Power System Engineering

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Lecture – 27
Sag & Tension Analysis (Contd.)

Next part is that d; d it is given effective load acting on conductor in kg per meter. Using equation 83 that We is equal to root over F square plus W plus W i whole square that is your W is equal to root over F square plus W T square F is equal to 0.81 kg per meter you have computed this one here it is and your this W T we have computed 2.97 kg per meter.

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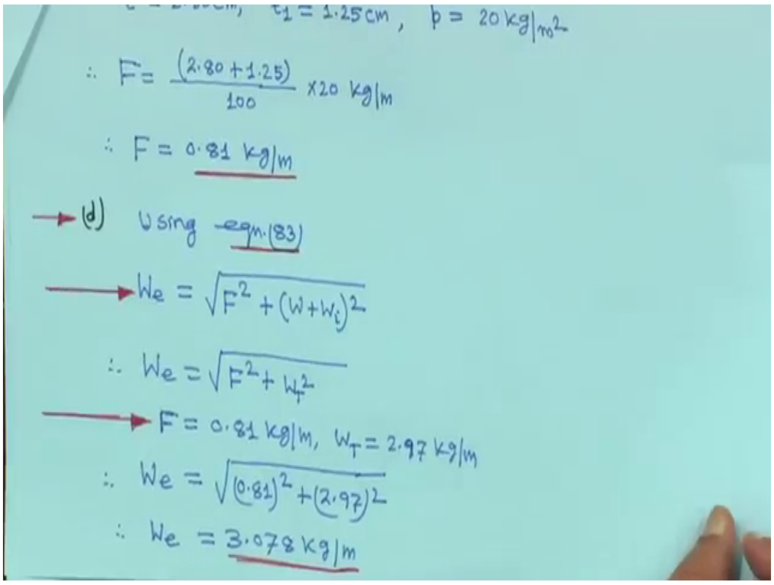

So, then you can easily calculate W e is equal to root over 0.81 square plus 2.97 square this is 3.078 kg per meter; this is your d.

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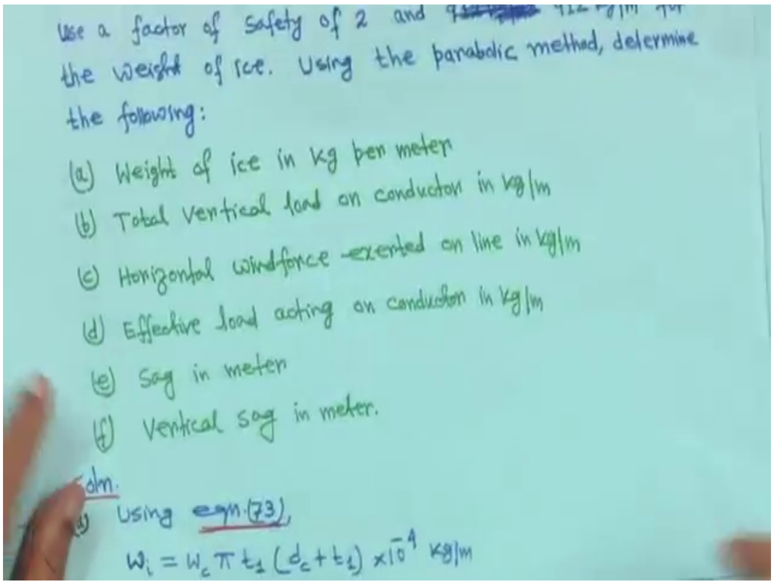

Then e is; Sag in what you call a effective load, d we have computed. Now, e is the sag in meter and F vertical sag in your meter.

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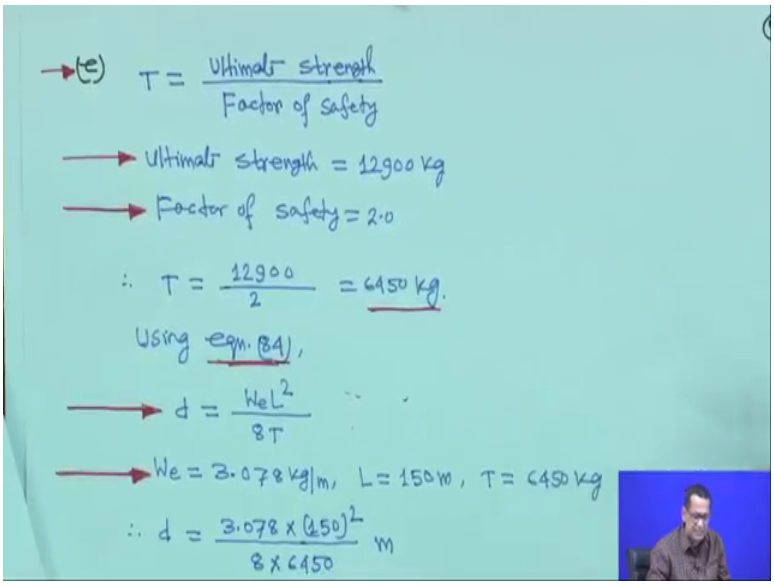

Now, then it factor of safety that term is used. So, factor of safety is given that T is equal to actually ultimate strength divided by factor of safety. Now, ultimate strength is given 12900 kg and factor of safety is equal to 2 therefore, T will be 12900 by 2. So, this you should keep with your mind the T is equal to ultimate strength divided by factor of safety therefore, T will be 6450 kg. So, using equation 84 you know d is equal to We L square upon 8T.

So, we is equal to 3.078 kg per meter that we have calculated, L is given 150 meter and T just we have computed 6450 kg. If you substitute d is equal to 3.078 into 150 square divided by 8 into 6450 meter. So, this is actually 1.342 meter this is your d another thing is last one is the vertical sag in meter.

