Hydraulics
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Module No. # 06
Canal Design
Lecture No. # 04
Design of Alluvial Channel – 3

Either we scouring or it will not cause deposition of the sediment in the bed. So, that was the principle and by that principle we could do design of alluvial channel and that particular velocity, we termed as critical velocity. And then, but these 2 theories or the equations derived or equations used in these 2 theories are empirical and based on some observation and that way it has some drawbacks, and in, again in the entire procedure there are some drawbacks, those drawbacks also we did discuss in the last class. And then, as these are empirical, so people were trying to develop some analytical basis for designing alluvial channel. And then, USBR, United State Bureau of Reclamation, so they started working on one method, called tractive force method.

And we stated in the last class, what the tractive force method is and we will be continuing with that tractive force method and say, 1st in the last class we did define what is, say, a tractive force? So, it is the force exerted by the flowing water on the perimeter of the channel or say, on the material of the sides and bed. So, the, in suppose uniform flow condition if we talk about, then weight of the fluid in the direction of the flow is actually the tractive force and that we will try to equate with the resistance force to find, what is the critical tractive force and all.

Well, then we were talking about unit tractive force, that means, this tractive force per unit area. Well, so that we refer as unit tractive force, which is also called as drag force or shear force. So, these different nomenclatures are used and then, we were discussing in the last class about distribution of tractive force.

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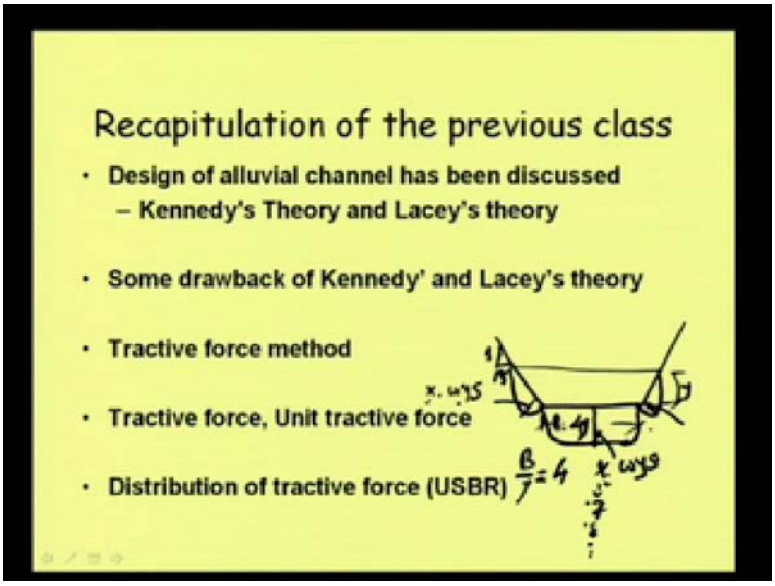

Means, say we could see the unit tractive force, that unit tractive force means that was coming. In fact, as average unit tractive force because the force exerted by the fluid, we were considering on the entire surface. Well, the surface, which is in contact with the water during that length of the channel and then we divided it by the entire surface length, which is in contact with the fluid motion, which is in contact with fluid, here our fluid is water, of course, we are talking about. And so that way, the stress what we are getting, tractive force, that per unit area is in fact, a on average basis, so average tractive force.

But in reality, the tractive force exerted by the fluid on the side of the canal will not be uniform all over the surface. It will be more, may be at the bottom, at certain point at the centre point, it may be more than, if it is a trapezoidal channel, then on the side towards the top, the tractive force will be less, but towards the bottom on the side, that will be more. So, that way, tractive force distribution we were talking about and we did draw a diagram for trapezoidal channel where we could just draw a trapezoidal channel and we were showing, how the tractive force distribution can be plotted on the side and on the bed of the channel well. But that distribution, we draw like this just to recall, because from here we will be moving ahead again.

