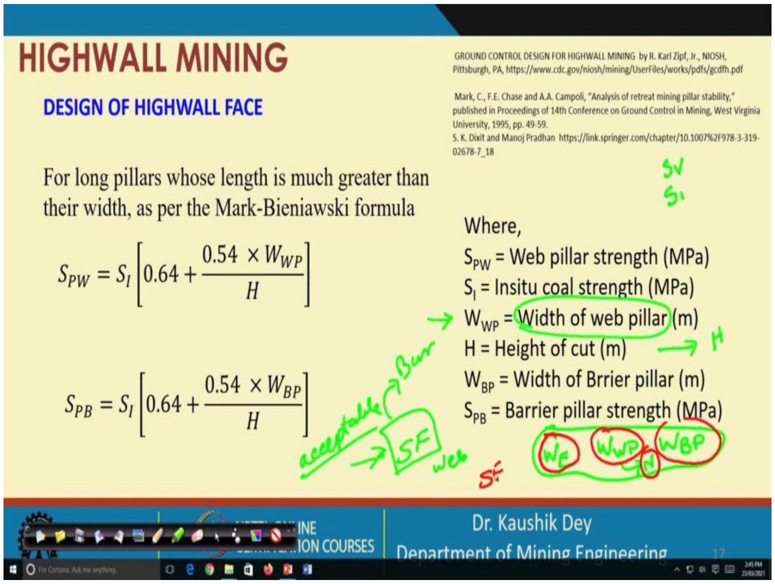
For designing the barrier pillar width, our consideration is that that we are considering all the web pillars have failed; and there is no stress carried out by this web pillar. So, while we are designing, it is very pessimistic decision that we are considering all the web pillars will fail; and all the loads has to be taken by the barrier pillar only. So, in consideration that, we are again going for the tributary area method; so, tributary are method means this is one barrier pillar.

And as per our considerations all the web pillars in between these two are no more; so the total area load is coming on to these. That means we are extending this one the 50 percent of that; so, all this 50 percent load is coming on to this. So, this is now the panel width we are considering, plus the barrier pillar width, and divided by the barrier pillar width. This is the stress coming on this one, and this is the vertical stress of the material.

So, we are considering this and this is a very pessimistic way; by this way we are determining the stress coming on to the pillar barrier pillar. And with this considerations we are determining the safety factor here.

(Refer Slide Time: 26:43)





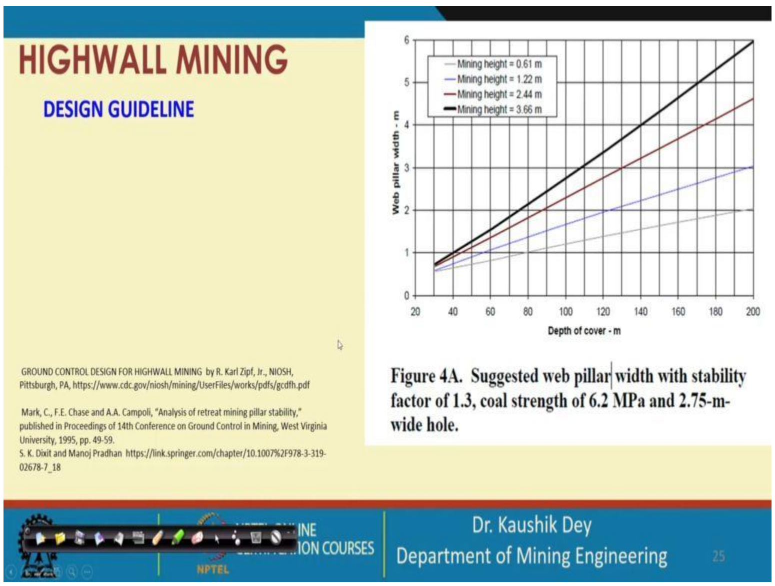
And in this safety factor considerations we are considering S_{PB} by S_{BP} in this case; so that is the strength, this is the stress. This strength is already we have calculated using the Mark-Bieniawski's formula; and this is using the tributary method. So, this is the method we are following in designing the barrier pillar width, and the web pillar width.

