Soil and Water Conservation Engineering
Prof. Rajendra Singh
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur

Lecture – 14
Graded Bunds

Hello friends, welcome to NPTEL online certification course on Soil and Water Conservation Engineering. I am Rajendra Singh professor in agriculture and food engineering department of IIT, Kharagpur. We are in week number 3, lecture-14; and the topic today is graded bunds.

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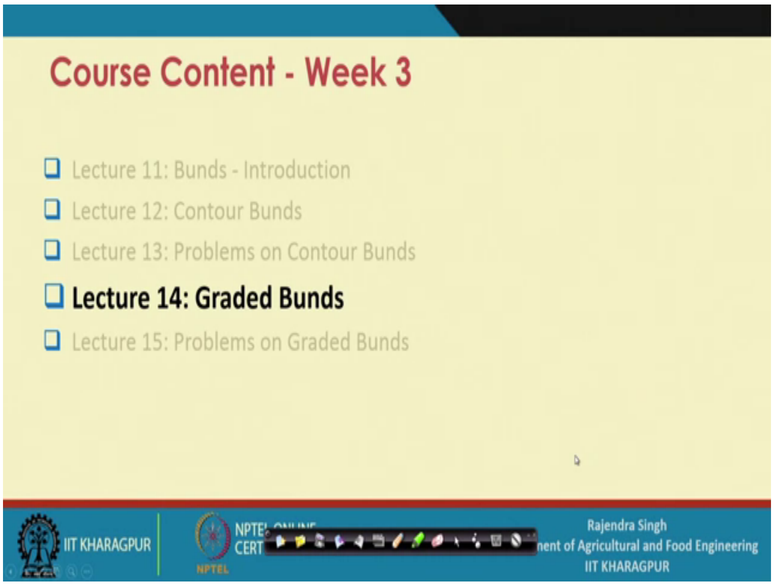

Just to remind you of the course content of week 3, in this week we started lecture -11 with introducing bunds; a lecture-12 we went through the concepts of contour bunds; and lecture 13 we saw how to apply those concept for designing contour bunds. In today’s lecture we will go through concepts of graded bunds; and then lecture-15 we will see, how to solve problems on graded bunds or how to design graded bunds.

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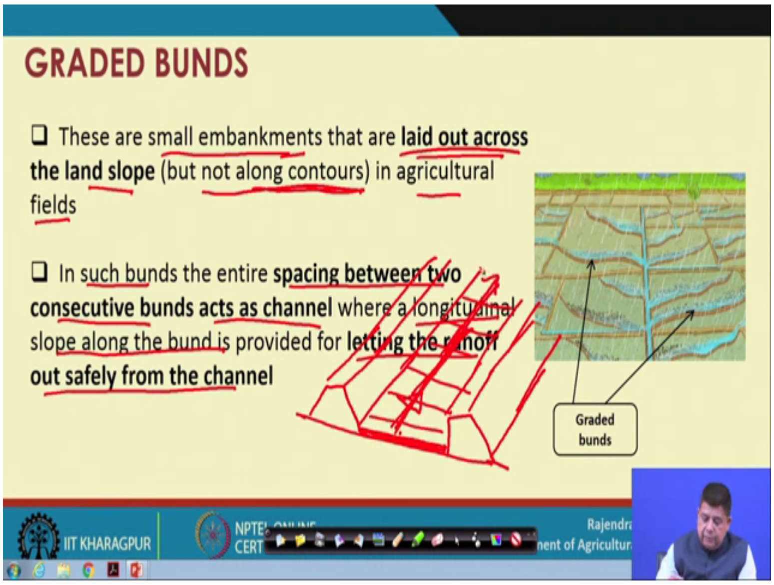

Just recap this we already saw earlier that that graded bunds are small embankments that are laid across the land slope but not along contours in agricultural field. So, basically small embankments just we saw already that be the contour bunds or graded bunds, they are typically small embankments and also the cross section is typically trapezoidal.

And they are always like we have already seen that all the conservation measures we adopt, there always taken across the land slope, because we want to check the flow water that is the basic purpose. And important point here is which an not along contour. This is to distinguish that the graded bunds are different than contour bunds. In case of contour bunds, we always put the bunds on contour lines, wherein graded bunds we do not have to follow the contour bunds this is the major difference.

In these bunds that is graded bunds, the entire spacing between two consecutive bunds acts as a channel, where a longitudinal slope along the bund is provided for letting the runoff out safely from the channel. So, basically what it says is that if this is your land slope and suppose we are adopting these graded bunds, two consecutive bunds, so that simply means that what it is saying that in the case of contour bund we saw that whatever rainfall occurs in between these two bunds that we try to store that that we try to conserve over the total area.

But in this case, what we also saw that the function of this is basically disposal of excess water, safe disposal of excess water, so that is why this entire area here. And when we say area there is a length perpendicular to the board also that is very important. We have to understand that this is there is a this if we can draw like this in this direction so this is something like this; in this direction this will continue along the length of the field.

So, this is we are talking about is this is the horizontal interval, and this is the length. So, this along this length, there is a longitudinal slope we provide a longitudinal slope. And this entire thing the area between these two bunds that acts as a channel, so that this entire area acts is a channel and then we provide a longitudinal slope along the bund for taking the runoff order away to some safe disposal.

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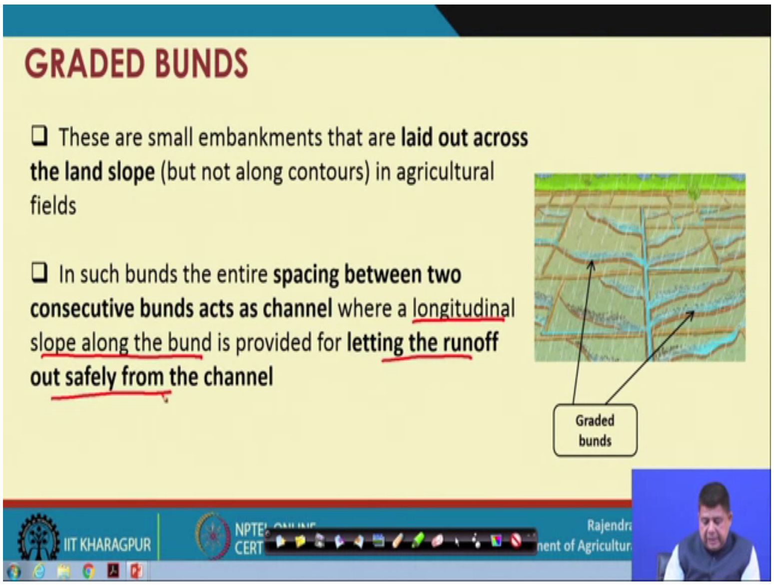

So, basically that is where this ah this longitudinal slope along the bund is coming to picture, and obviously, then the entire channel is used for letting the runoff out safely from the channel that is the purpose.