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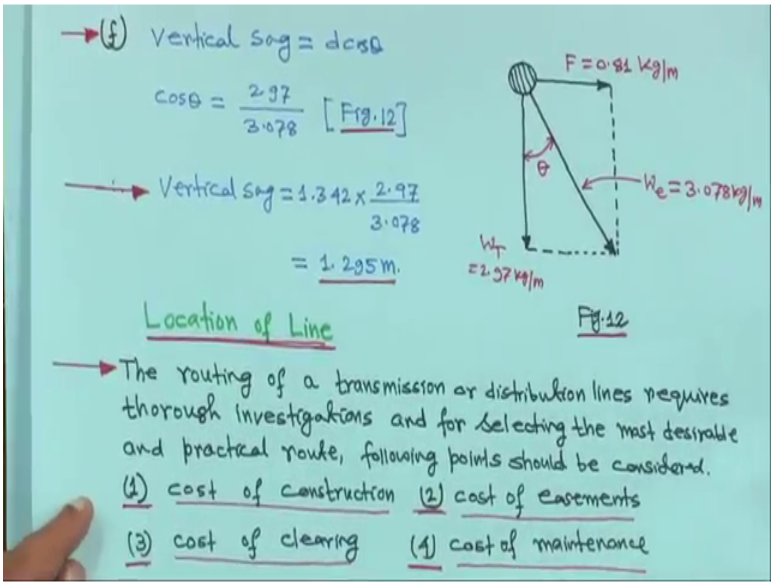

So, vertical sag we have seen earlier it is d cos theta. So, in this case F is acting this way 1.81 kg per meter W T is 2.97 kg per meter resultant is 3.078 kg per meter and this angle is theta. So, vertical sag will be your d cos theta. So, cos theta is equal to from here you can find out 2.97 upon 3.078. So, 2.97 upon 3.078, for figure 12, from this figure therefore, vertical sag will be 1.342 into 2.97 upon 3.072. So, it will be 1.295 meter. So, this is the your what you call the one numerical swing part by part that how we will proceed for solving numerical.

Next one is that location of line. So, again we will come to a numerical first little bit theories are there location of line. So, the routing of a transmission or distribution lines requires thorough investigation and for selecting the most desirable and practical route following point should be considered. When you are designing transmission line certain things you have to consider; one is cost of construction, two is cost of your easements and three, cost of clearing and cost of maintenance. So, all sort of things are there cost of clearing it is I mean a many things are there.

So, all these things just we will know, but a detail study will not go into that in this course because it is a time mounting. So, we will just know that at undergraduate level that these are the things.

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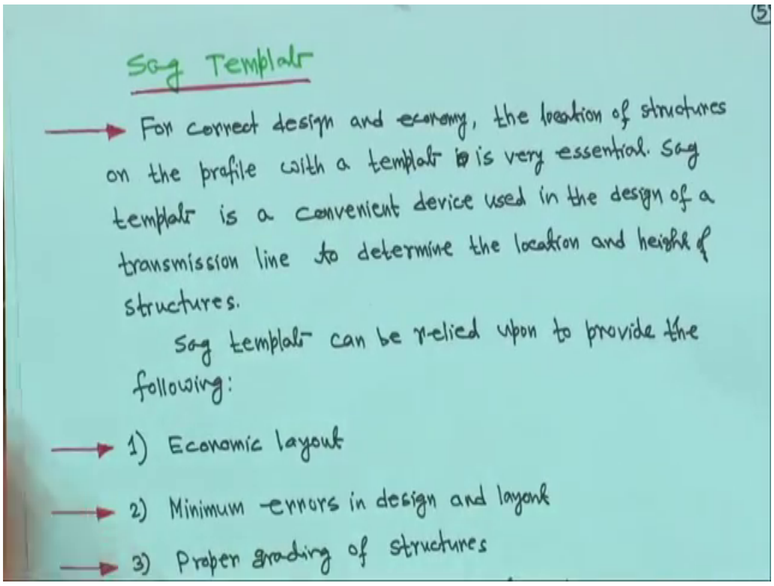

Then, sag template; for correct design and economy of your the location of structures on the your what you call this is sag template also sag template is given, but sometimes this may not be exactly what you want, but some ideas you have. For correct design and economy the location of structures on the profile with a template is very essential that is sag template we call say. So, sag template is a convenient device use in the design of a transmission line to determine the location and height of the structure.

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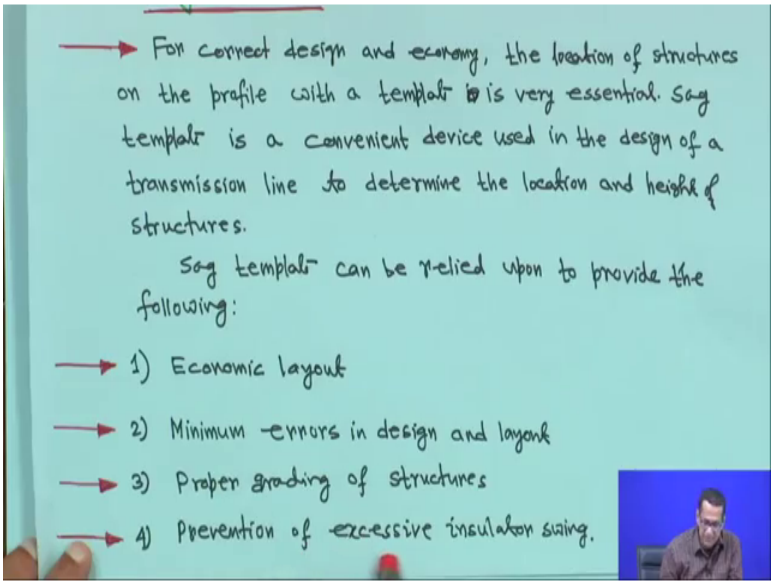

Sag template can be relied upon to provide the following; first thing is economic layout, minimum errors in design and layout proper grading of structures and prevention of excessive insulator swing. All these things will be there on sag template.

