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

Lecture – 14
Problems on Graded Bunds

Hello friends, welcome to NPTEL online certification course on Soil and Water Conservation Engineering. I am Rajendra Singh, professor in agricultural and food engineering department of IIT Kharagpur. We are in week number 3 lecture 14, lecture 15. And today, we will be solving problems on graded bunds we saw the principles of an components of graded bunds. In previous lecture, today we will utilize them to solve Problems on Graded Bunds.

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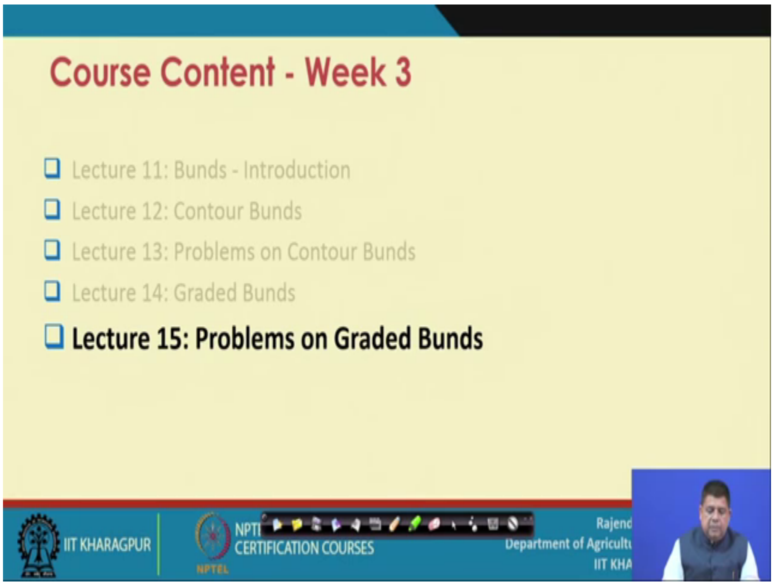

Just to give you an idea of the course content, which we have gone through. In this particular week, we started this week with lecture 11 where, we introduced bunds; then in lecture 12, we went through contour bund; that is design parameters, design principle, design considerations and lecture 13. We applied those design parameters considerations into solving some of the problems, dealing with the design of contour bunds.

In previous lecture, that in lecture 14 we covered graded bunds and today, we will be solving problems on graded bunds.

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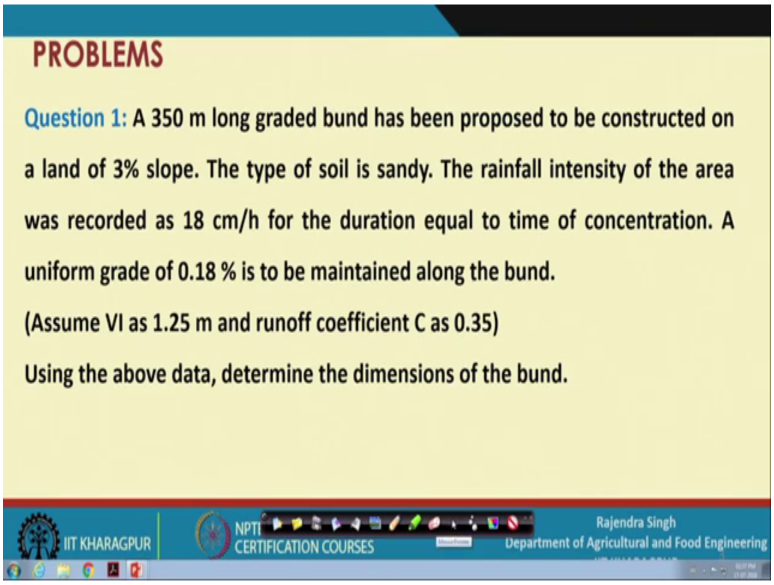

Let us start with problem number 1 which reads a 350-meter-long graded bund has been proposed to be constructed on a land of 3 percent slope. So, length of the graded bund is given as 300 meters and slope land slope is given as 3 percent the type of soil is sandy. So, soil we have to we are dealing with it is sandy soil.

The rainfall intensity of the area was recorded as 18 centimetres per hour for the duration equal to time of concentration. This is very important the duration of the rainfall is also given that is, rainfall intensity is given as 18 centimetre per hour, but the important thing is the rainfall was for duration equal to time of concentration.

And we have to maintain a uniform grade of point one 8 percent along the bund. So, this is also so it is a graded bund so that is why a uniform grade of 0.18 percent has to be maintained.

Further it problem says that assume VI that is vertical interval is 1.25 meters and the runoff coefficient C is 0.35. Using the above data determine the dimensions of the bund. So, we have to determine the dimensions of bund and dimensions of bund. We saw that simply means we have to design or decide on the top width the bottom width height side slope of the bund.

So, this is typically this is how a cross section of a bund looks like. So, what we have to decide on this side slope and then we have to find out, what is the bed width or bottom width? What is the top width? And of course, the height; so, this is what problem wants want to design utilizing the data that is given. So let us see how to go ahead with this.

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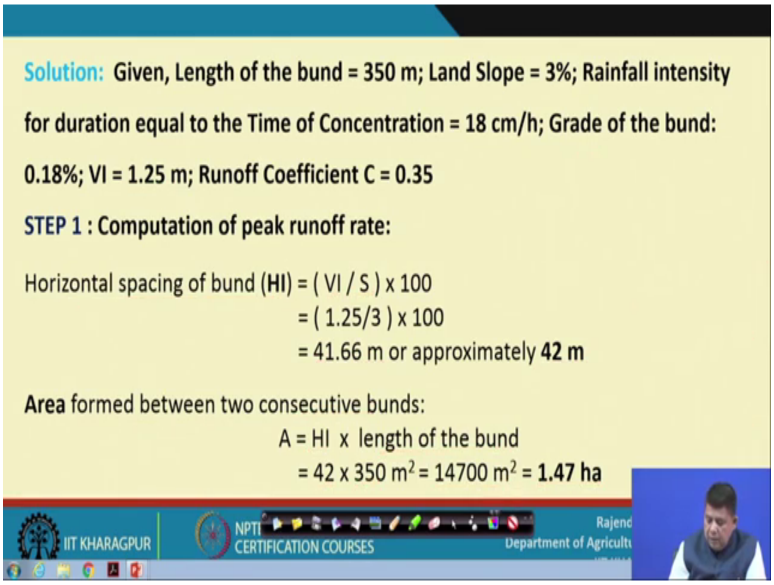

Now, just to have a check on the data which is available with us length of the bund is given as 350 meters, land slope is given as 3 percent, rainfall intensity for duration equal to time of concentration is given as 18 centimetre per hour. The grade of the bund is given as 0.18 percent vertical interval is 1.25 meters and runoff coefficient C is 0.35.

Now, in any of such problems we have to where we have to decide on the dimensions of the bund. So, the determining factor of course, is the amount of water the flow that the structure has to handle, in this case it the graded bund. So, we remember the graded bunds are designed for safe this removal of excess flow so; that means, whatever flow is generated over the area between these 2 bunds we have to design a in such a way that the dimensions and all. So, that it is taken off safely from the area. So, that is why the computation of peak runoff rate becomes the most vital thing this is the first thing.

And just to give you an idea I mean are just to remind you that we discussed how to determine the peak runoff rate. And we also decided we said that for design for determining the peak runoff rate from any area watershed catchment. We use rational method which I also mentioned that, you should always remember because this such a fundamental thing. And this is given as CIA by 36. This is the formulae and also remember, when we discuss this formula, we also said that there certain units which we should always remember. So, in this case Q is in cubic meter per second C is the runoff coefficient which is the coefficient the value is given here in 0.35.

I is rainfall intensity for duration equal to time of concentration exactly the data which is already given. So, we have been given rainfall intensity already in the problem. And the unit here is centimetre per hour and A is the A is the drainage area and the unit if you are used is hectares

So, that means, we need to know for these CIA and in this problem C is already given I is already given already given. So, we have to find out that is the drainage area and; obviously, because we are talking about the graded bunds. So, the area lying between 2 consecutive bunds that is the drainage area we are talking about in this case. So, we have to find that out. So, let us say let us see how to do that.

So, for doing that the first thing we need to remember or determine is the horizontal spacing of bund. Because, we remember we said that if this is what we are talking about this is one graded bund. This is another graded bund. So, this is the area we are talking about the area between these two, we talking about.

So, in this case; obviously, we decided that there is something called horizontal interval. So, this is horizontal interval any corresponding point we can take into bunds and the horizontal distance between that is horizontal interval. So, that is horizontal interval basically and the length of the bund length will be perpendicular to the board basically. So, so this is what the area we are looking for that is the area where, in which whatever rainfall occurs that we have to handle. So, that is why that becomes the drainage area or that that will decide the peak runoff rate which we have to handle. So, that is why the first thing we need to determine is horizontal interval.

And we know that from previous class also and also in contour bunds we know that there is a direct relationship between horizontal interval and vertical interval that is H I equal to V I by S into100. And I also said that, you do not have to remember this formula because this is vertical interval, this is horizontal interval. And at the same time we also know that it is S by 100. So, this land slope is S percent. So, S by 100 generally, we take it S is we designate S for land slope.