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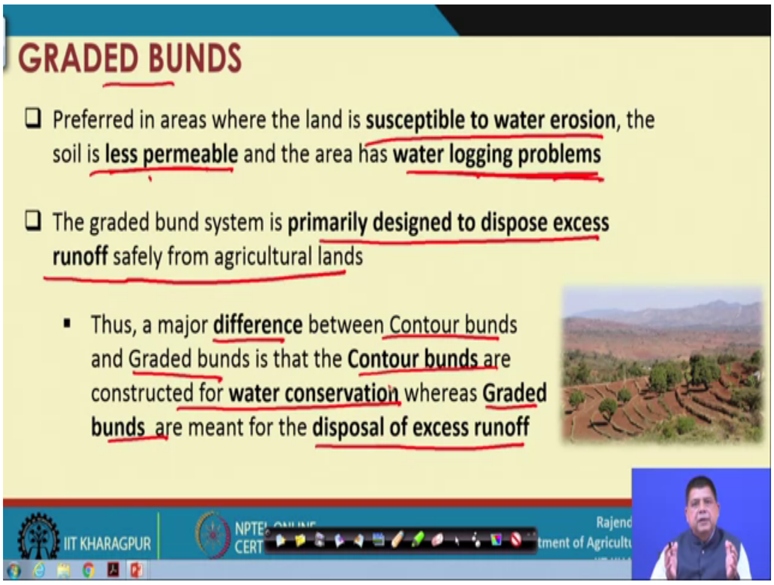

These are preferred in areas where land is susceptible to water erosion soil is less permeable and the area has water logging problem. So, whenever of course, susceptible to water erosion that is why we are going for any erosion control measure, be it contour or graded bund, but in this case the qualifying statements are that soil is less permeable; that means, the infiltration rate is very low or infiltration capacity is very low. And the area has water logging problem that is water gets stored because infiltration capacity is low. So, wherever these conditions are there, we go and adopt graded bunds.

And just to remind the graded bund system is primarily designed to dispose excess runoff safely from agricultural lands. So, any area which is water logged or where the soil is less permeable; obviously, we do not want water to get stored there and that is where we adopt graded bunds, so that the excess runoff can be safely disposed off.

So, the major difference between the contour bund and graded bund is that the contour bunds are constructed for water conservation. So, there water conservation measures where are graded bunds are meant for disposal of excess runoff, so that is a one major difference between contour bunds and graded bunds. And in the case of contour bund, the area between two bund, that is used for conserving moisture; where in the case of graded bund the area between two is used as a channel for safely discharging the water or carrying the water to a safe outlet. That is the major difference between these two bunds types of bunds.

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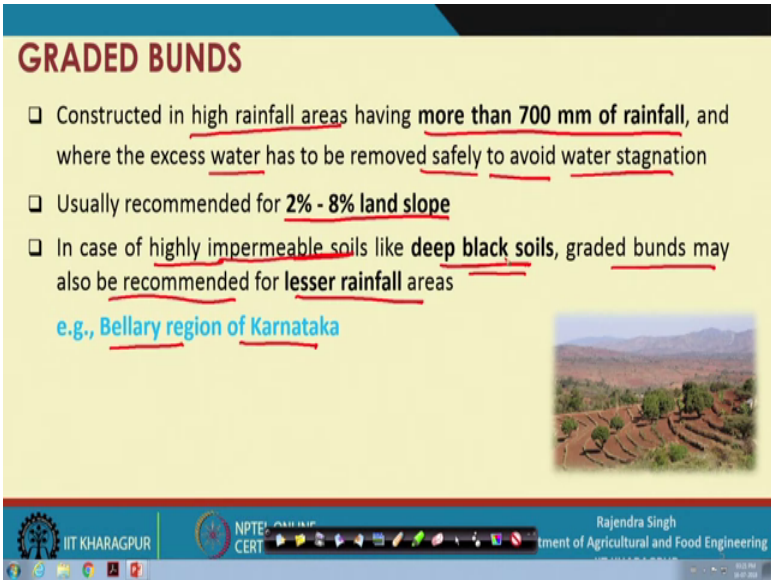

Now, typically adaptability is concerned, these are constructed in high rainfall areas having more than seven millimetre 700 millimetres of rainfall and where the excess water has to be remove safely to avoid water stagnation. So, basically in high rainfall areas having more than 700 millimetres of rainfall this is the typical adaptability condition.

And usually recommended for 2 to 8 percent of land slope, so we saw that 2 to 8 percent of land slope is or less than 8 percent is recommended for both contour and graded bunds. And general recommendation for contour bund is to 6 percent; here it is 2 to 8 percent. Contour bunds are for usually adopted in less than 700 mm of rainfall, where graded bunds are adopted for more than 700 mm of rain fall under normal circumstances.

In case of highly impermeable soils like deep black soil, graded bunds may also be recommended for lesser rainfall area. So, if they have to be adopted in less than 700 mm of rain fall, then the conditions has to be very specific that the soil has to be highly impermeable or infiltration capacity has to very low. For example, like it happens with the deep black soil and that is why if you go to Bellary region of Karnataka, in Southern State of Karnataka then you will find that typically because the soils are deep black soils there. So, graded bunds are preferred in those areas.

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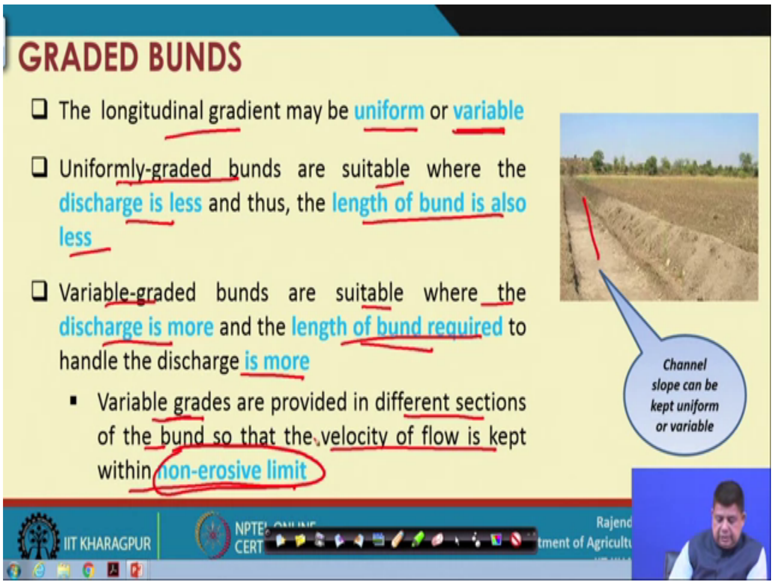

Then we have already seen that we provide some kind of a longitudinal slope here. So, this is the channel. So, we provide some kind of longitudinal slope depending upon which direction we have to take the water. And these gradient maybe uniform or variable that is also possibility. You can have a uniform throughout the length or the grade could vary also.

The uniformly graded bunds are suitable where the discharge is less and thus the length of bund is also less. So, if the bund of discharge to be handling is less and the length of the bund or the length of the field itself is less, then we go for uniformly graded bunds. And variable graded bunds are suitable where the discharge is more and length of bund required to handle the discharge is more.