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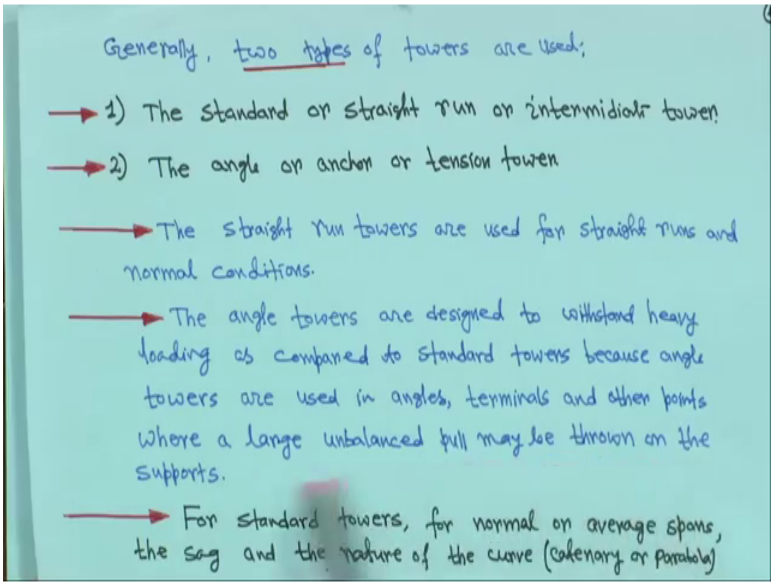

So, generally two types of towers are used. One is the standard your or straight run or intermediate tower, another one the angle or anchor or tension tower. So, the straight run towers are used for straight runs and normal conditions whereas, the angle towers are designed to withstand heavy loading as compared to the standard towers because angle towers are used in angles, terminals and other points where a large unbalanced pull may be thrown on the support.

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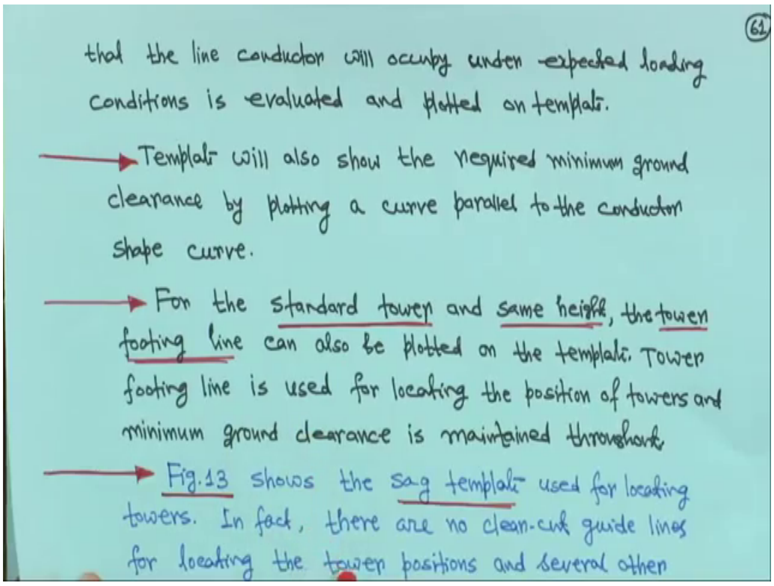

So, for standard towers for normal or average spans the sag and the nature of the curve catenary or parabola, that the line conductor will occupy under expected your loading conditions in evaluated and plotted on template, but the let me tell you one thing for sag template all these things are given it may not be your exactly to your design, but you have some kind of ideas.

So, template will also show the required minimum ground clearance that is true by plotting a curve parallel to the conductor shape curve I will show it later and for the standard tower and same height the tower footing line can also be plotted on the template that also I will show you. So, tower footing line is used for locating the position of towers and minimum ground clearance is maintained throughout. So, this figure – 13 shows the sag templates used for locating towers. In fact, there are no clean cut guidelines for look you are locating the tower position and several other alternative may be use this is not a mandatory thing, but other things also it can be used.

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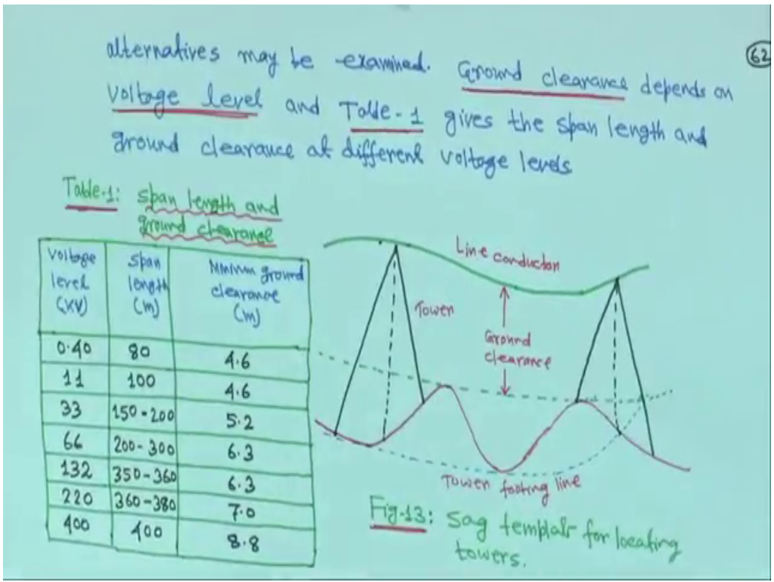

So, for ground clearance depend on voltage level as table one something is given and gives the span length and ground clearance at different voltage level; for example, suppose this is the line conductor and this is your ground clearance and this is the tower footing line this dashed line actually is the tower footing line, this is a sag template, this is tower this is tower and this is the ground clearance and this is the line conductor. So, sag template for locating towers. So, is exactly exact thing what you call whatever you design you may not get whatever you this thing, but you will have some kind of idea.

So, this way I have some just to show you something and I have drawn this is the tower footing line. So, that will help you actually. So, and this is the line conductor assuming I mean some sag may be there may be they are not at the equal height or equal level. So, that is why line conductor is drawn like this and voltage level is given say point that is 400 volt, 11 KV, 33 KV, 66 KV, 132 KV, 220 KV, here 400 KV a span length.