So, that simply means by triangle we can write that S by V I equals to 100 by H I or H I is equal to 100 V I by S. So, that is the formula here 100 V I by S. So, you as I also said in the previous class you really do not need to remember all the formulae all the time you can many a times you can derive the formula.

So, in this case for us vertical interval is already given land slope is already given as 3 percent that is here. So, data both the unknowns are given here. So, putting the value of V I and S if you calculate that, we find that H I is equal to 41.66 meters or approximately 40 2 meters.

So, area between forms between 2 consecutive bunds already we have explained that that it is H I times length of the bund. So, H I is we have calculated length of bund is already given. So, this is in meter this in meter total area and square meter. So, that comes out to be 14700 square meter, but remember in CIA we with the unit required is hectares. And that is why we have to divide this by 10000 square meters that is that is 10000 square meters is equal to 1 hectare you remember. So, by doing that we get the area as 1.47 hectares that that is that drainage area.

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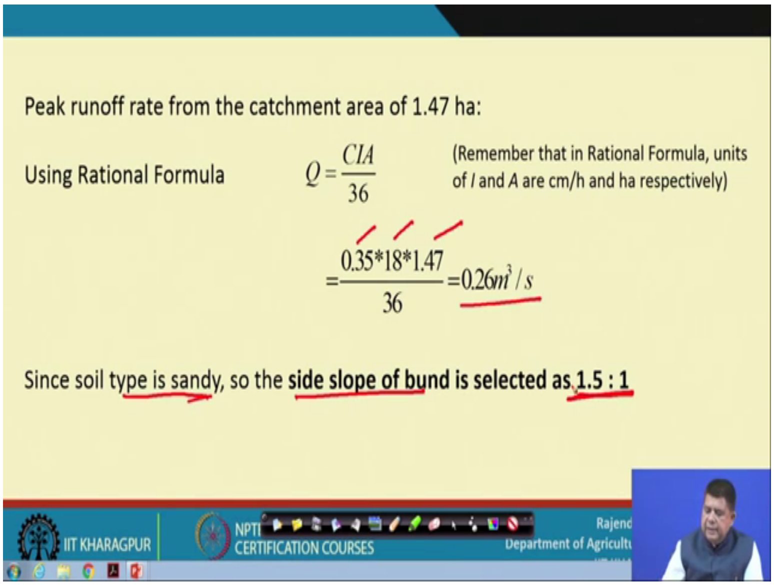

And once drainage area is known, then we can put the value in Q equals to CIA by 36. So, C is known 0.35, I is given as 18 centimetre per hour. The drainage area, we have already calculated is 1.47 hectares by 36. So, the value of Q comes out to be 0.26 cubic meter per second and that is the discharge our system has to or graded bund system has to handle. So, we this is important finding for us.

Now, let us come to now we know what is the discharge that our system has to handle. So now, we can go ahead and decide on the components of the graded bund or the cross section basically. So, first thing we decide is the side slope of the bund and that we I have already seen that is a function of type of soil and because the soil is given is sandy. So, the side slope of the bund will be 1.5 is to 1. So, this is already a standard value. So, we are taking that is 1.5 is to 1.

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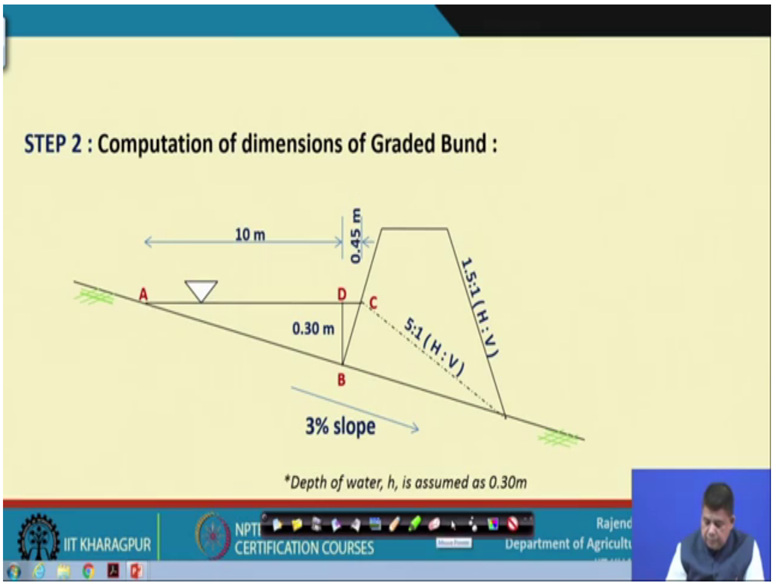

Now, this come the definition sketch. So, this is typically we say as D or H that is depth of impounding and this land slope is 3 percent. Now, what we are doing here? We can calculate the values, but what we are doing here? That is, this is one of the alterations that you can also assume the value and go forward and calculate. So, what we are doing here that we are assuming that a depth of water h is 0.3 meters.

So, this is our assumption rest of calculating the value what we are doing, we are starting with an assumption, which can we can always do. So, we are once we assume this as 0.3, this slope we already know is 1.5 is to 1 so; that means, if this is 0.3 this is H this is this distance is 1.5 H or 1.5 times or 0.3.

That is how we are getting 0.43 meters. And this is 3 percent slope. So, this is 3 percent this is 0.3 so; obviously, if we calculate this will come out to be 10 meters. So, that is why AD is 10 meters and DC is 0.45 meters.

And then again this is can be soil. So, again that this is a seepage line and the slope is slope is being taken as 5 is to 1 because say a sandy soil. So, this all these components we I mean all these parameters design parameters are here in front of us and then we have to on the total height and the base width and the top width and then we have to see that it should be able to handle the discharge for which it is being designed.

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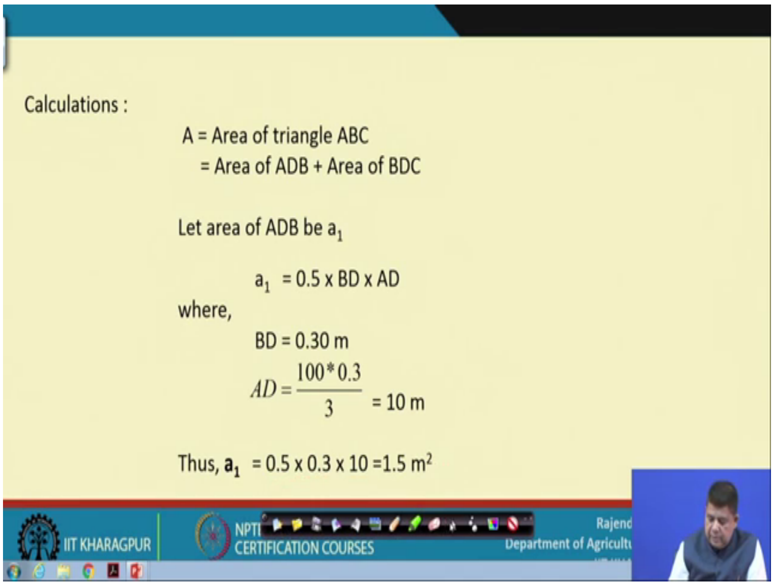

So now basically the total area will be area of triangle ABC that is area of ADB and area of BDC. Let me just go back to the previous equation. So, basically what we are saying is that are this is the total storage area. So, it is sum of 2 triangles that is total area is an area sum of area ADC plus area BDC. This is this is 1 and this is 2 1 and 2 this is 1 or 2 2, 2 triangles are there.

And we have all the values here. So, we know that ADC is half times this will be AD C will be half into point 3 into 10 and BDC will be half into 0.3 into 0.45. So, this is how the values will come.

So, that is what we are doing here that is 10 meters a1. We are calculating half into 0.3 into 10 1.53 square meters and second triangle.

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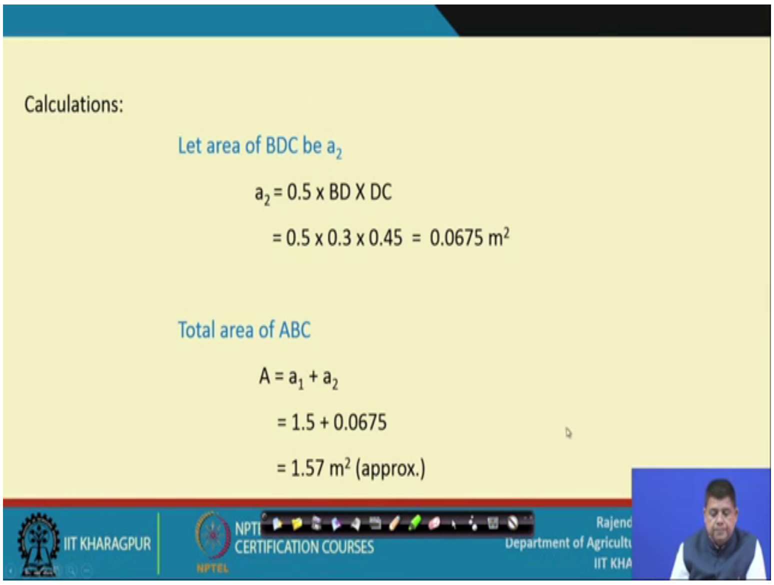

Ah BDC a 2 which is half into 0.345 into that is comes out to be 0.0675 square meters. So, total area of ABC is a 1plus a2 comes out to be 1.57, the square meters. So, this is the total area which we have it should that we storage area. Basically, we are talking about.