So, on the contrary, if the discharge is more and the length of bund is more, then we provide variable grades. And variable grades are provided in different sections of the bund, so that velocity of flow is kept within non-erosive limit. So, with the case of uniformly graded or variable graded, this condition of non-erosive velocity is always true that is you always have to see that water flows only at a non-erosive velocity, so that there is no erosion in the channel. And but in the case of variable grade, if it is the length of the bund is more, we can provide variable grades in different sections of the bund.

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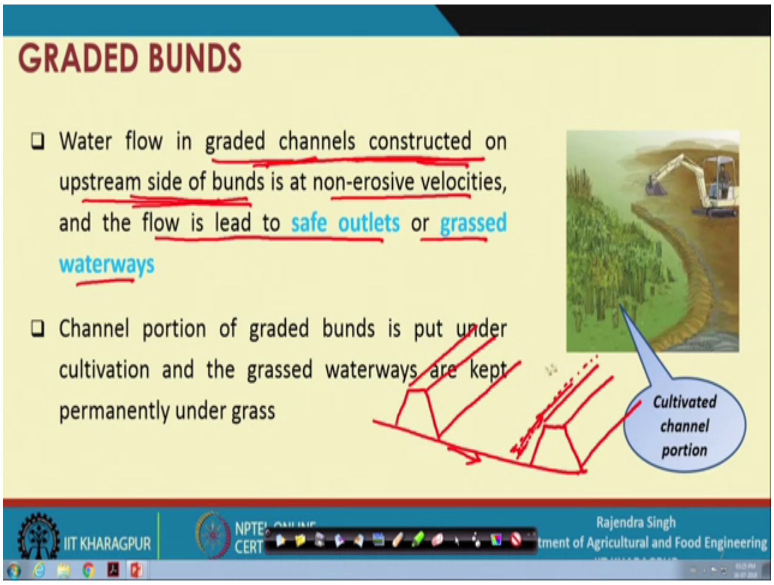

So, water flow in the graded channels constructed on upstream side of bunds is at non-erosive velocities and the flow is lead to safe outlets or grassed waterways. Sometimes, I mean though we have said that the entire area between the two bunds can be used as channel, but sometimes if the discharge in not so much or it is not expected to be very high, then we also provide that just construct channels upstream side of the bund.

So, that only means what that just now we saw that if this is our example; once again I draw this two consecutive bunds and again to make it and easy to understand let us say that we are putting a third dimension also so that means, this is the land slope across this is across we are constructing these bunds and this is the area we are talking about.

So, in the previous case, we saw other while defining the grade bund we said that entire channel area is used as a channel I mean entire area between these two bunds is used as channel. But in some cases like the case it is saying here that graded channels constructed on the upstream side of the bund. So, if this is the upstream side of the bund, in this case it will be here because the slope is in this direction, we are saying slope is in this direction. So, water will flow so that simply means by the side of this bund itself we construct the channel. The channel is constructed here and the grade is provided there, and the remainder of area is left as it is so that is also a possibility.

But, in any case, the channel portion of the graded bund is put under cultivation and the grassed waterways are kept permanently under grass. So, depending opening upon we always cultivate the bund area which is the which is why we really go for this conservation measure, but the grass waterway or waterway wherever we are carrying the water through that should be kept under grass, so that erosion can be checked that is very important.

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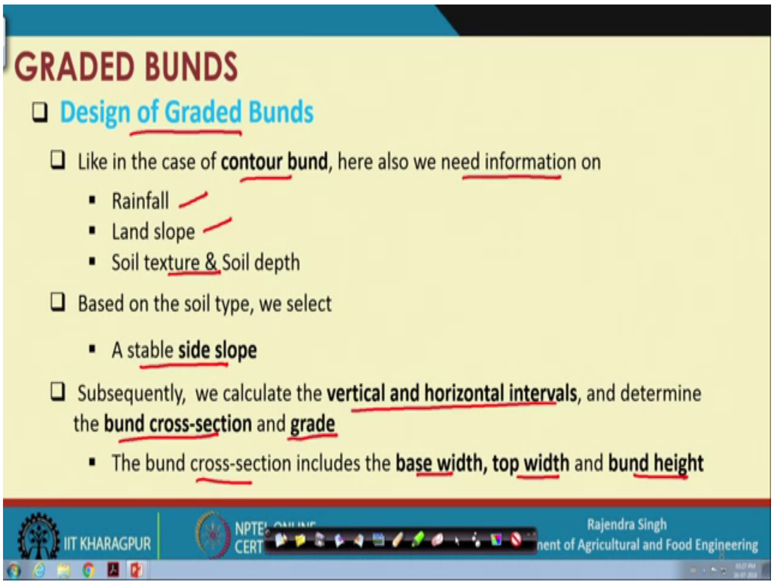

Now, coming to design of graded bunds, there are certain aspects we have to keep into account. So, like in the case of contour bund, we need information on rainfall which gives us an idea about how much water really the structure is likely to handle. The land slope which basically first thing is it decides is help us in deciding the adaptability which kind of bund or also this land slope is used in designing various other parameters of the structure, then soil texture and soil depth. So, these are the three basic information which we required.

And based on the soil type, we select a suitable side slope. And subsequently calculate the vertical and horizontal intervals, and determine the bund cross-section and grade. And bund cross-section when we set includes base width, top width and bund width. So, these are kind of ah reputation for what we have already seen in case of contour bund.

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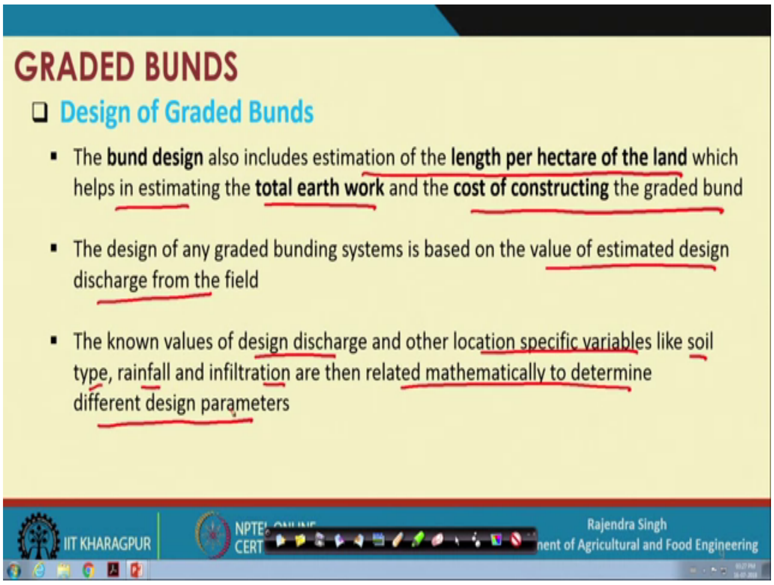

The bund design also includes estimation of length per hectare of land which helps in estimating the total earth work and cost of constructing the graded bunds.

The design of many graded bunding system is based on the value of estimated design discharge from the field which is quite obvious. And then known value of design discharge and other location specific variables like soil type, rainfall infiltration are related mathematically to determine the different design parameter, so that we will see one after the other.