Generally, for 400 volt it will be 80 meter this is distribution side 11 KV also distribution side it is 100 meter then 33 KV is 150 to 200 meter 66 span length will be 200 to 300 meters. 132 – 360 meter say and 220, 360 to 380 meter say and 400 say 400 meter and minimum ground clearance it will be 4.6 meter, 4.6 meter, 33 KV 5.2, 66 – 6.3 and 132 also 6.3 and 227 meter and 400, 8.8 meter this should be a minimum ground clearance. This is required actually.

So, this is actually called your sag template. It should give you ground clearance then tower footing line all sort of things, but may not be what you call mandatory thing, but it may help you.

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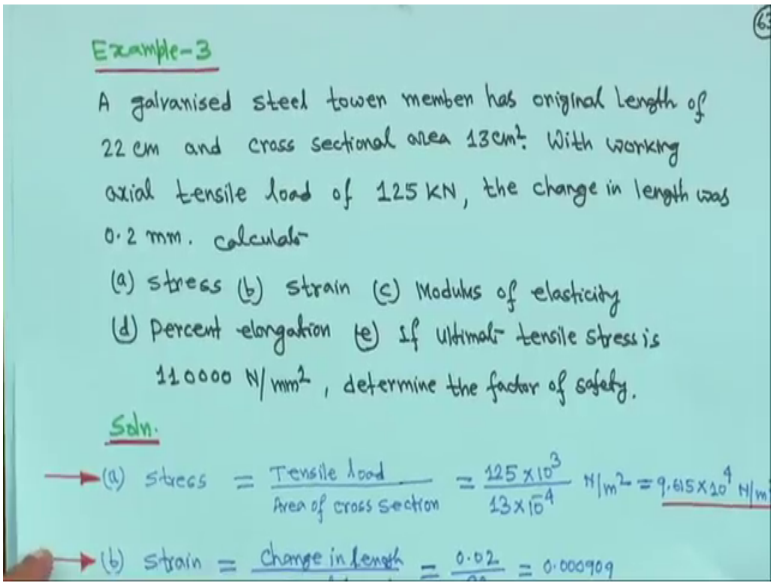

Next, we will take another example that is example – 3 say regarding conductor vibration. Little bit will come at the end suppose a galvanized steel towers meant your tower member has original length of 22 centimeter and cross sectional area 13 centimeter square with working axial tensile load of 125 kilo Newton, the change in length was 0.2 millimeter calculate number 1, stress, b – the strain, c – modulus of elasticity, d – percent elongation, e – If ultimate tensile stress is 11 your what you call 110000 Newton per millimeter square, determine the factor of safety.

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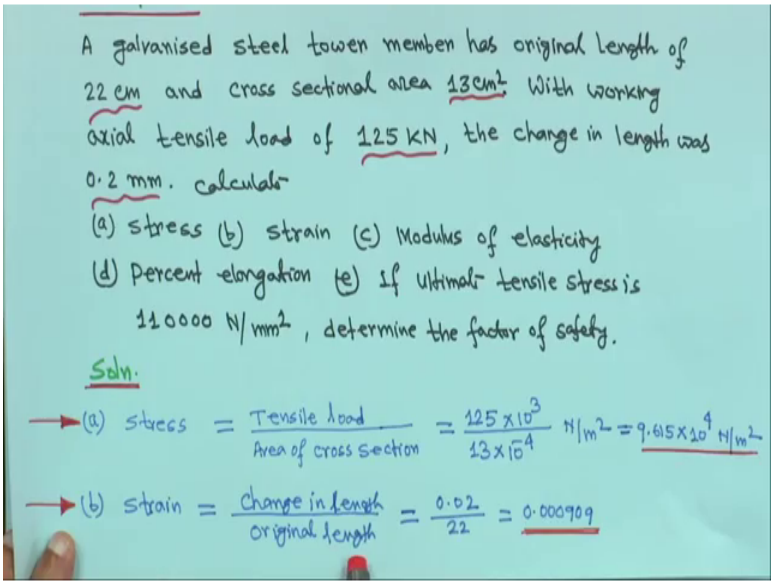

So, 5 things you have to find out. So, stress is equal to you know tensile load by divided by area of cross section. So, tensile load is given 125 kilo Newton here, if I mark now by reading then this will be this thing 125 kilo Newton this is 22 centimeter 0.2 millimeter. So, this one what you call stress a tensile load is given 125 kilo Newton. So, 125, 10 to the power 3 and area of cross section it is given that your 13 into 10 to the power minus 4 meter square because it is 13 centimeter square. So, convert it to meter square. So, this will be this is Newton and denominator is meter square. So, this will be 9.615 into 10 to the power of 4 Newton per meter square.

Now, strain you know is equal to change in length divided by original length. So, change in length is given 2.2 millimeter; that means, 0.02 centimeters and divided by 22 centimeter length. So, 0.02 by 22, 0.000909 this is the strain.

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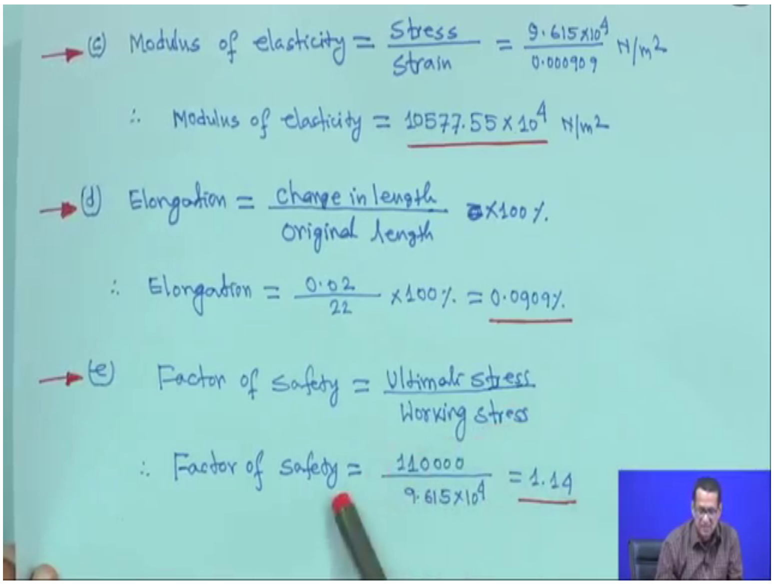