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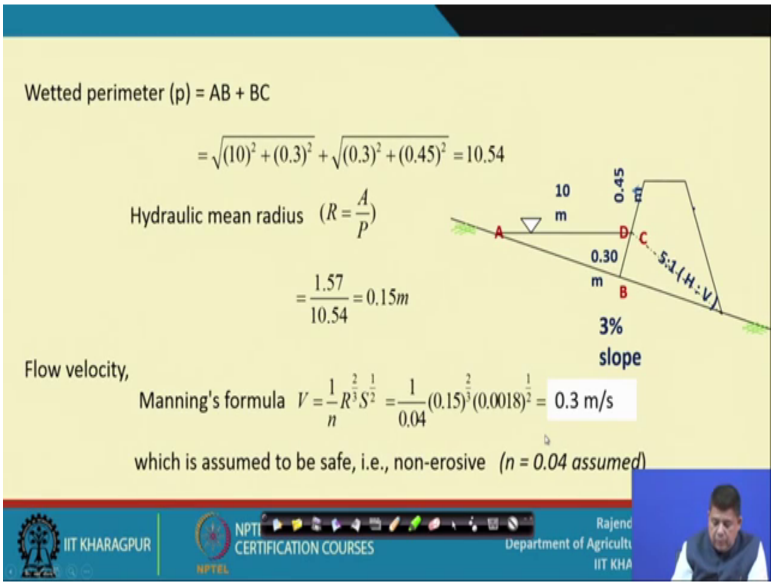

Now, next thing we have to calculate is wetted perimeters and wetted perimeter, we saw that it is nothing but the length that is in constant touch with water. In this case, it will be AB and BC. So, AB and BC we can again same triangle 2 triangles are there. So, we can find out AB square equals to BD square plus AD square that is 10 square plus 0.3 square.

This is here and this BC is square equals to BD square plus DC square. That is 0.3 square plus 0.45 square that is, square root is be taken. So, on solving we come we get a 10.54 that is wetted perimeter is 10.54.

So, hydraulic radius is A by P A, we have calculated P we have calculated that comes out to be 0.15 meters and then; obviously, for flow velocity we have to use the Manning's formula which is 1 by n R to power 2 by 3 is to the power half. So, 1 by n, n value we normally assume as 0.05. So, that is what which is being assumed and this is 0.15 and the grade of the channel is given 0.0018. So, will percent we are writing as 0018 percent same and then we are calculating the value of velocity which is 0.3 meter per second. We are getting and you remember non erosive velocity means, it should be less than 0.5 percent and 0.65. In any case so this is here this velocity is non erosive.

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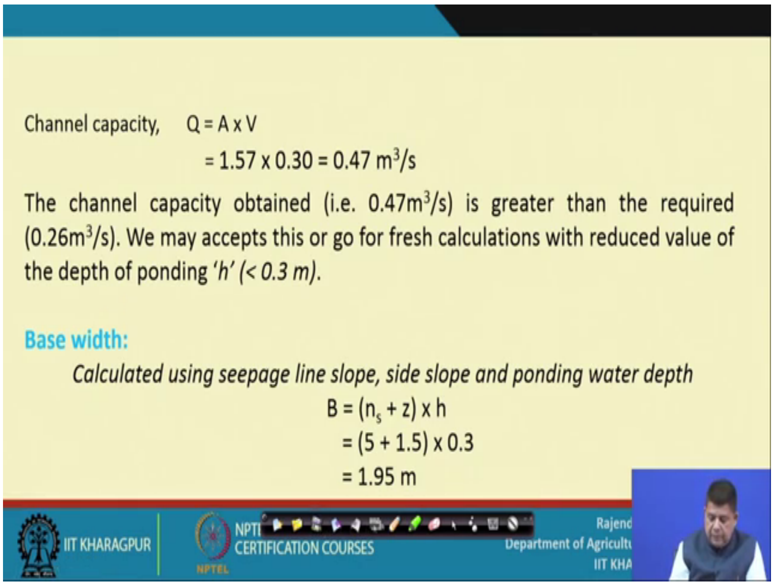

So that means, from knowing the velocity and area we can calculate Q which, is here. The channel capacity obtain 0.437 is greater than the required. We require only this much and we are getting much greater. So, we may accept this or we may go and reduce the value of depth of ponding h. So, that is what I mean if you assume the value you have to do iterate it. So, that iteration process is there, but we are not doing, but because you can do that anywhere and once A h is calculated.

Then the base width will be n S plus j times h. That is 5h plus1.5h many times you have done that. So, it will comes out to be 1.95 meters and the top width will be.

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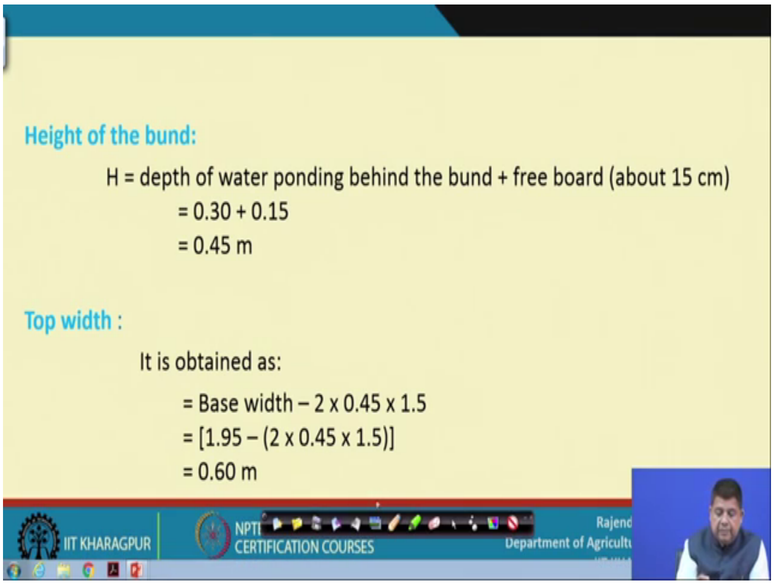

The total height of the bund will be depth of water plus free board. Generally, we are assuming 25 percent, but let us say we are assuming here is 15 centimetres. So, the total height comes out to be a 0.45.

So, that top width will be base width minus 2 times of top total height times 1.5 which is the side slope. So, that comes out to be 0.65. So, this way the different dimensions of the bund.

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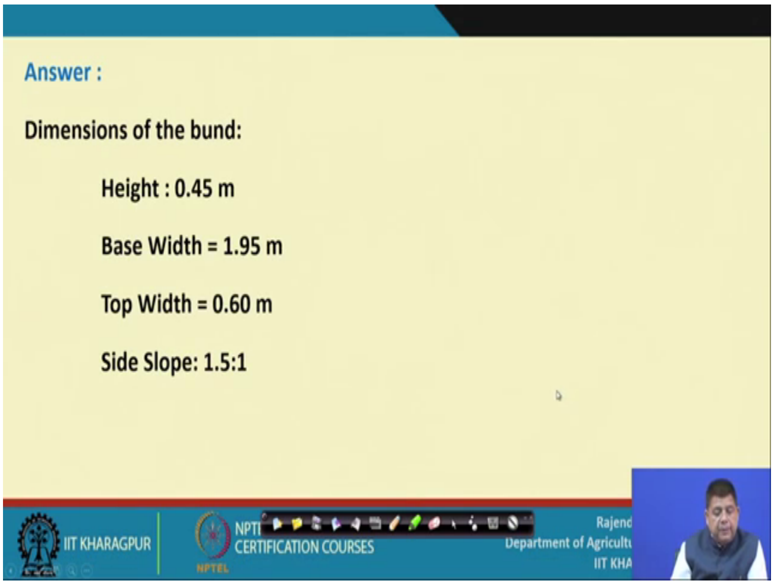

We obtained are the height is 0.45 meters base width is 1.95 meters top, width is 0.6 metres and side slope that is soil dependent, which we started with this 1.5 is to 1. So, this is how we have designed a handled the particular problem.

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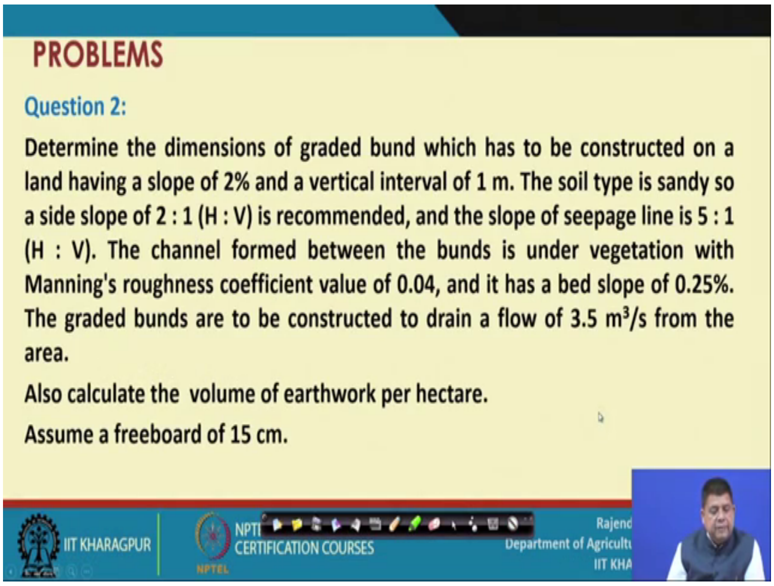

Let us take the next problem, determine the dimensions of a graded bund which has to be constructed on a land having a slope of 2 percent and vertical interval of 1 meter soil type is sandy. So, a side slope of 2 is to 1 is recommended and the slope of the seepage line is 5 is to 1. So, these slopes are already given the channel formed between the bunds is under vegetation with Manning's roughness coefficient value of 0.04. And it has a bed slope of 0.25 percent. The graded bunds are to be constructed to drain a flow of 3.5 cubic meter per second. So, in this case flow is already given.