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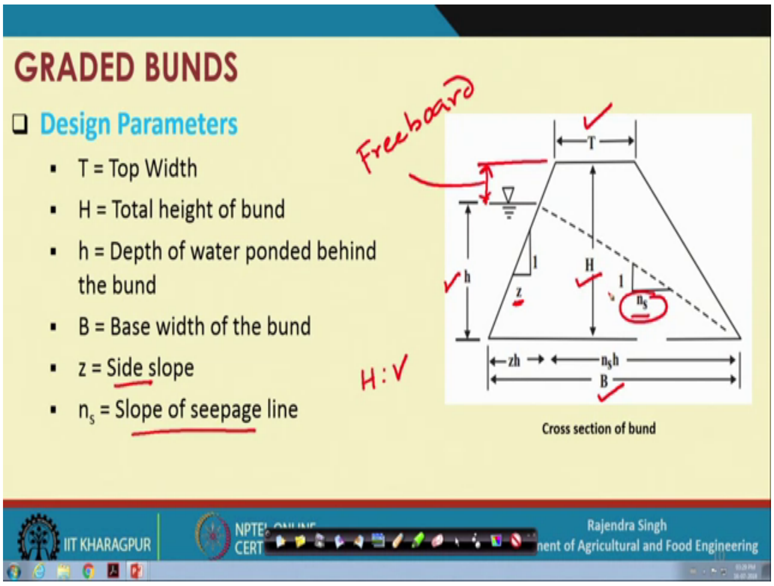

Now, coming to definition is sketch that is various design parameters, very similar to the graded bund contour bund, but here also once again we see this is the trapezoidal cross section normally we use, this is the trapezoidal cross section.

Here you can see, and the bottom width is B, top width is T and H is the total height of the bund; and h is the depth of water pounded behind the bund or theoretical dept which we normally calculate first. And then we provide the here basically the difference between h and H is nothing but we provide a kind of freeboard. So, this h is you calculate, and then we add freeboard to get the total height.

And z here is the side slope, we say we always said that it we slope we always we represent in terms of horizontal is to vertical; that is two horizontal is to one vertical. So, this value is z, z is nothing but this side slope we have to put. And the n s is the slope of the seepage line, because the seepage line also has a particular slope, and that is being represented here by n suffixes s. So, these are the various components we have to keep an eye on.

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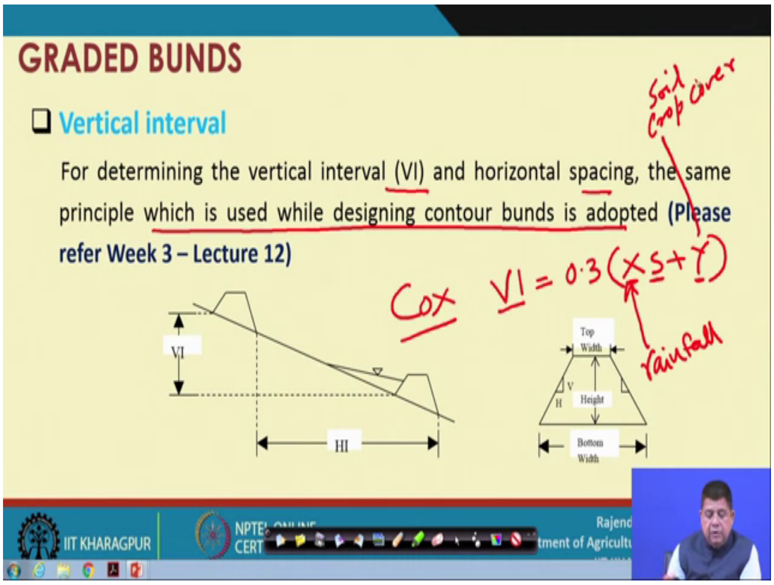

Now, vertical interval determine the vertical interval and horizontal spacing the same principle which we used while designing contour bunds is adopted. And this is vertical interval, this is a horizontal interval. We remember we had three different formulas the, but the as I said that the Cox formula is most commonly used for calculating the vertical interval, where it is given as 0.3 X S plus Y, X S is the land slope where VI is the Vertical Interval.

And X and Y, they are the factors accounting for rainfall; this X is accounts for rainfall of the location, and Y accounts for the soil characteristics and also the crop cover conditions. And the values of X and Y we always obtained from tables which we have seen in lecture number 12 and 13 both those lectures we have used this tables to find the values of X and Y.

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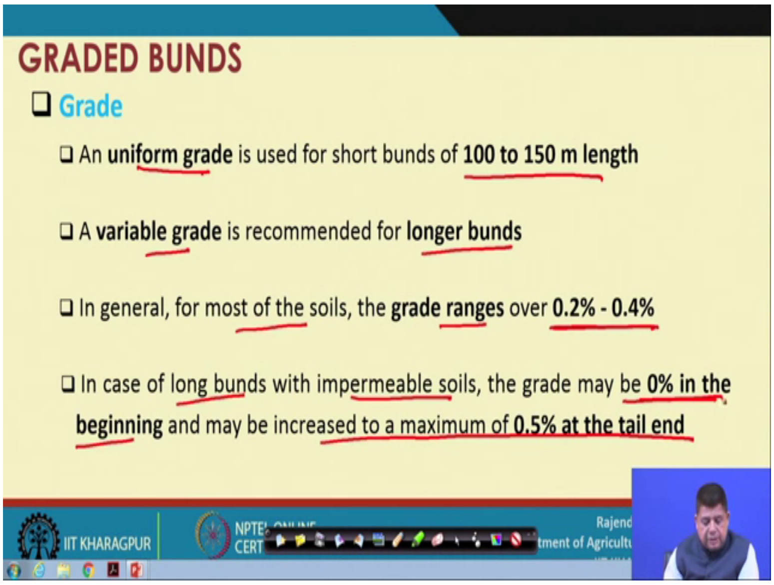

Now, grade is one is grade is concerned, an uniform grade is used for shot bunds of 100 to 250 metres. And variable grade when the bund length goes beyond 150 metres. For most of the soils the grade range is over 0.2 percent to 0.4 percent, but in case of long bunds with impermeable soils, the grade may be 0 percent the beginning that is the variable grade we are talking about, and maybe increased to a maximum of 0.5 percent at the tail end. So, general recommend is to be 0.2 to 0.4 percent, but a for a longer bund it could be start from 0 percent in the beginning, and it could go as high as 0.5 percent in the tail end.