So, as this strength if you again go back to this slide again. If you see the strength is depending on the width of the pillars; so that is why we have to consider the width first. Then, we will find out what is the safety factor coming. So, this width, width of cut, width of web pillar, width of barrier pillar; this 3 has to be assumed.

And we have already measured or estimated S_V, and the S_I that is the strength of the insitu strength of the coal. These two are, we are having, and this depending on the highwall miner is fixed. And we have to assume some N, the number of web pillars in between the barrier pillars. So, these are he considerations; based on that we have to find out the safety factor for the web pillar, safety factor for the barrier pillar.

And if this safety factors are not acceptable at this end, then we have to recalculate it using some new values of this one; new values of this one, this one, this one, and this one. And again the new safety factor has to be determined, unless and until we are arriving at a satisfactory result of the same. So, this is more or less related to the design criteria of the highwall face.

(Refer Slide Time: 29:28)



HIGHWALL MINING

DESIGN GUIDELINE

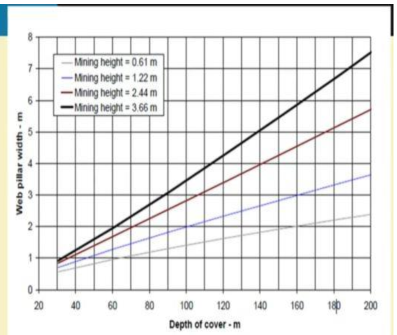


Figure 4B. Suggested web pillar width with stability factor of 1.6, coal strength of 6.2 MPa and 2.75-m-wide hole.

GROUND CONTROL DESIGN FOR HIGHWALL MINING by R. Karl Zipf, Jr., NIOSH, Pittsburgh, PA, https://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/gcdfh.pdf

Mark, C., F.E. Chase and A.A. Campoli, "Analysis of retreat mining pillar stability," published in Proceedings of 14th Conference on Ground Control in Mining, West Virginia University, 1995, pp. 49-59.

S. K. Dixit and Manoj Pradhan https://link.springer.com/chapter/10.1007%2F978-3-319-02678-7_18

HIGHWALL MINING

DESIGN GUIDELINE

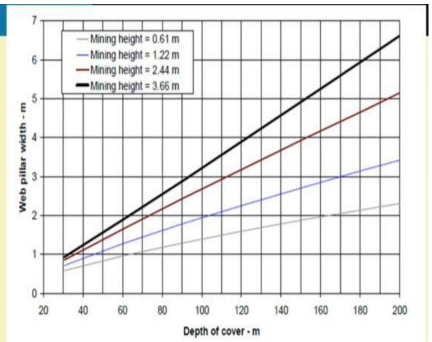
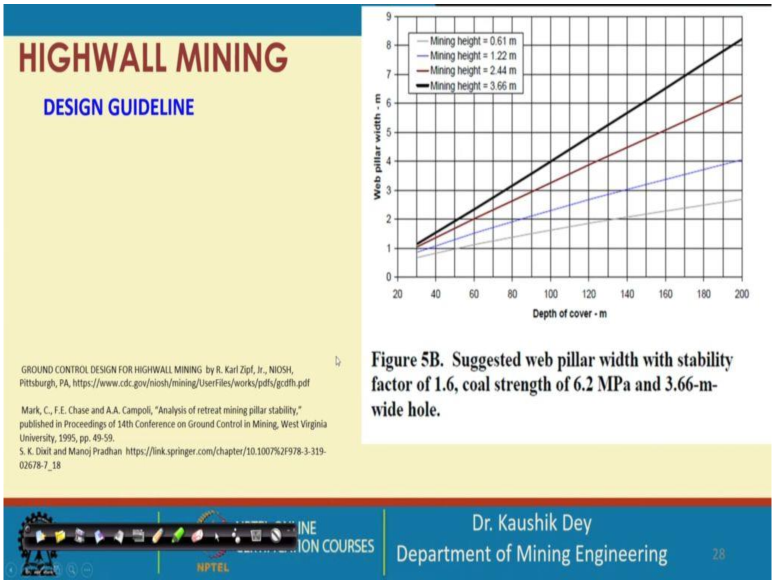


Figure 5A. Suggested web pillar width with stability factor of 1.3, coal strength of 6.2 MPa and 3.66-m-wide hole.