So, we have to determine the dimensions of the bund and also calculate the volume of earth work per hectare assume a free board of 15 centimetre. So, almost all data is already given including the flow in this case.

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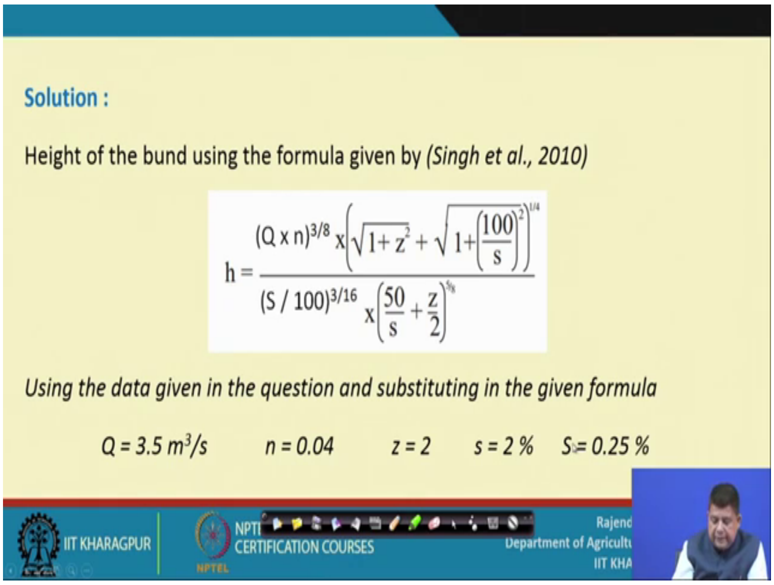

So in this case, we can straight away try to use the height of the bund formula which we saw we almost derived using such paper. So, is where h is a function of Q n z and 2 slopes capital S and small s remember capital S is the channel bed slope and S is the land slope. So, all the values are given Q equals given as 3.5 cubic meter per second. N is given as 0.04 and z is 2 S is 2 percent capital S is 0.25 percent. So, all the unknown values are given.

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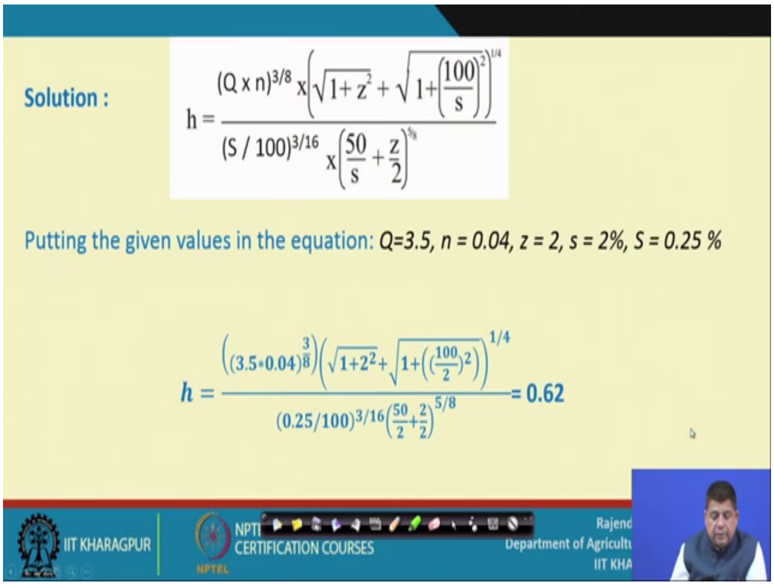

So putting these in equation,

we can solve h and solve for h and that comes out to be the value comes out to be 0.62 meters; so h comes out to be 0.62 meters.

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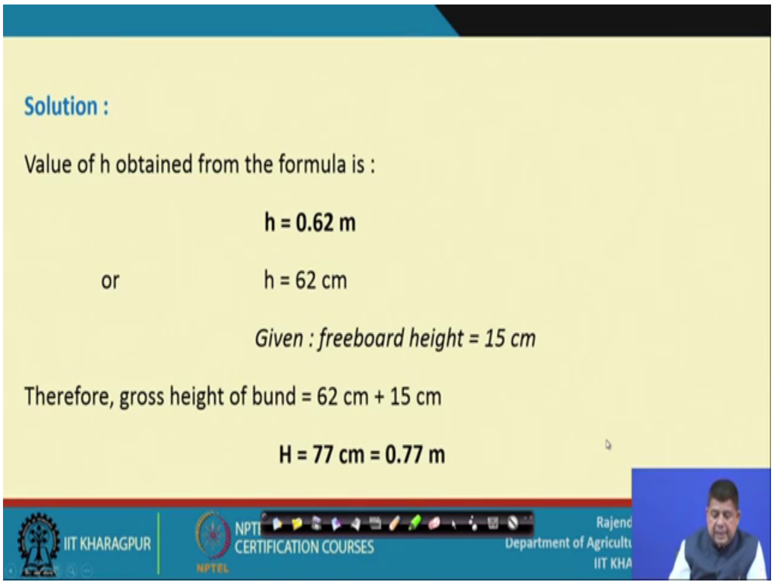

And once h is known then; obviously, we have to get the total gross height of the bund the free board value is given is 15 centimetres. So, the gross height of the bund is calculated height plus 15 centimetre that is 77 centimetre or 0.77 meters. That is the value of h we have obtained.

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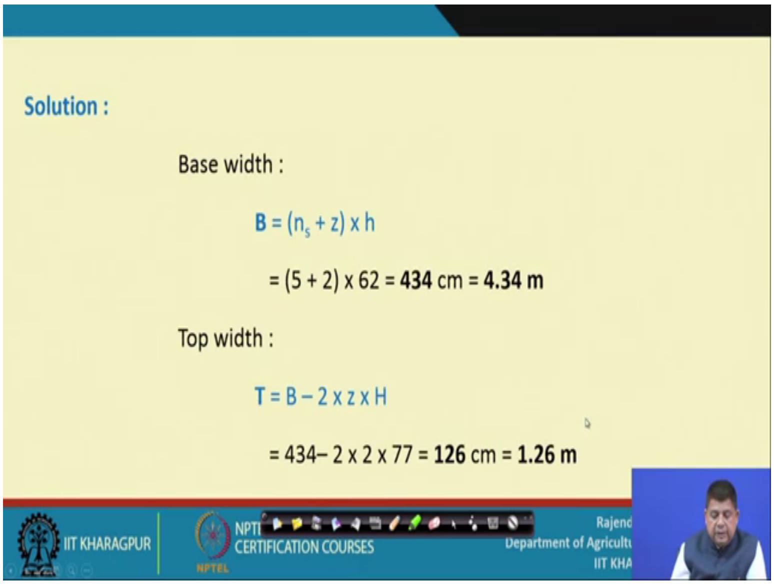

And once h is known, rest of the things are simple we know that bed width is depends on n S plus z equal to going to times h n S is given as 5 is to 1 that is the seepage line slope z is given as 2 is to 1 that is z is equal to 2 h. We have already calculated 62. And so, that comes out to be 4.34 meters.

Top width is B minus 2 times z and capital H that is the gross height. So, 434 minus 2 into 2 into 77 that is a gross height or it is 1.26 meters. So, because in this problem everything else was given we straightaway, calculated the value of h and thus it was simpler to calculate all other values.

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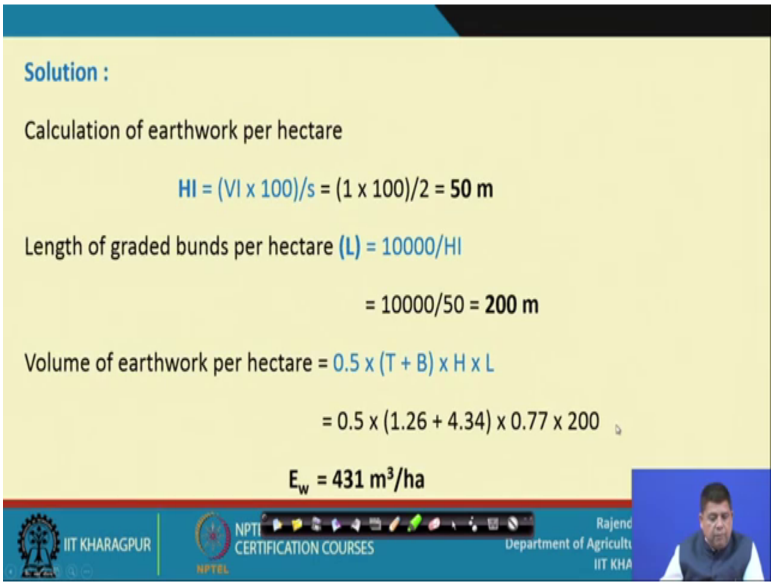

So, now we have to in of the second part of this is we have to calculate the earthwork. And for earthwork per hectare we required horizontal interval and we already know the relationship between horizontal interval, vertical interval the value of vertical interval is given. So, horizontal interval comes out to be 50 meters to length of graded bund per hectare is 10000 square meters divided by H I in meters that, is around 200 meters.