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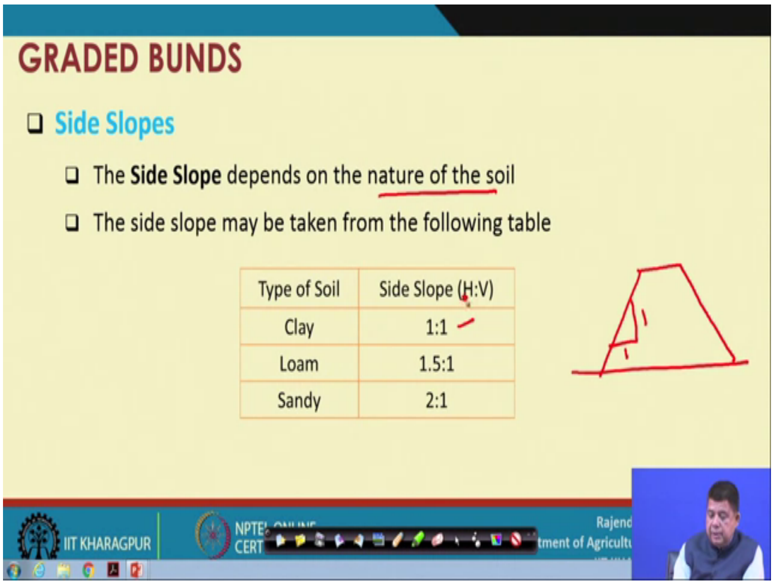

The side slope recommendations remain the same, because they are function of soil characteristics, and so they do not change the type of bund. So, here the side slope is 1 is to 1, and the side slope we are talking about is this side slope. So, 1 is to 1; so if it is a clay soil, this is 1 is to 1, if it is loam soil it is 1.5 is to 1, horizontal is to vertical remember H is to V and sandy soil 2 is to 1. So, you remember these things we always used.

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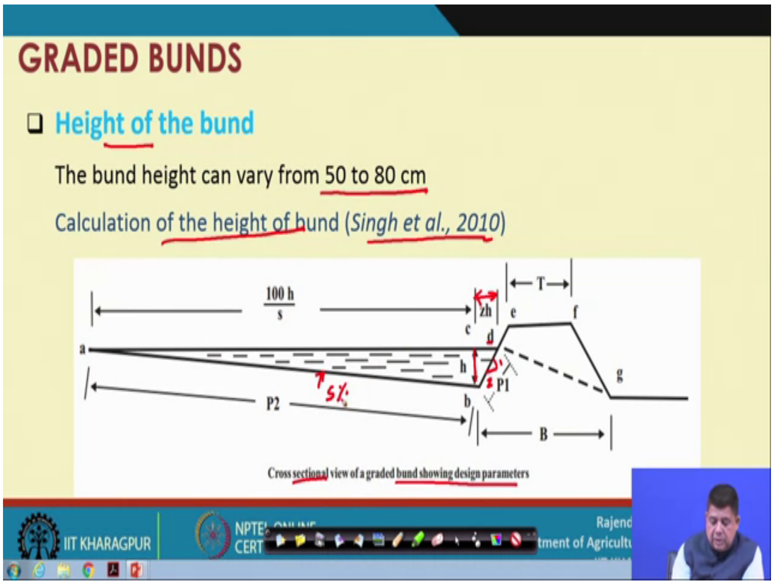

Now, the most important thing that is the height of the bund; the height of the bund general recommendation is it could vary between 50 to 80 centimetre that is the general recommendation, that could be 50 centimetre to 80 centimetre. But the calculation of the height of bund we can do, and there is a research paper published by Singh's and others in 2010 and so we will use that paper to express the same thing.

And this is the cross sectional view of a graded bund showing design parameters, most of the design parameters all already we have seen, and some of these will be requiring and will be using slowly. So, here what is we are seeing that h is the h is the height of the bund which is being used, and d is the this is the this triangle there are two triangles which are used here, the two triangles being used here are a, b, c; and b, c, d. And z generally we use z as z is to one slope, so that is why if this is h. So, this becomes z h.

Similarly, this is s percent slope or s by 100; so that is why for h it will be h 100 by s, or 100 h by s. So, this length will be hundred h by, s because the soil this is s percent slope.

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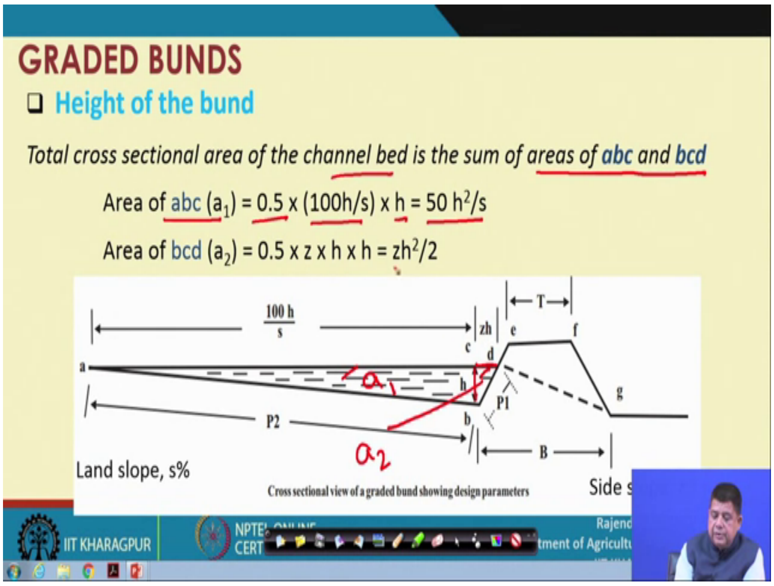

So, this with these definitions let us see the total cross sectional area of the channel bed will be sum of areas of a b c and b c b c d. So, this is one triangle, this is the other triangle there are two triangles; this is one triangle, this is second triangle so these two triangles area will be there. So, area of a b c that is this is a b c are this is this area a 1 is half into the vertical that is h, and the base which is 100 h by s; so that is being used simple triangular formula. Area of the triangle formula we are using here, which comes out to be 50 h square by s.

Now, for this one this is a 2. So, a 2 is half into h times this which is z h; so, half into z, h times h or z h square by 2. So these are the two areas.

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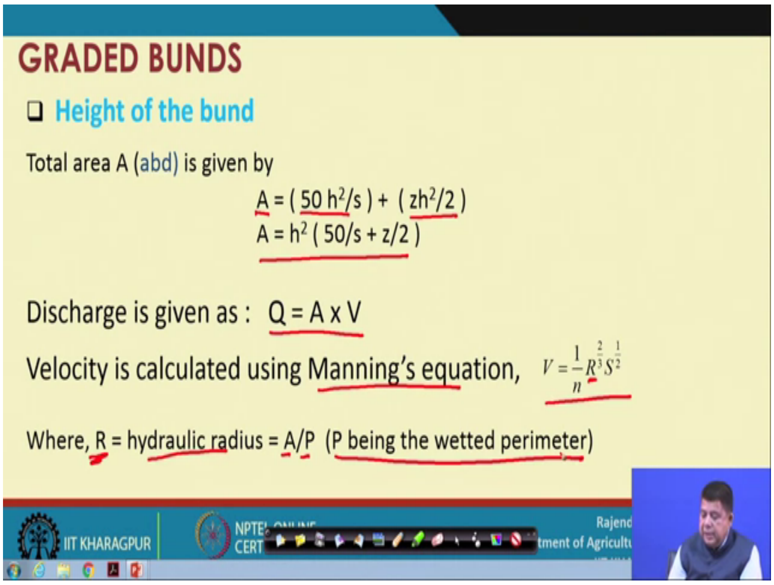

So, total area will be; obviously, the some of these two. So, the total area is some of these two, that is 50 h square plus s, plus z h square by 2 or h square taking common 50 by s plus z by 2, so this is the A in terms of h and s.