Next, is modulus of in this third point is ours that modulus of elasticity. So, modulus of elasticity is equal to stress upon strain that is stress we got 9.615, 10 to the power 4 and strain also you got 0.000909 Newton per meter square. So, modulus of elasticity is coming 10577.55 into 10 to the power 4 Newton per meter square. d – Is elongation is equal to change in length divided by a original length into 100 percent.

So, elongation is equal to change in length your 0.02 and divided by 22 into 100, so, 0.0909 percentages. e – last one the factor of safety, ultimate stress by working stress ultimate stress you have given 110000 and working stage is 9.615 into 10 to the power 4. So, factor of safety is 1.14.

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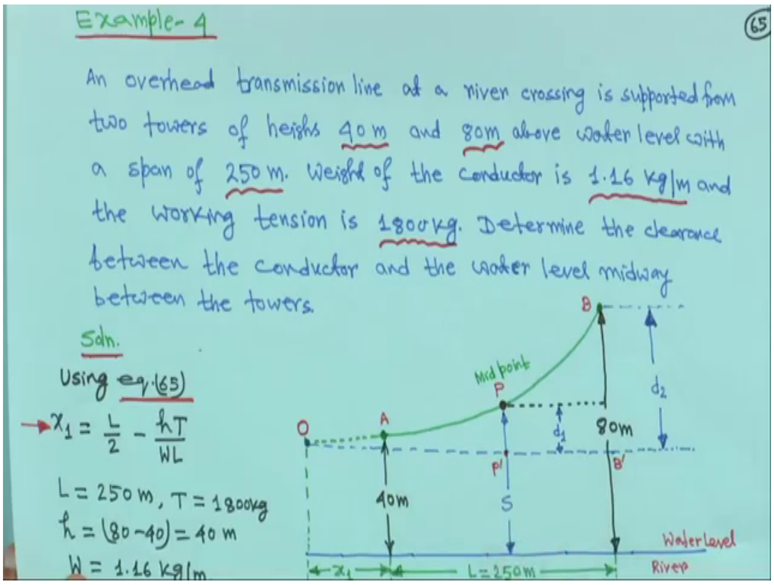

Next, we will take another example this all these theory whatever you have made it is has to be supported by some good numerical. Now, this one that an overhead transmission line at a river crossing is supported from two towers of height, one is 40 meter and another is 80 meter above the water level with a span of 250 meter. Weight of the conductor is 1.16 kg per meter and the working tension is 1800 kg. So, determine the clearance between the conductor and the water level midway between the towers.

So, this is the two point A and B and this is that your curve dashed line is that imaginary curve this is the point O. So, this is the midpoint and the distance between the two towers is given 250 meter. So, these two points horizontal distance L is equal to here 250 meter and this is the river and this is the water level and this distance BB dash is 80 meter is given that the sorry that from here to here the river level to here it is eighty meter this distance is d 2 not given and this from point a to the river level, it is 40 meter.

Now, this from here to here a to b 250 meter and we have taken somewhere dashed line imaginary one that is your x 1, because it will when you draw it will come like this. So, that is why this figure should come later, but I am showing before you before this thing because from this problem you cannot draw this one. You have to check this condition whether it is less than 0 or not here it is coming that is why it will be dashed line. For example, using equation 65, x 1 is equal to L by 2 minus hT upon WL, L is given 250 meter, T is given 1800 kg, h is 80 minus 40 meter, that is your this d 2 actually nothing, but your h. So, h is equal to your 80 minus 40. So, 40 meter and W is equal to 1.16 kg per meter.

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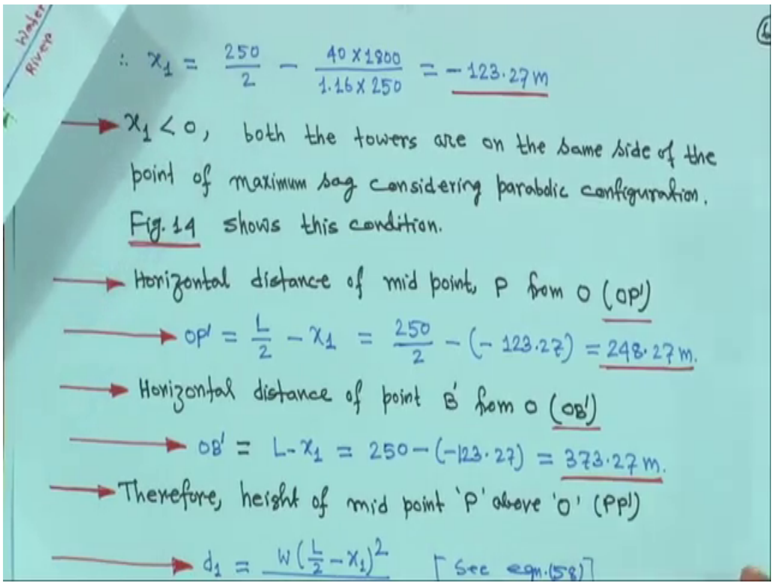

That means, your x 1 is equal to 250 by 2 minus 40 into your 1800 divided by 1.16 into 250 W into L that is coming minus 123.27. That is why after getting this minus only I have drawn this graph, looking at that data you cannot plot the graph because x one is negative. So, if this imaginary line if this dashed line is imaginary line and this is the point O; that means, it is coming to the other side, while it does not exist. Actually this is the total to the two towers, so, this is not existing.