Horizontal interval and the volume of earthwork per hectare is cross section times length the cross section of the bund times the length per hectare. And cross section is function of TB and H and TB and Hh all we have determined. So, it is 0.5 times T T B H all the values we have obtained L also we have calculated. So, earthwork comes out to be 431 cubic meter per second. So, that is pretty straight forward it was simple because values were all given to us.

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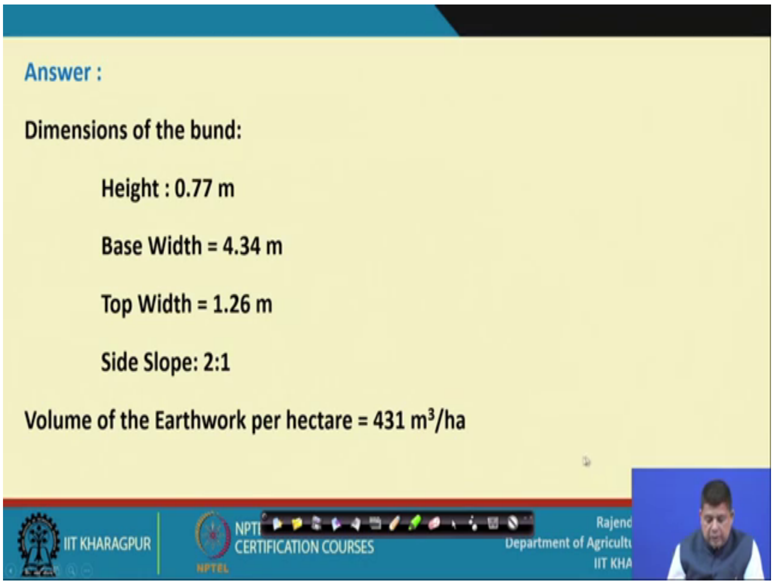

So, the final answers are dimensions of the bund height equals to 0.77 meters, base width 4.34 meters, top width 1.26 meters side slope 2 is to 1 and volume of earthwork per hectare 431 cubic meter. So, this is what the answer will be.

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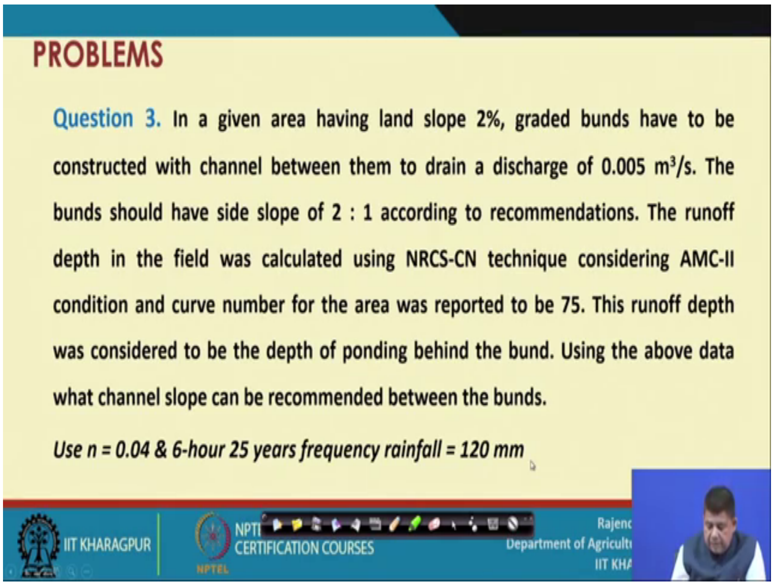

Take the third problem in a given area having land slope of 2 percent graded bunds have to be constructed with channel between them to drain a discharge of 0.005 cubic meter per second.

The bund should have side slope of 2 is to 1 according to recommendation the run off depth of the field was calculated using NRCS curve number technique. Considering AMC 2 condition and curve number for the area was reported to be 75. This runoff depth was considered to be the depth of ponding behind the bund. Using the above data what channel slope can be recommended between the bunds. Use n equals to 0.04 and 6 hour rainfall 24 hour frequency rainfall is 120 millimetres.

So, in this case we have been lot of data is given, but important thing is that we have to calculate the runoff volume in depth terms using NRCS curve number technique. So, that is important.

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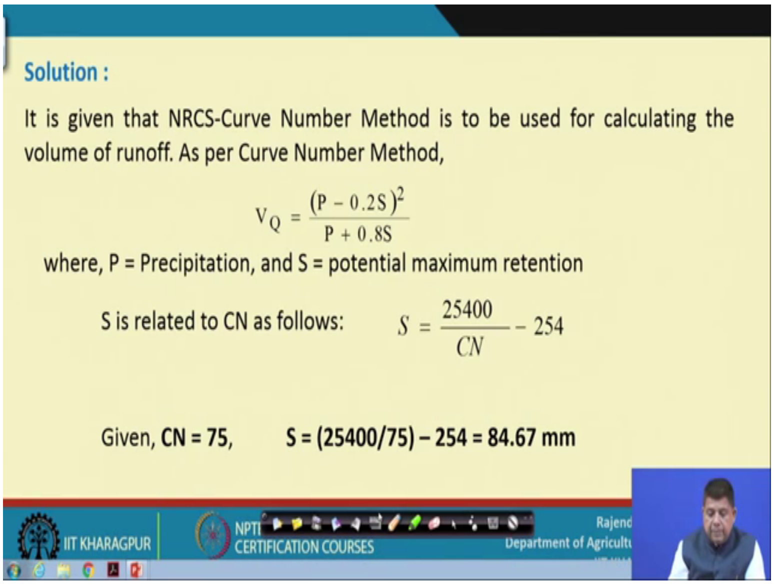

And if you remember the NRCS curve number method used for calculating the volume of runoff in depth units. And this is how the curve number looks formula looks like VQ equals to P, which is precipitation S which is potential maximum runoff and P minus 0.2S square by P plus 0.8S and S is related to curve number by this formula S is equal to 25400 by curve number minus 24, 254. This is when S is in millimetres, this particular formula is used.

And because curve number is given by putting curve number here. We can get the maximum potential retention S value is 84.67 millimetres and for this area the precipitation value is also given to us.

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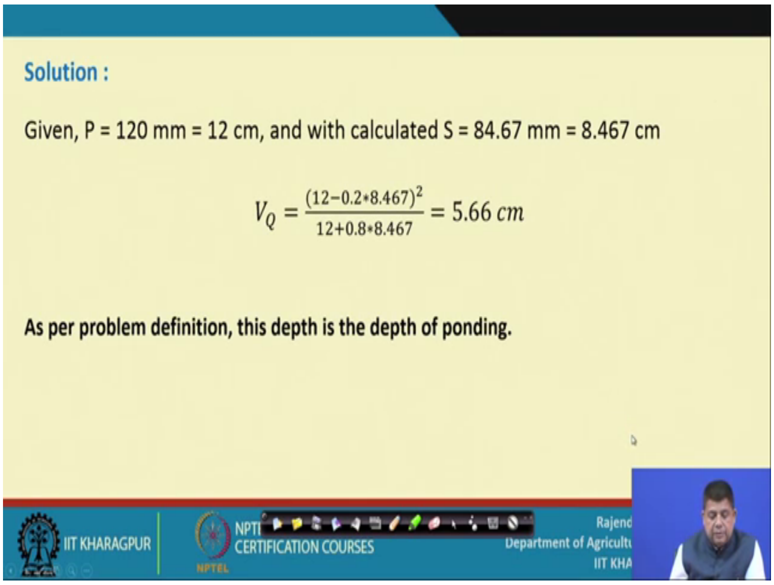

That is precipitation is given as 120 millimetres or 12 centimetre. And value of S we have calculated is 8.467 centimetres. We are converting into centimetre because the value of P and S required for in the curve number method are in centimetre.

So now putting these values in desired units in this formula we get VQ equals to5.66 centimetres and as per problem definition this is the depth of ponding. So, depth of ponding previous cases we calculated in this case calculating VQ we directly get the depth of ponding. So, this is another variation of the problem which we might face.