And discharge typically is given by the continuity equation q equals to A V, and where velocity is calculated using Manning's equation which is given by V equal 1 by n R to the power 2 by 3 S to the power half, where R is the R which is here is the hydraulic radius as given by A by P; where, A is the cross sectional area and P is the wetted perimeter.

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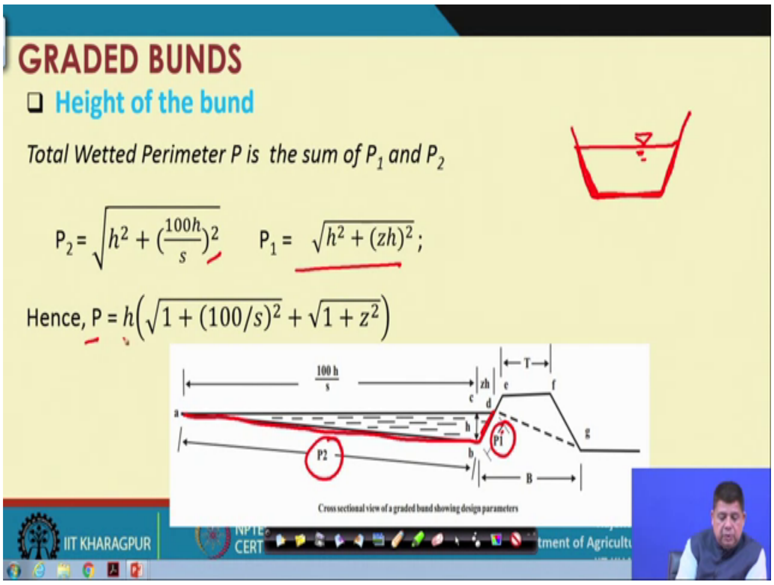

So, we have to if you have to apply this equation V, then we have to calculate the wetted perimeter. And wetted perimeter basically, is basically if you read the channel any channel. So, if it is a channel, where this is the water level and we have to find out the wetted perimeters. So, all the surfaces the sum of the length of surfaces which are in contact with water, this is referred to as wetted perimeter. So, this is wetted perimeter.

Say using same principle here, the water conduct is here and on the surface, and that is why the wetted perimeter is this length which is P 1, and this length it is P 2. And from the triangle formula Pythagoras theorem, P 1 will be nothing but P 1 square is h square plus z square h square or P 1 is square root of h square plus P 1 is h square z h square this is one. Similarly here, P 2 will be square root of h square plus 100 h by s square so here. So, total P the total wetted perimeter P will be sum of these two. So, here h taking h common, this is what we get. So, this is how we get the wetted perimeter.

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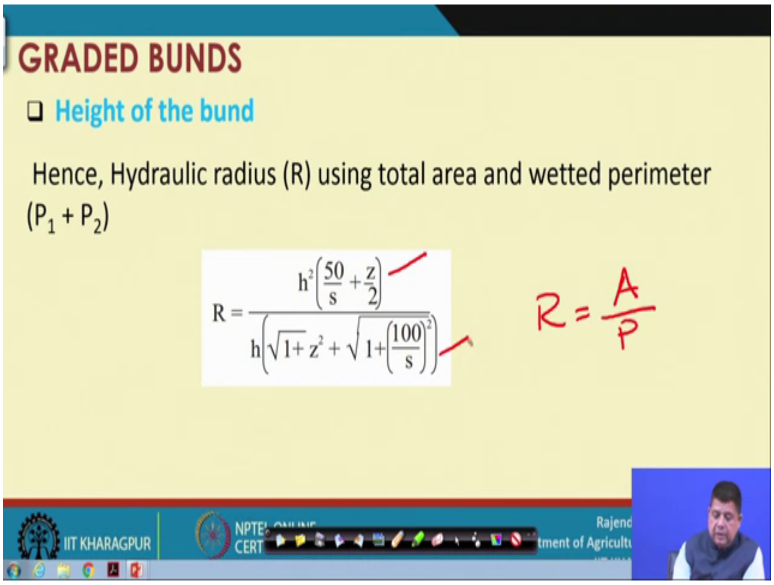

So, now, we have know the area, we know the wetted perimeter, so we can calculate the hydraulic radius. The hydraulic radius is R equals to A by P. So, A R equals to A by wetted perimeter. So, A, we have calculated, wetted perimeter we have calculated, so that is how we get the value of R in these terms in terms of z h n s basically.

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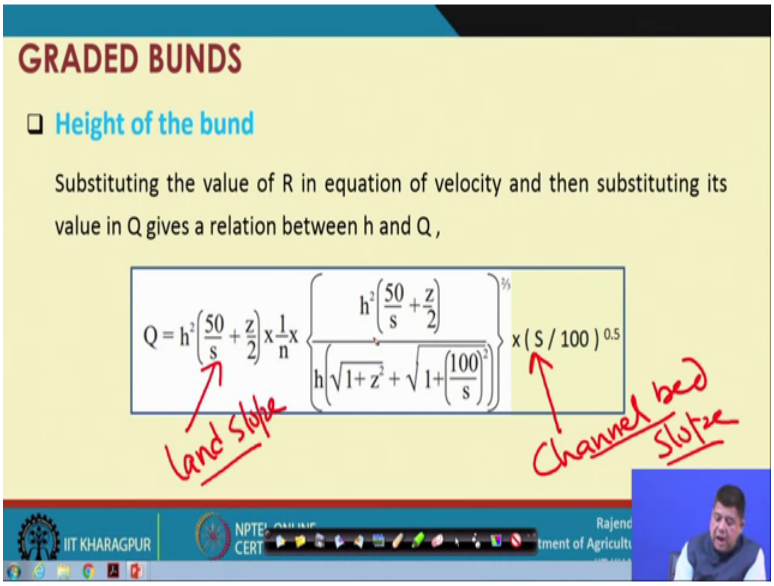

So, now we can put everything into the velocity R equation velocity. And then substitute the value in Q equation. So, basically what we are saying is that Q equals to A times V, and A times 1 by n R to the power 2 by 3 S to the power half. So, this is here.

So, if we can put in this equations, remember there are two slopes being used here; this is small s is bed slope, that is all the all the time we are using this in all equations; Whereas this S which is coming it sorry; this is this one is land slope and this one is channel bed slope. So, there are two slopes. One is being designated by small s, one by capital S.

So, let us not get confused small s is land slope, capital S is channel bed slope. So, we have to remember this in this formula. So, basically we are simply putting the values of area and R which calculated S already is there in continuity equation.