So, that, suppose it is a trapezoidal channel of course, we were considering a channel where our y, that is the depth, y is, say, I mean, 1-4th of the bed or we can say, the bed, which is 4y of the depth, well 4 times the depth, in that case we got that tractive force distribution. Of course, pattern will be same, it is like that and here it is almost uniformly distributed, it is almost uniformly distributed and here, again, it will be like that, here it is more. So, maximum tractive force we could get at this point and so this maximum tractive force, and if we just compare the maximum tractive force, if we compare the maximum tractive force at the bed and at the side, you can see, that at the bed it is more and this can be expressed in terms of w, y and S. It is the unit, this w is unit, weight of water, so this unit weight of water, then depth, then the bed slope. So, based on that, we could derive the expression, but there will be a term, say 0.77, that means, it is not exactly equal to wyS, but it will be a percentage of wyS, this will be... And maximum can be wyS, that I will show just in the next slide, but this can be, say 0.77, 0.8, something like that, this can be, and so that factor we can write, say x; x into wyS, where x can be, say 0.7, 0.8 like that, 0.6, anything it can be and that way this can be, can have different value.

Well, then similarly, y also can be, I mean, similarly in the side tractive force also, this can be expressed as w, y and s, and similarly here also, a product will be coming. So, x into that, I am writing here and now this was given for this particular channel, where width of the channel is 4 times the depth of the channel. And we did discuss what the value of x there, and then this slope, ok, my diagram is not proper, but this slope is, say if it is 1, this is 1.5; for that sort of side slope, if it is 1 this is 1.5, and for that sort of side slope and for this shape, where B is equal to, where B is equal to 4y, for that we gave some value of x in the last class. And that way, we were discussing, how shear stress or other we, we call it is a how unit tractive force get distributed tractive stress, get distributed on the side.

Well, now, say in reality, we will be having different type of channel, say B by y ratio. Here, our B by y ratio is 4B by y, if we make it is 4, but always the B by y will not be 4, and here our side slope is equal to 1 is to 1.1, 0.5 is to 1 rather, but this will not be always same. So, if the side slope changes, say 1 is to 2, like that if it is changes, z value then, and the B by y ratio changes, then how this will vary, how this maximum tractive shear stress or unit shear force varies, so that we need to know. And USBR, united state bureau of reclamation, again gave some curve for that, which curve can be? This curve can be used, this curves can be used for design of tractive force, let us see how these curves are.

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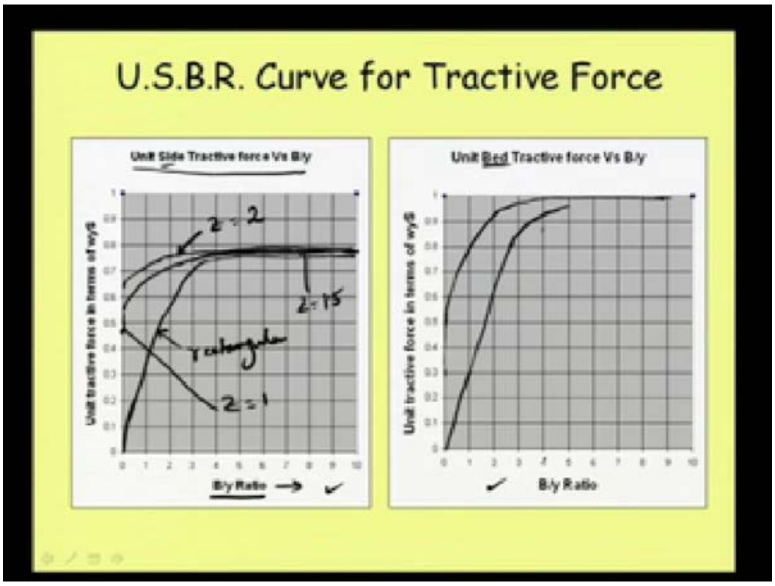

Well, first you can see, this is, here in this graph, on this side it is B by y ratio is plotted on this side, say B by y ratio, they examine, say up to 10 we can have and then on this side, that is on the y axis, on the y axis it is unit tractive force in terms of wyS; w means again, unit weight of water.