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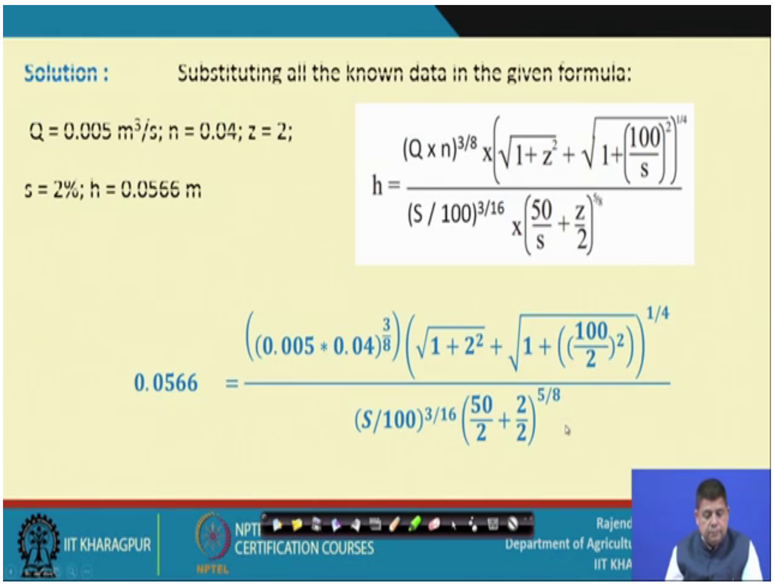

And once we have obtained this. When once we have obtained, we can substitute all the values because Q is known n is known z is known s is known and h is known we can substitute in this. So, only unknown is capital S or channel bed slope. So, by putting all the values in this equation and solving, we get s equal to or the channels slope equal to 0.0674 percent

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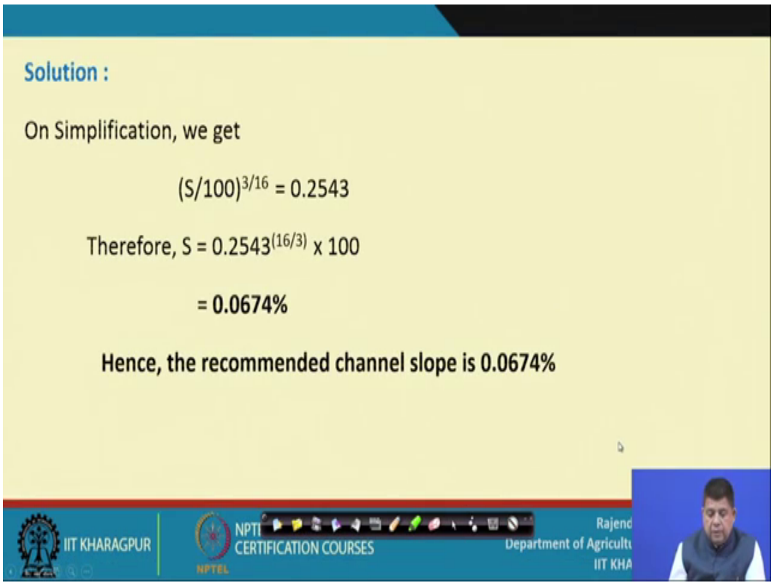

. That is the recommended channel slope is 0.0674 percent that is what we have to calculate we had to calculate in this particular problem.

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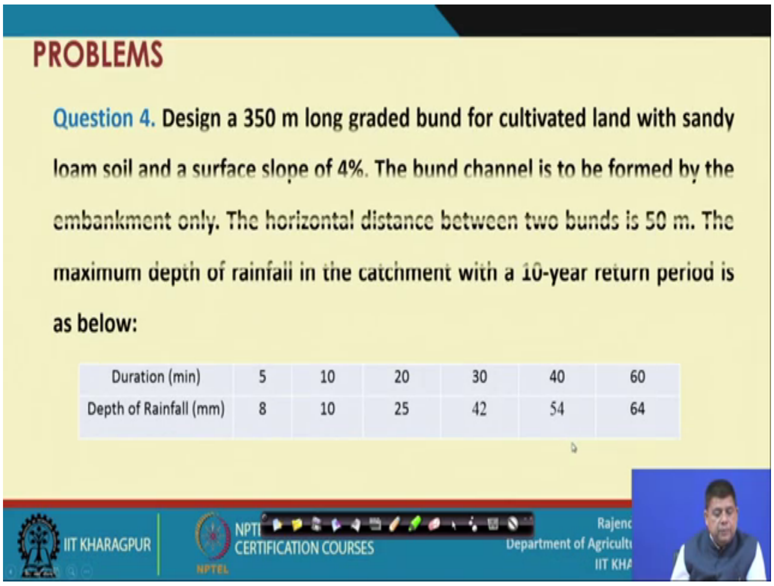

So now we go to the last problem design a 300 metre long graded bund for a cultivated land with sandy soil sandy loam soil surface slope of 4 percent bund channel is to be formed by embankment only. The horizontal distance between 2 bunds is 50 meters the maximum depth of rainfall in the catchment with 10 year return period is given below. So, duration versus depth of rainfall relationship is given here.

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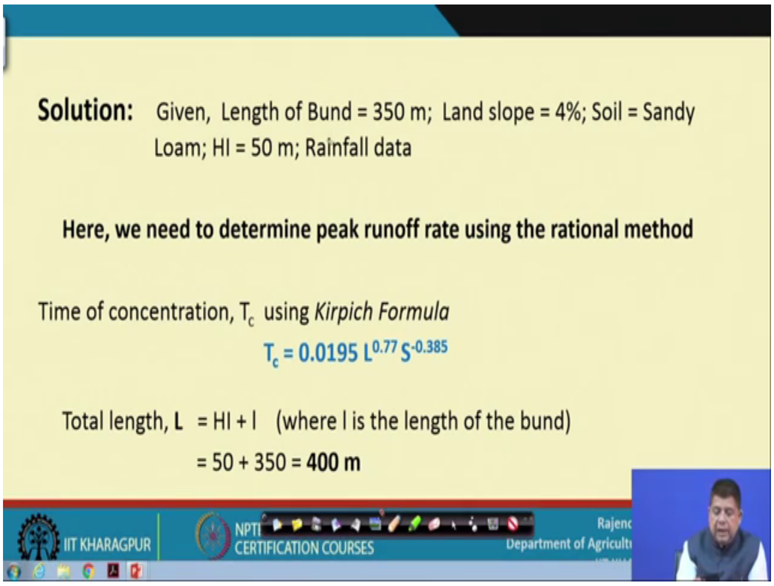

So, data available are length of bund 350 meters land slope 4 percent soil sandy loam H I 50 meters and rainfall data is given so; obviously, here again we have to determine the peak rate of runoff using the rational method in the previous case which we handle rational method. They are we had been given rainfall for time of concentration for duration equal to time of concentration, but this is not the case.

So, here we have to calculate the time of concentration T c using Kirpich formula which is T C equals to 0.0195 L to the power 0.77 S to the power minus 385 and the total length which the flow has to flow path length which we consider is horizontal interval plus length l which is the length of the bund itself the perpendicular distance we always talk about.

So, because if we consider here in 3 dimension if you see here so; that means, any drop which occurs first it has to flow here that is horizontal interval and then the length. So, that is the maximum length which comes out to be 400 meters in this case.

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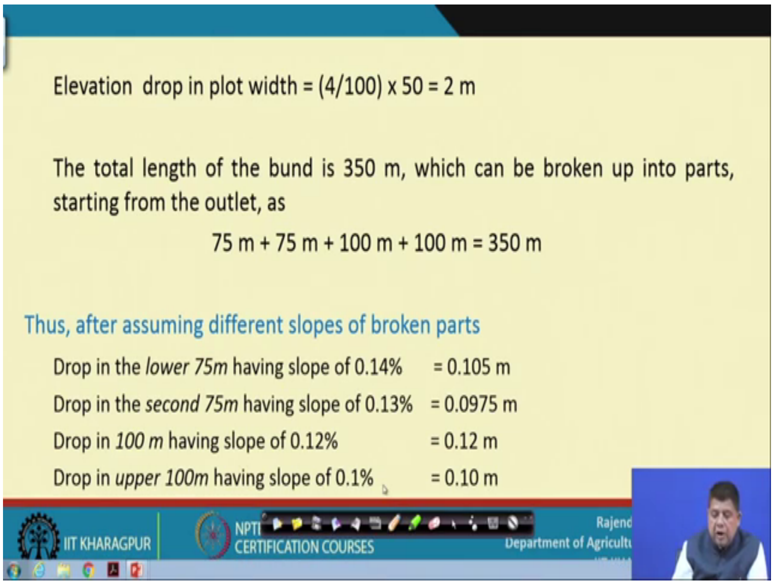

And total elevation drop will be plot width is 4 percent slope over 50 meter is 2 meters. The total length of bund is 350 meters. So, what we are doing as a variation we can say that we are breaking that into 4 different parts 75meter 75 meter 100 meter 100 meter. And we are saying that the variable slope is provided. So, the lower 75 as 0.14 percent the second 75 is 0.13 drop 100 meter is upper one has 0.1 percent. So, for each we can calculate the slope value because length is known slope percent is known. So, slope length we can find out.