So, that is if x 1 is less than 0, that is negative both the towers on the same side of the point of maximum sag. So, considering parabolic configuration figure – 14 shows the condition this is if you consider a parabolic one this is your figure – 14. So, both points are on the same side of that maximum sag.

So, a horizontal distance of midpoint P from OP dash is equal to OP dash is equal to L by 2 minus x 1 that is this is my what you call this is O about to P dash it will be your this one your OP dash will be L by 2 minus x one that because x 1 is coming negative actually it will be L by 2 if you take the real unit it will be this total A to B is L. So, o from here to here say from this point to this point is horizontal will be L by 2 plus x 1 as x 1 has become negative that is why you are making like these that OP dash is equal to L by 2 minus x 1 actually it will be 250 by 2 minus of minus this thing ultimately it will be added up.

So, that is why it is 248.27 meter. So, this is your O to P dash and horizontal distance of point B dash from that is OB dash this is O to B dash this 250 is there. So, L minus x 1 minus we are putting because x 1 is negative, otherwise if you take the real unit it will be L is equal to 250 and x 1 will be 123.27 meter, but anyway. So, OB dash is equal to L minus x 1 is equal to 250 minus of minus 123.27 that is 373.27 meter.

Therefore, height of the midpoint P above O, PP dash, so, this is the midpoint between A and B this is the midpoint then what will be the height PP dash that is d 1 what will be the PP dash that d 1. So, we know this that d 1 is equal to in general formula is WL square by 2 to see equation 58.

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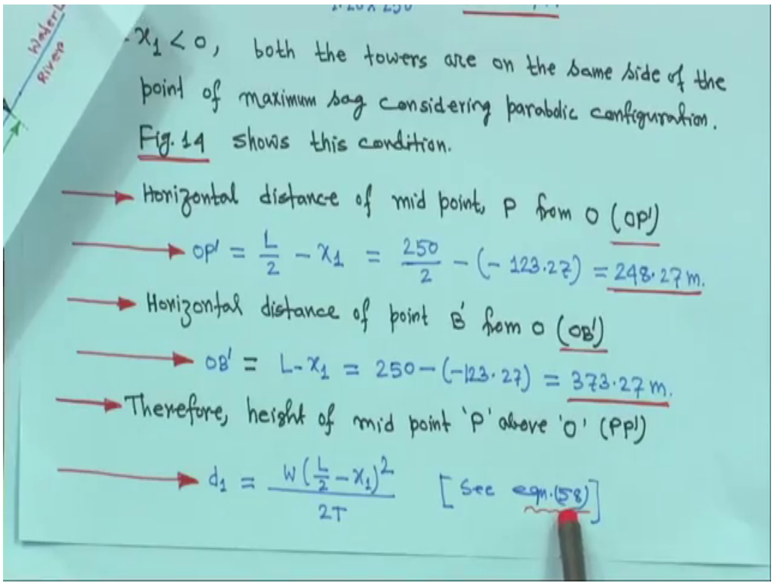

This is we are getting from your equation 58. So, it will be d 1 is equal to W L by 2 minus x 1 whole square upon 2T, that means d 1.

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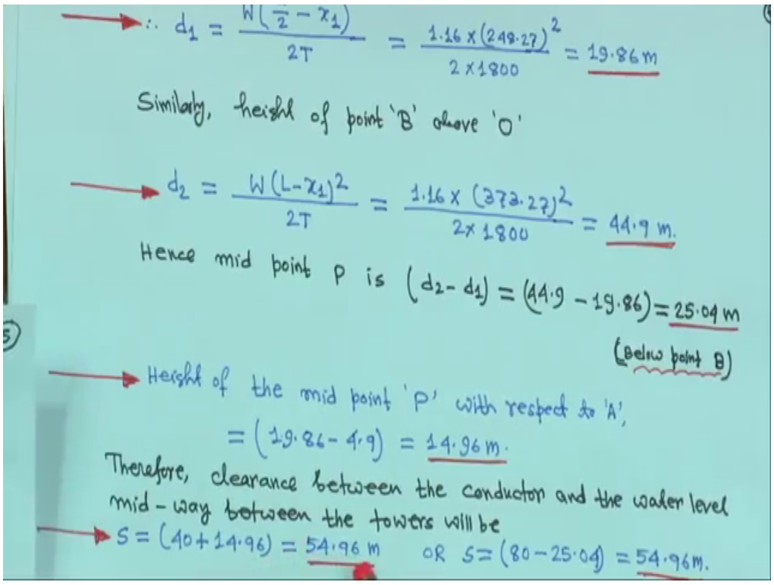

But, this d 1 is equal to W L by 2 minus x 1 whole square upon 2T. So, that is 1.16 into the L by 2 minus x 1 we have computed; that means, these distance this is actually OP dash, this distance you have calculated 248.27 meter. So, it is 248.27 whole square by 2 into 1800. So, that is 19.86 meter that is your d 1 from this figure this is the d 1 and similarly, height of point B, d 2 is equal to WL minus x 1 whole square upon 2T. L minus x 1 we have computed 373.27 meter. This is the 373.27 meter we have computed, therefore, your W is 1.16 into 373.27 square by 2 into 1800 that is 44.9 meter, its midpoint P is d 2 minus d 1.

So, this is actually d 2 minus d 1 that is h, d 2 minus d 1. So, midpoint P is it is 44.9 minus 19.86. So, 25.0 meters that is below point B. So, this is your this point below point B because d 2 you got, d 2 44.9 meter you have got, the total this is the d 2 and then d 1 you have got this is from here to here d 2 and d 1 you have also got. So, below point B means this distance from here to here this distance d 2 minus d 1. That is your 20 that is below point B I am writing this below point B I mean from here to here that is d 2 minus d 1.