GROUND CONTROL DESIGN FOR HIGHWALL MINING by R. Karl Zipf, Jr., NIOSH, Pittsburgh, PA, https://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/gcdfh.pdf

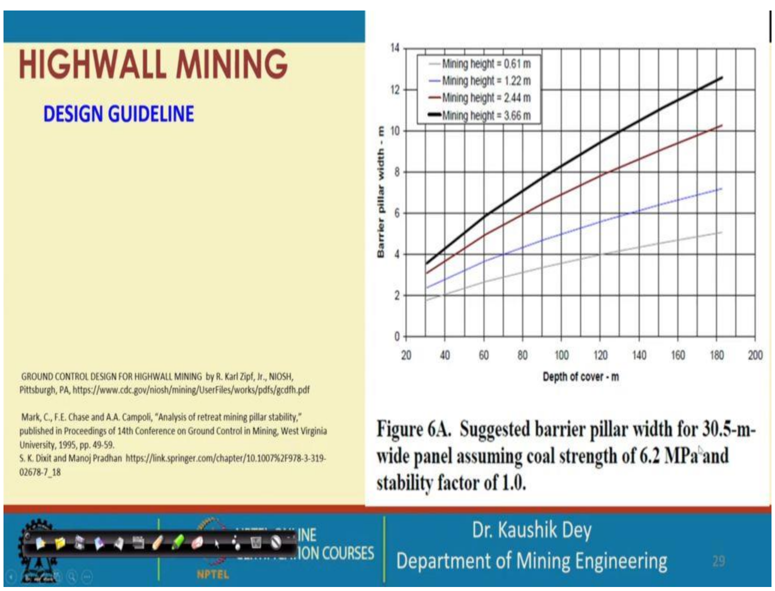
Mark, C., F.E. Chase and A.A. Campoli, "Analysis of retreat mining pillar stability," published in Proceedings of 14th Conference on Ground Control in Mining, West Virginia University, 1995, pp. 49-59.

S. K. Dixit and Manoj Pradhan https://link.springer.com/chapter/10.1007%2F978-3-319-02678-7_18



And these are some of the design guidelines made for the suggested web pillar width with stability factor of 1.3; coal strength is considered this one. And width of excavation is considered this one; and this is depth of cover along with that the web pillar width. So, this is just practical use of this equations; this is another one, where safety factor is 1.6. This is where the width of excavation is more; this safety factor is more for that.

(Refer Slide Time: 30:04)



HIGHWALL MINING

DESIGN GUIDELINE

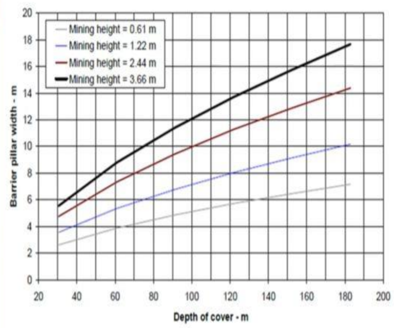


Figure 6B. Suggested barrier pillar width for 61.0-m-wide panel assuming coal strength of 6.2 MPa and stability factor of 1.0.

GROUND CONTROL DESIGN FOR HIGHWALL MINING by R. Karl Zipf, Jr., NIOSH, Pittsburgh, PA, https://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/gcdfh.pdf

Mark, C., F.E. Chase and A.A. Campoli, "Analysis of retreat mining pillar stability," published in Proceedings of 14th Conference on Ground Control in Mining, West Virgi University, 1995, pp. 49-59.