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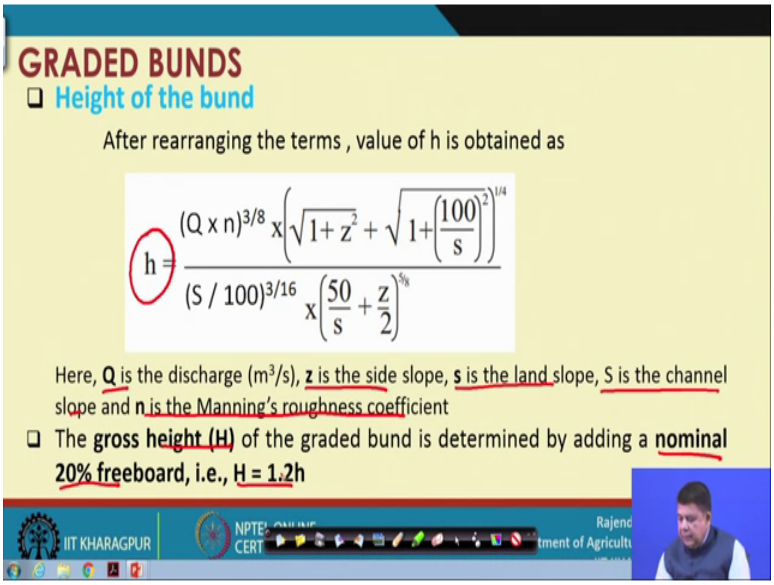

So, after arranging these terms finally, for h we will give get this equation, we have simply simplifying the terms that is h equals to Q times n to the power 3 by 8 square root of 1 plus z square plus square root of 1 plus 100 S by square, thus whole power is 1.4; S by 100 to the power 3 by 16 and 50 s by z by 2 power 5 by 8, where Q is the discharge, z is the side slope, h is the land slope, capital S is the channel bed slope and n is the Manning's roughness coefficient. So, this is how using this formula, we can calculate the h. And then gross height or the height of the bund can be determined by adding a nominal 20 percent or 25 percent freeboard. So, H will be 1.2 or 1.25 h whatever we want to calculate that is how it will come like.

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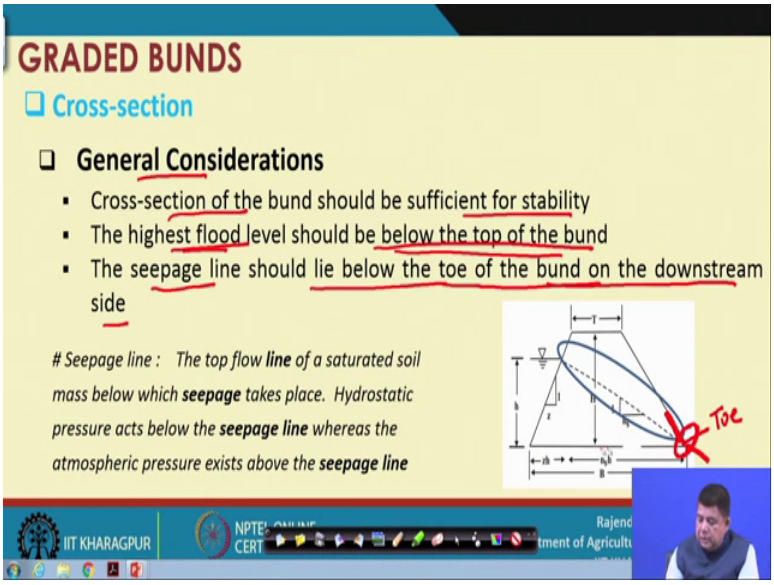

So, now we reach ah once we have calculated h, then we can go and calculate other things like cross-section. So, there some general considerations while designing the cross-section. Cross section of the bund should be sufficient for stability, which goes without saying; so the structure has to always be stable and that we have to keep into account.

The highest flood level should be below the top of the bund and that is why we always provide the freeboard, because we do not want that that is why we always calculate the theoretical height, and we calculate, we add the freeboard, so that overtopping is avoided.

And this third consideration is the seepage line should lie below the toe of the bund on the downstream side. And seepage line is basically what happens that, because the material of construction is material of construction is soil so obviously, whenever standing water is there, seepage starts taking place and slowly this whole thing gets wet.

The problem is that we want to avoid ah this we do not want that this downstream side should be wet, because the moment it happens there might be failure of the structure, because the toe will fail. So, there will be cutting of the two and then the entire structure will fail; so that is why, we should always ensure that seepage line should lie below the toe of the bund of the downstream side. And that is why, when we take the seepage line we always ensure that the seepage line crosses the toe and the R we case always say that seepage line, must pass through the base of the structure; so that is what we always recommend.

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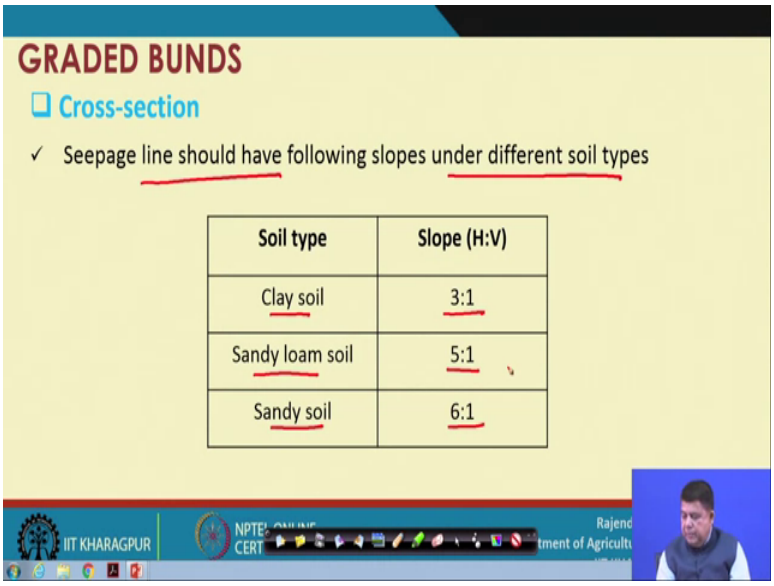

Now, coming to cross-section, the seepage line should have the following slope under different soil types. So, for clay soil it is 3 is to 1, for sandy loam soil 5 is to 1, for sandy soil it is 6 is to 1, so these are the general recommendations. So, while calculating the base width we must take into account the seepage line, slope recommended for different soil. So, we know that what is the soil material of construction. So, based on that, we should always take that into account.

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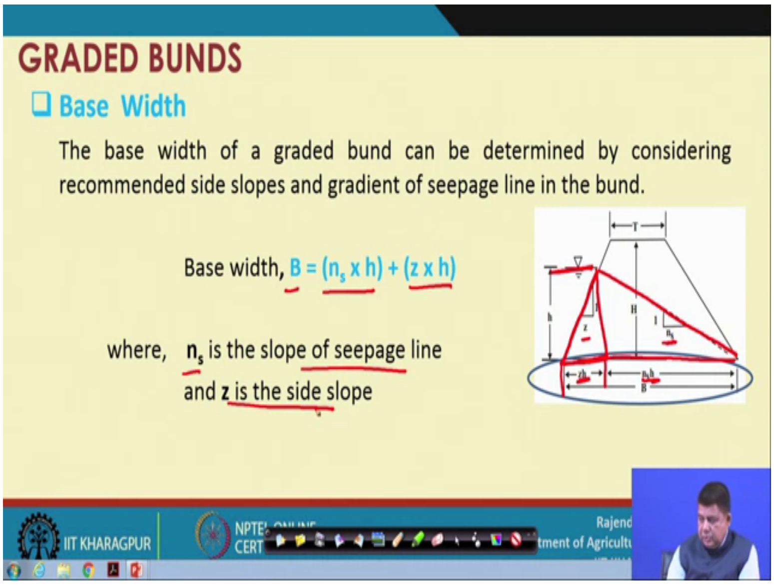

Now, the base width when we calculate; obviously, we have to take this into account. So, base width when we say, so base width will be having two components basically; if this is the h, so this one is to account for this slope, that is the z the side slope of the bund itself, and this one to account for the slope of the seepage line. So, this slope is n s, this slope is z and the height is h; so obviously, this is z h and this one will be n s times h. And that is why the total base width B is n s times h plus z times h, where n s is the slope of the seepage line and z is the side slope.