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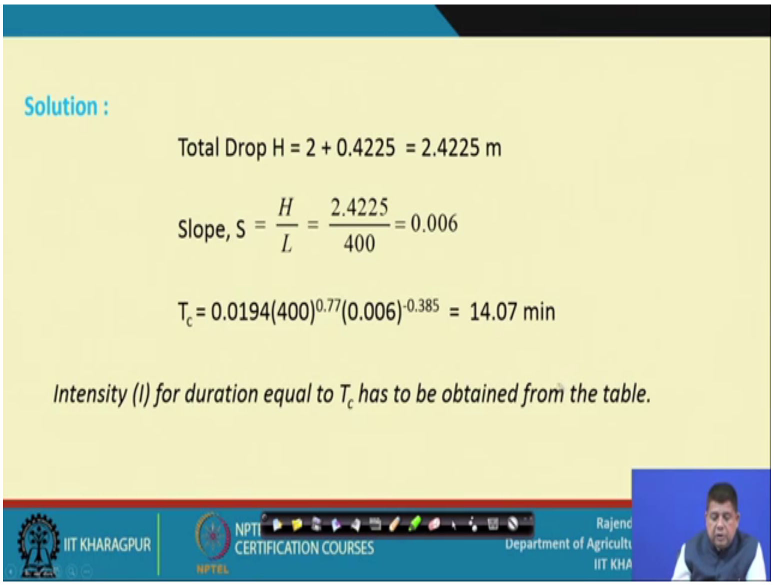

And thus the over the channel the total drop which comes out to be a 0.4225 meters and the total drop comes out to be 2 plus this that is 2.4225 meters and; that means, the total slope will be H by L. That is the total drop by over length this is drop this is length 0.06. So, in formula now we know L we know S. So, by putting this formula we get a value of 14.07 minutes. And then we have to use this for obtain the data from the table itself.

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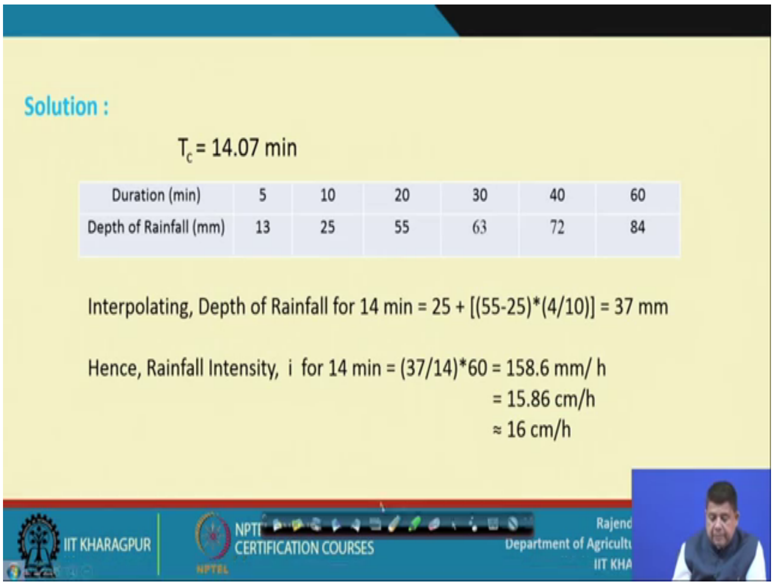

So, if you look at the table the value is given for 10 and 20. We have to obtain for 14 so; obviously, we can we can always interpolate in between these 2. So, interpolating we get 25 plus 55minus 25 by 10 times 4. So, total it comes out to be 37 millimetres.

The rainfall intensity for 4teen minutes that is rainfall in 14 minutes is 37 millimetres. So, the intensity will be 37 by 14 into 60 that is 158.6 millimetre per hour or roughly say 16 centimetre per hour.

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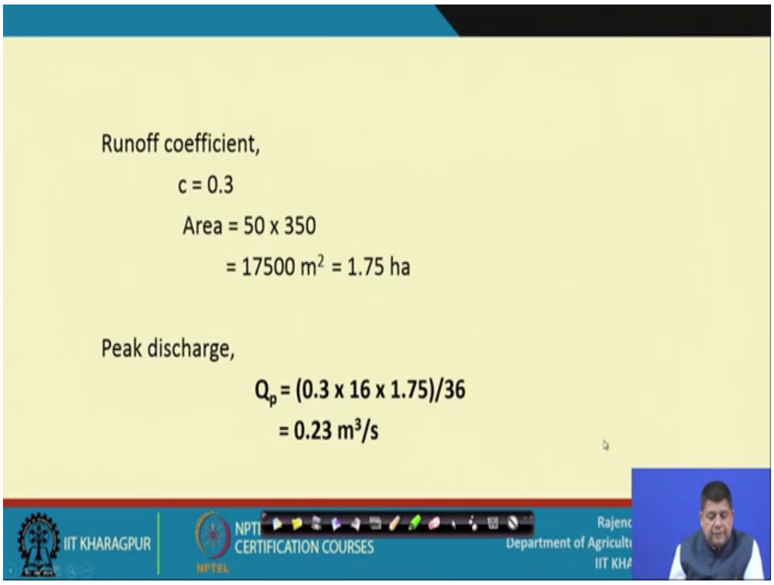

So, once TC is known we can the intensity is known we know the C, we know the total area because H HHI and L are known. So, area is known. So, we can put in rational formula to get the value of QP which comes out to be 0.23 cubic meter per second.

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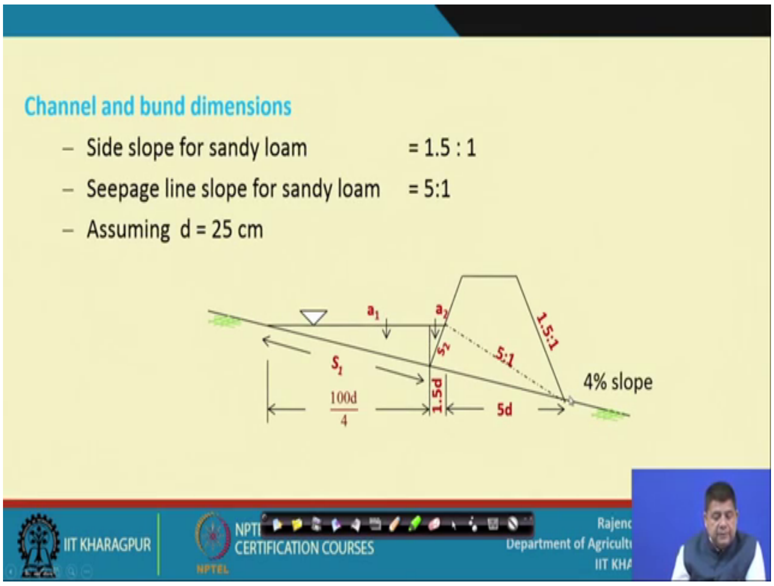

So; that means, we have to handle this discharge. And then rest of the things, side for sandy loam is known 1.5 is to 1 for seepage line. For sandy loam is 5 is to 1. We assume a depth of 25 centimetres and like previously, we have solved this problem we can go ahead and get the cross section etcetera

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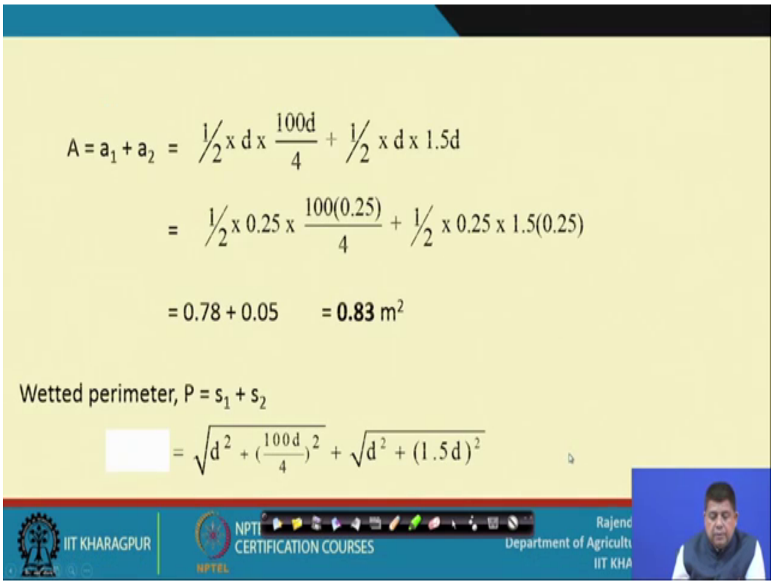

So, here the sum of 2 areas will find out which comes out to be 0.83. If I am calculate the wetted perimeter and the once we have done that,

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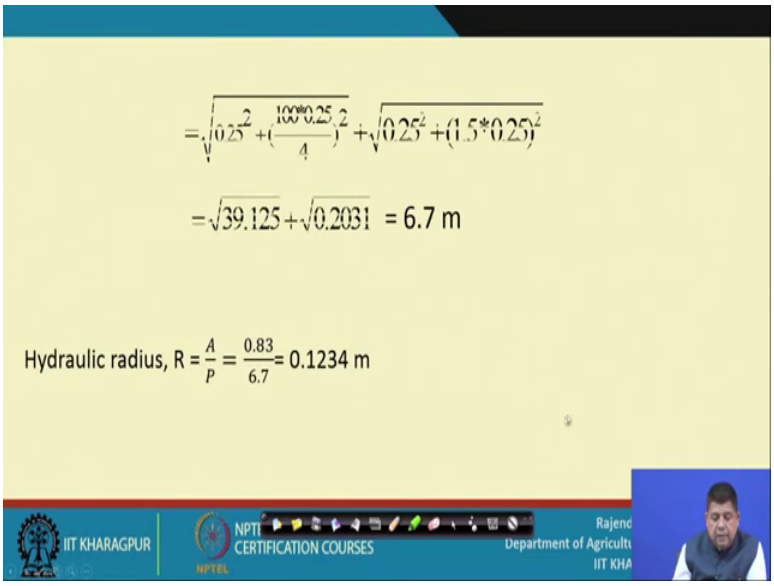

We calculate the hydraulic radius which comes out to be 0.1234 meters and once hydraulic radius is known.