S. K. Dixit and Manoj Pradhan https://link.springer.com/chapter/10.1007%2F978-3-31 02678-7_18

HIGHWALL MINING

DESIGN GUIDELINE

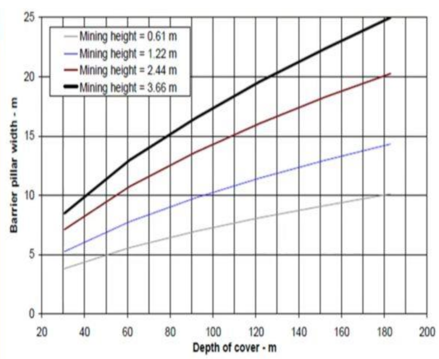
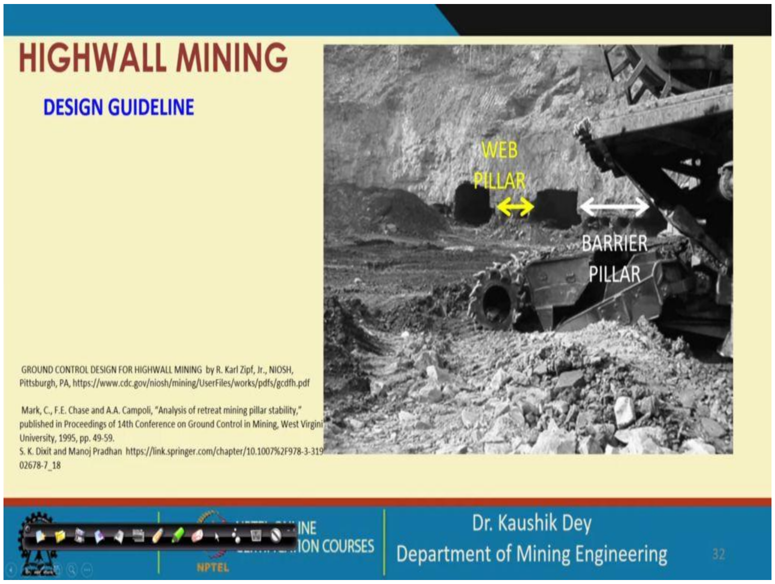


Figure 6C. Suggested barrier pillar width for 122-m-wide panel assuming coal strength of 6.2 MPa and stability factor of 1.0.

GROUND CONTROL DESIGN FOR HIGHWALL MINING by R. Karl Zipf, Jr., NIOSH, Pittsburgh, PA, https://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/gcdfh.pdf

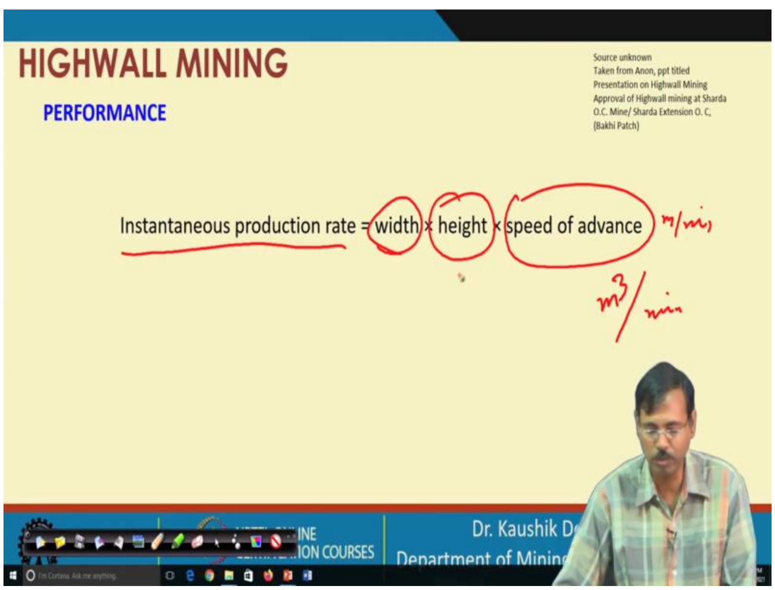
Mark, C., F.E. Chase and A.A. Campoli, "Analysis of retreat mining pillar stability," published in Proceedings of 14th Conference on Ground Control in Mining, West Virgin University, 1995, pp. 49-59.

S. K. Dixit and Manoj Pradhan https://link.springer.com/chapter/10.1007%2F978-3-31 02678-7_18



Then, we are using for the barrier pillar, this is for the barrier pillar, this is for the more wider barrier pillar. And this is a photographic representation; this is a 4 meter web pillar and 9 meter barrier pillar. This is a practical case, where it is used; these are some of the photographs of that one.

(Refer Slide Time: 30:38)



This is the performance of a highwall miner, can be calculated using this formula instantaneous production rate, is the width of the cut, height of the cut and speed of the advance. If you multiply it this, then this is coming meter cube; if it is meter per minute, then it is meter cube per minute, or meter per hour. Then it is meter per hour. So, this is the production rate, can be calculated from the highwall miner. And this is the end of the topic highwall mining. Thank you.