So, height of the midpoint P with respect to A, I mean with respect this is this is with respect to A it will be your 19.86 minus 4.9 that is 14.96 meter that is this one we just got know this one just hold on, this 65 this is this is x 1, this is 248 meter this 372, this is d 1 and this is your 19.86 meter this is 25.0 and height of the midpoint P with respect to A then it will be your 19.86 minus 4.9 meter when this is this is with respect to this point A, that means, if you calculate I mean this height I mean this one from A to this one if I can make it from here to here this point, it is coming actually 4.9 meter.

So, that is your 19.86 minus 4.9, so, 14.96 meter actually this one to calculate this one from say this is A and suppose this point some point say it is A dash. So, you can easily calculate that, what is A dash? This will become actually 4.9 meter. So, height of the midpoint with respect to A; that means this one I mean if you make a horizontal line if we make a horizontal line from here. So, from here to here d 1 we have got your 19.86 meter and this one actually will become 4.9 meter.

So, ultimately it will become your 19.86 minus 4.9, so 14.96 meter this one this calculation one 4.9, I have not calculated here, but I ask you to make this calculation I think I have not calculated here. I do not have that thing. So, therefore, the clearance between the conductor and the water level midway between the towers will be then 40 plus 14.96, whatever I mean this is forty look from this is 40; that means, this point also if you a dash this point is also says some a double dash, it is A from here to there it is 40 plus these 14.96 is coming. So, 54.96 meter or otherwise S is equal to if you make opposite way this total is 80 and this one you have got 25.04.

So, S is equal to 80 minus 54.96 meter even from this calculation from this one easily you can calculate this AA dash. You can easily calculate because from the top this is your 80 meter and your what you call and 25.04 that is your a hence midpoint with d 2 minus d 1 is 25.04 therefore, your this point that this your midway between the towers I mean from here to here it will be 80 minus your 25.04 that is your this height.

That means this height, if you subtract then you will get your 54.96 meter and yes this is your from here to here your this thing this point is 40 from here to here. So, this in your what you call either this way you can calculate 40 plus 14.96, 54.96 meter or from the top you can calculate eighty minus 25.04 that is also 54.96 meter therefore, clearance between the conductor and the water level midway; that means, from here to here it will be 54.96 your what you call a meter.

So, this is actually that how one can calculate if this kind of problem comes, but this dashed line negative line first you have to calculate all these things and this is actually from here to here this is actually this height is actually 40 meter and this is also 40 meter.

So, anyway, this is your what you call that for this kind of problem that if it first you check whether x 1 is negative or not and accordingly you please do it.

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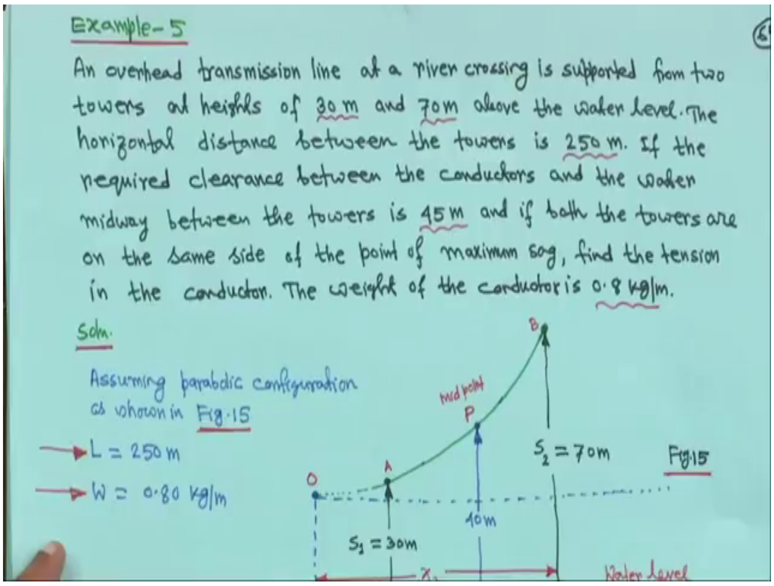

So, next we will take another example. So, here that example – 5, here also x 1 will become negative that is why I have made it this way first let me read the problem and over a transmission line at a river crossing is supported from two towers at heights of 30 meter and 70 meter above the water level.

The horizontal distance between the towers is 250 meter. If the required clearance between the conductors and the water midway between the tower is 45 meter and if both the towers are on the same side of the point of maximum sag find the tension in the conductor the weight of the conductor is given point a 8 kg per meters. So, it is we are assuming a parabolic configure, unless and until it is mentioned you always assume parabolic configuration.

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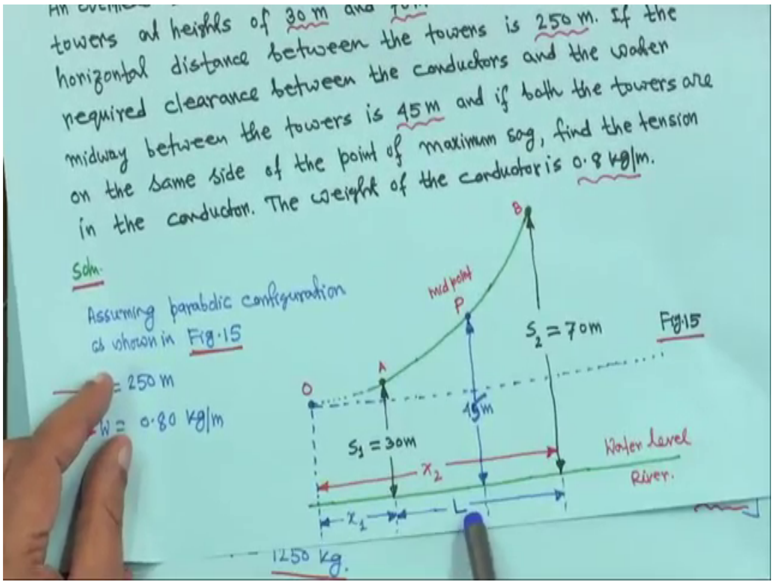

So, that is why assuming parabolic, if it is mentioned catenary or that then you have to do that otherwise if it is not. So, you take L is equal to 250 meter it is given, W – 0.8 kg per meter, that is also given and then h that is difference between these two, this is 30 meter height and this is 70 meter.