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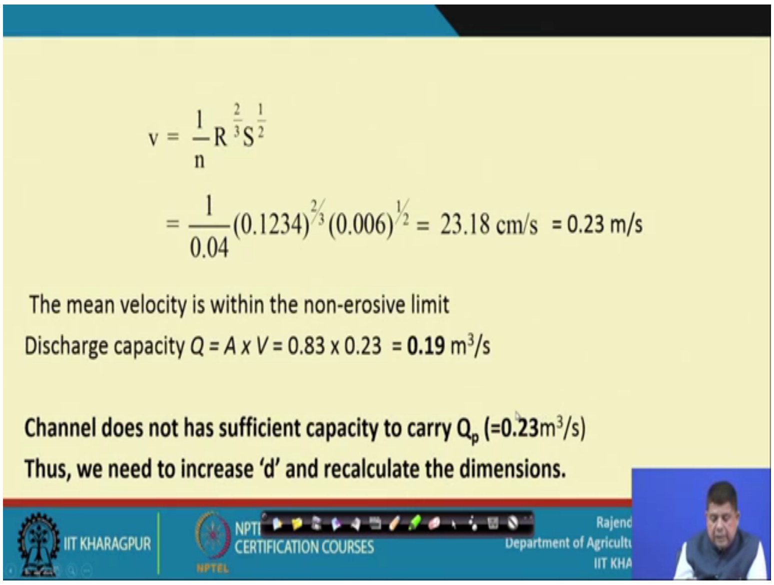

Then, we can use the values in Manning's equation to calculate the velocity of flow which comes out, 0.23 meters per second which is non-erosive. So, no problem and discharge capacity Q equals to AV comes out to be 0.1319 cubic meter per second. The problem is that channel capacity we are calculating 0.13, but discharge we have to handle is 0.3 cubic meter per second ; that means, the channel does not have sufficient capacity to carry QP. So, we need to increase d and recalculate the dimension so this is that variation because this calculated value is not sufficient to handle the desired discharge.

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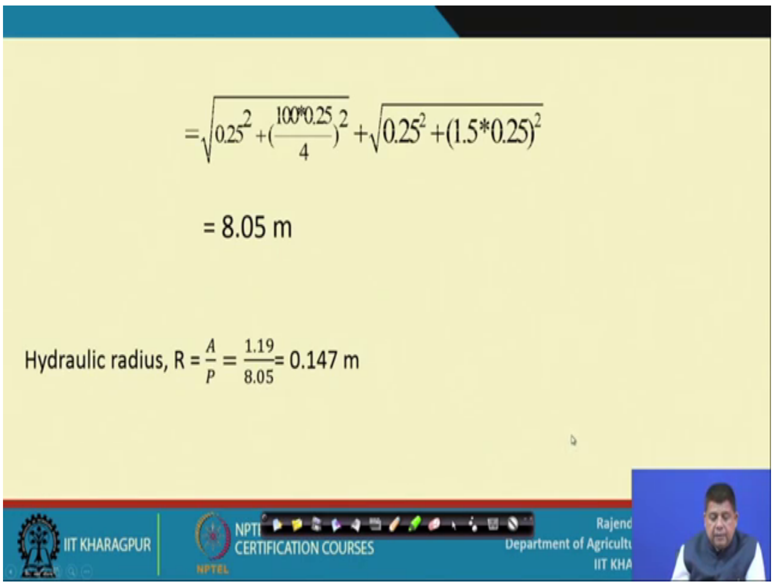

So; obviously, then it is a just A iteration. So, we will go and change the value, calculate A calculate P, then calculate hydraulic radius which new value comes out to be 0. 147.

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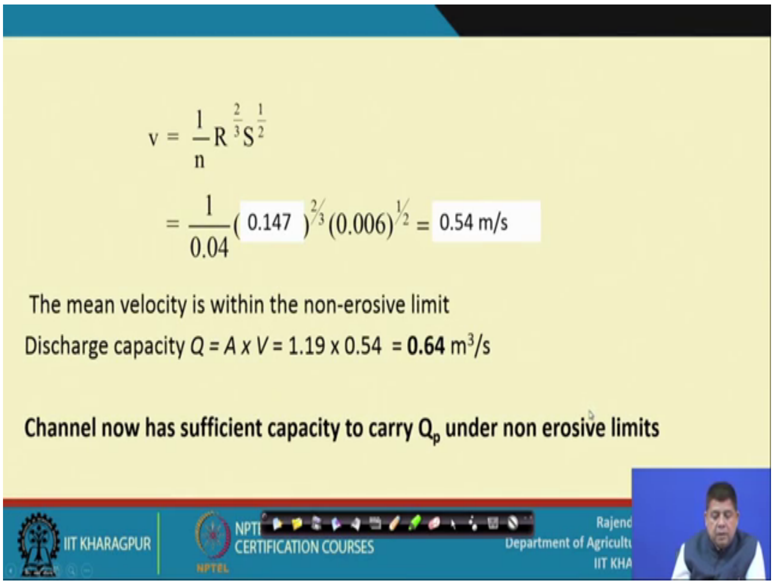

And then, we have to now calculate once again the velocity which is 0.54 fine still fine. And then Q value we have to calculate which comes out to be 0.64 square cubic meter per second, which is sufficient because the discharge we have to handle was 0.23. So, channel now has sufficient capacity to carry Q P under non erosive limits so; that means, we have handled the problem.

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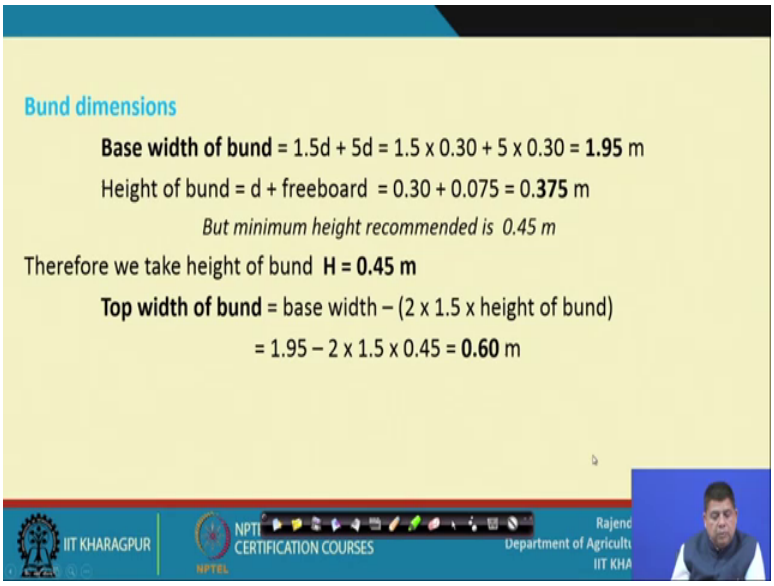

So, the bund dimensions the discharge is handled. So, the bund dimensions can be calculated the base width of bund we know how to calculate height of the bund we know how to calculate, then top width of bund we know how to calculate. So, once H is known everything else can be calculated easily.

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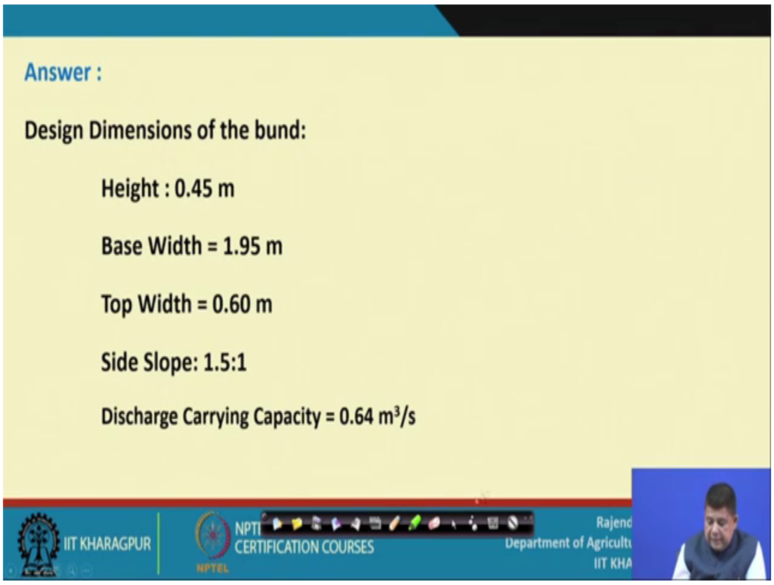

So, thus in this case that final answers are height of bund 0.45 metres base width 195 top width 0.6 side slope 1.5 is to 1 discharge capacity is 0.64 cubic meter per second whichis slightly higher, but we accept that.

So, with this we have handled 4 different kinds of problems and where I mean ultimately we have to have flow with us and once flow is there that, for estimating that flow. We might have to use rational method. We might have to find out the time of concentration if required and also which is possible to use the S C S curve number technique. So, all these will be used for finding out the flow once flow you known then, we can either assume the value of d or go and calculate the value of d and then other dimensions. So, if you practice few more problems like this and we will be giving putting some problems into assignment I think things will be very clear to you.

Thank you very much.