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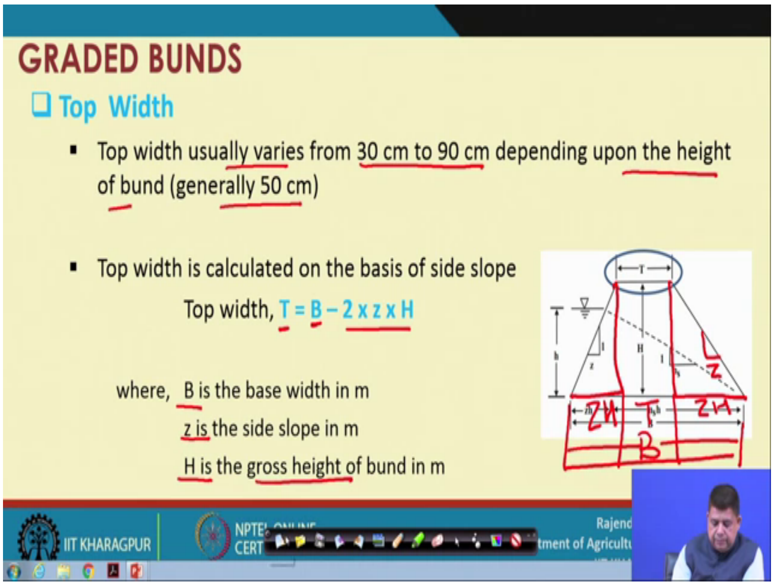

Now, once the base width you calculated. The top width which generally varies between 30 centimetres 90 centimetres depending upon the height of the bund, generally it is 50 centimetre. You remember, in case of contour bund also we say that for Indian conditions, the top width is 0.5 metres and bottom width is 2 metres. So, that is general recommendation.

So, top width calculation; obviously, will take into account the total height of the bund which we have calculated. And so here, T top width T will be base width minus 2 times two triangles have to be deducted; this is the one triangle, this and this is second triangle. So, this slope is z we know, so and this is capital S, so this is capital H and this is also z times capital H. So, B is this is B, so this is T. So, T equals to B minus 2 H 2 z H, so that is how top width can be calculated; where B is the base width, z is the side slope and H is the gross height of the bund.

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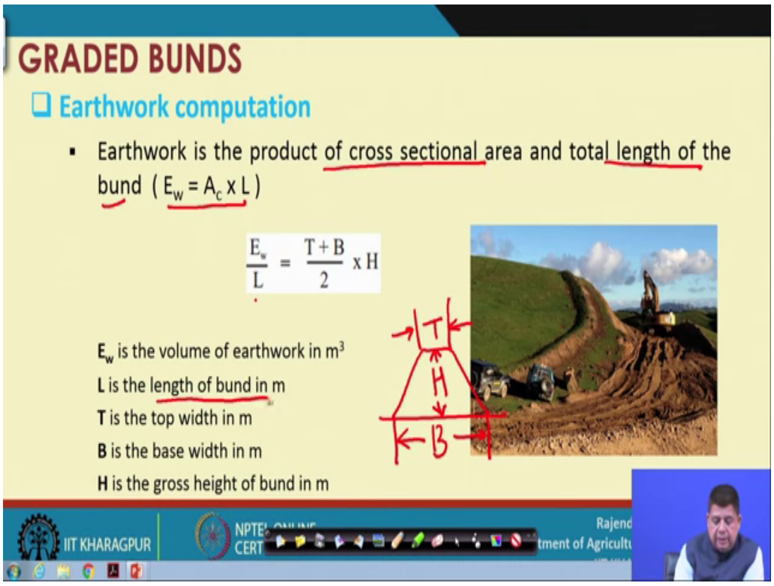

And then comes the earthwork computation like contour bund, here also earthwork is product of cross sectional area and the total length of the bund. And the earth work ah that is earthwork was to A c times L or E w by L we can say the area of cross section, and area of cross section we know always it is a trapezoidal section; so this is B, this is T, this is H, this is B, this is T, and this is H.

So, area of cross section of a trapezoid is half times some of T plus B times H, so that is same here T plus B by 2 into H that is the earthwork, volume of earthwork in cubic metres, and L is the length of the bund in metres. So, this is per hectare basically we are calculating. So, this is how it can be where L is the length of the bund in metres.

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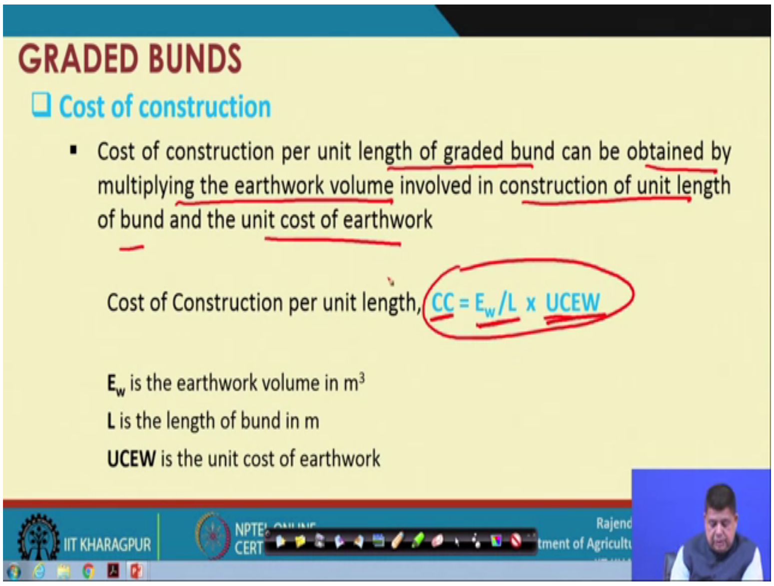

And say is then the cost of construction per unit length of the graded bund can be obtained by multiplying the earthwork volume involved in construction of unit length of bund and unit cost of earthwork. So, if we know that the unit cost of earthwork is U C E W, then the cost of construction per unit length will be E w by L which that is the unit length we earthwork per unit length times unit cost of earthwork. So, using this, we can calculate what will be the total cost of construction also.

So, with this we come to end of the graded bund. We also saw here that I mean how to consider various slopes, that is slope of the seepage line of the bed slope depending on the soil conditions. And if we know the total flow that we have to handle how to calculate the h, and we also saw the derivation of a direct formula, otherwise also it can be solved, but we solve a direct formula. And then we will apply all these concepts into next lecture to see how to really solve design problems on graded bund.

Thank you very much.