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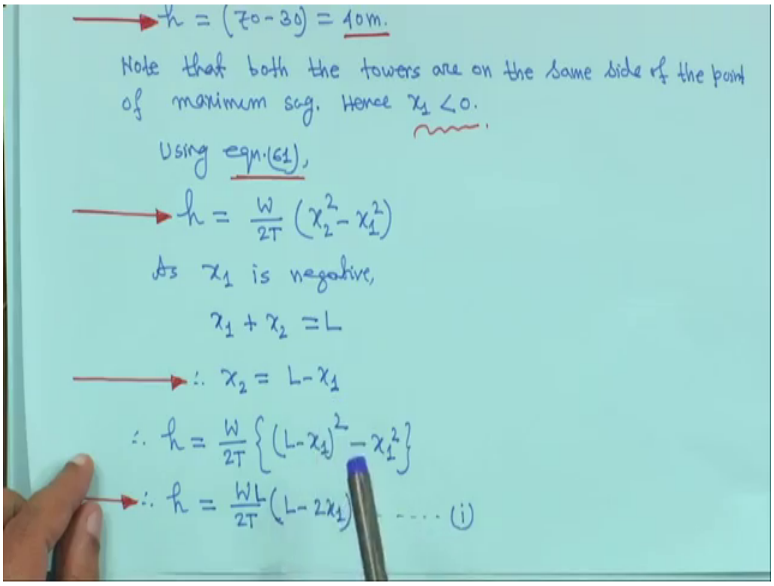

So, h will be 70 minus 30. So, it will be 40 meter h will be 40 meter. Note that both the towers on the same side of the this thing point of minimum sag when x 1 less than equal less than 0, then it is mentioned that both the points are the you know one side of that minimum sag just now we saw the previous problem; that means, automatically even it is not mentioning you have to you have to assume that x 1 is equal to negative. This is just you have to see if both the towers are midway because you both the towers are on the same side of the point of maximum sag.

If this sentence is given, that means, that both that x 1 is always negative this should be in your mind when you are solving numerical. Therefore, from equation – 61, h is equal to W by 2T, x 2 minus x 1 square, as x 1 is negative we have seen from in the previous example that x 1 plus x 2 is equal to L therefore, x 2 is equal to L minus x 1 therefore, h is equal to W by 2 and x 2 is equal to L minus x 1 you substitute here.

So, it will be L minus x 1 square minus x 1 square that is h is equal to WL upon 2T into l minus 2x 1, this is equation – 1.

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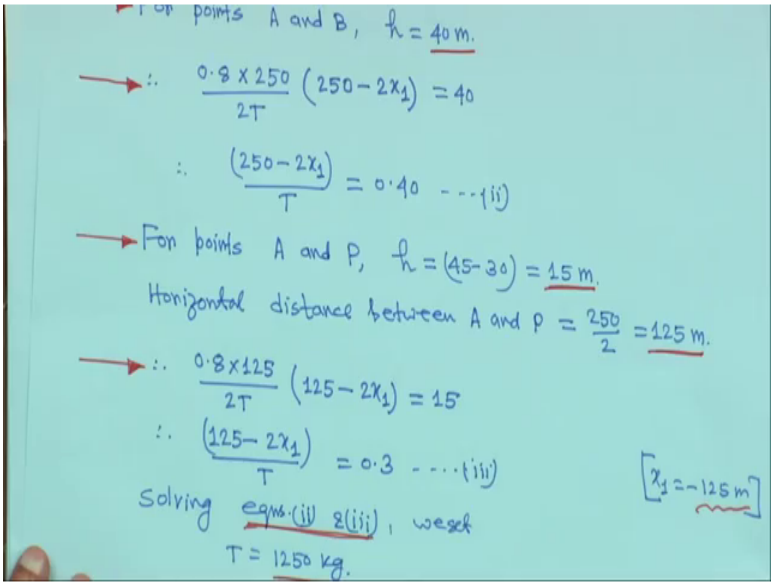

Now, for points A and B, that means, this diagram you can easily find out for points A and point B, that h is equal to 40 meter therefore, we can write that your WL upon 2T, I mean just now we got this one h is equal to WL upon 2T L minus 2x 1, here we will substitute all the data. So, it will be W is equal to 0.8 you need second and not telling L 250 divided by 2T then 250 minus 2x 1 is equal to 40, because L here is 250 minus 2x 1, that means, 250 minus 2x 1 upon T is equal to 0.4 this is equation – 2 and the now for points A and P, h is equal to 45 minus 30 that is 50 meter that is point A and P because A P is the anyway midway between this to point A and B.

So, your A and P, h is equal to 45 minus 30, so, 50 meter. So, all these which is given the between the two towers the water midway between the tower is given 45 meter. So, it is 40 therefore, points A and P, h is equal to 45 minus between A and P, h will be 45 because it is given 45 meter, by this thing your what you call this one that clearance between the conductors and the water midway between that tower is 45 meter, this is given. Therefore, your this thing your this is actually 45 meter by mistake I have written 40, it is 45 meter, therefore, this distance it is 45 minus 30, so, 15 meter. So, therefore, this h is equal to again 15 meter.

Now, horizontal distance between A and P it is midway point. So, horizontal distance between A and P it will be 250, L is equal to 250 it will be 250 by 2 therefore, it is 125 meter. Now, again the same thing 0.8 into 125 by 2 T into 125 minus 2x 1 is equal to 15, this is one equation, this is another equation. Only thing is that you have to put L is equal to 1 to 5 and your this thing and this h is equal to second case it is 15.

If you solve equation; 2 and 3 you will get T is equal to 1250 kg and at the same time if you solve x 1 here I have written here x 1 is coming minus 125 meter. So, that is why this is your it is on the negative side. So, this is 125, this is your what you call the tension. So, with that thank you very much, again we will come with few more examples.

Thank you very much.