So, suppose if I get a point here, 0.4 means, it is 0.4 wyS. Let me draw the curve and then, at it is actually a family of curve, it is not a single curve, it is family of curve, which were drawn for different side slope. Well, and for, even for rectangular channel, and for rectangular channel if I draw for a side, and this unit tractive force is for side tractive force, we are looking about that is in a channel, it is at the side. So, for rectangular channel it is like this, that is, from 0 it is starting and it is, it is going like this and then it is going like this, it is a smooth curve of course, it is going like this. So, this sort of curve was obtained for rectangular channel. Well, I, I must say, that my curve may not be exactly like the curve, that was given, but just I am trying to show what the trend is and this is for rectangular.

And then for trapezoidal, again, say it will be starting from about little higher from 0.5 and then it is going like this, that it will be going like this, this curve is going like this, my space is less painted, this little larger, but still let me try. And then, so this curve is for say z equal to 1.5, and then this is rectangular, this is rectangular and of course, if we draw for a, if we draw for a point, say z equal to 1, it will be almost following the same line, but it will be starting from here; it will be starting from here. So, this we can say, it is z equal to 1 and then if z increases to 2, if z increases to 2 the curve starts little higher and then it will be, but maximum limit is always remaining within 0.7 and 8. So, it is going like that, this is for z equal to 2. Well, so that way a family of curve was given, curve was given by USBR and following that we can just let us try our design, and that is quite helpful. Say, we, initially if we take, that our B by y ratio is 3, then from, from that point if we consider, that B by y ratio is 3, then what will be and if we consider that our, it will be a rectangular channel, then we can see what is the side tractive stress. That is, of course, after that we will need to check whether that channel will be sufficient for carrying the required discharge that will be coming later. And then, for again, the unit bed tractive stress, unit bed tractive force, say this is, we can plot that as given by USBR. When it is bed, then for rectangular this will be starting from here and this will be like this, this is going up to almost 1, it is going up to almost 1 like that and if I extend it, it will be going up to 1.

Then, say for trapezoidal, for trapezoidal, it was interesting to observe because it is bed, although it is trapezoidal, but say side slope, whether it is more or less, it does not influence that much, but still for the z equal to 2 and 1.5, we are drawing for bed. So, it starts from, say very close to 3, but it follows almost that one. Then from 5 onwards, it just leave this axis and then it goes like that and for higher value, for higher value of, in fact, it will be passing more steeper like this, and for higher value of B by y ratio it goes almost up to this point 1, almost up to 1.

So, what we can see, that for a B by y ratio of say 8, 9 or around that, this tractive force is becoming equal to wyS, that is, which we could get for wide rectangular channel. And just equating that, our component of gravity force acting in the direction of flow and that when we put as our tractive force tau, and then when we divide it by the contact area, then we get the tractive force per unit area, that symbol here itself we call as tau. And that value we got, that it is equal to w, r and s, where r is the hydraulic radius and for wide rectangular channel, we got it, that r is approximately equal to y, and that is why, we can consider this as wyS. And as our B by y ratio is increasing, means we are talking about a wide rectangular channel and B is larger as compared to y, that is why, B by y ratio is quite larger and as it is increasing, we are finding, that it is becoming this, this fraction or the product factor is becoming almost equal to 1 and what we could derive theoretically is valid here.

So, these are the curves that were provided by USBR. Now, that another point is more important here, that say, we are using this curves and now one curve is giving us the tractive force for the side, and this curves are giving for tractive force for the side and these curves are giving tractive force for the bed, that is, a tractive force exerted, we can say like this, tractive force exerted by the fluid on the channel, this is what we are talking about. And for design purpose, we should know again, how much is the resistance of this tractive force? And then, there is a question, that can we have some relationship between tractive force at side and tractive force at bed, can we have some relation between these 2, so that when we will try to find a permissible tractive stress, when we will try to find a permissible tractive stress, then for some of our analysis, we may get there tractive force at bed is equal to this much permissible tractive force, permissible to be more precise, we can say permissible unit tractive force at the bed is this much. Now, if we design it from that consideration that may not be safe because on the side it may not be safe.

So, we need to know, what is the permissible tractive shear stress, unit tractive shear force at the side? So, now, that if we could derive by having a relationship between tractive force at bed and tractive force at side, then it would have been much better. So, and that can be derived very easily, very easily from, from our conceptual understanding of the geometry of the channel and just they equating the forces, we can do that, and let us see.

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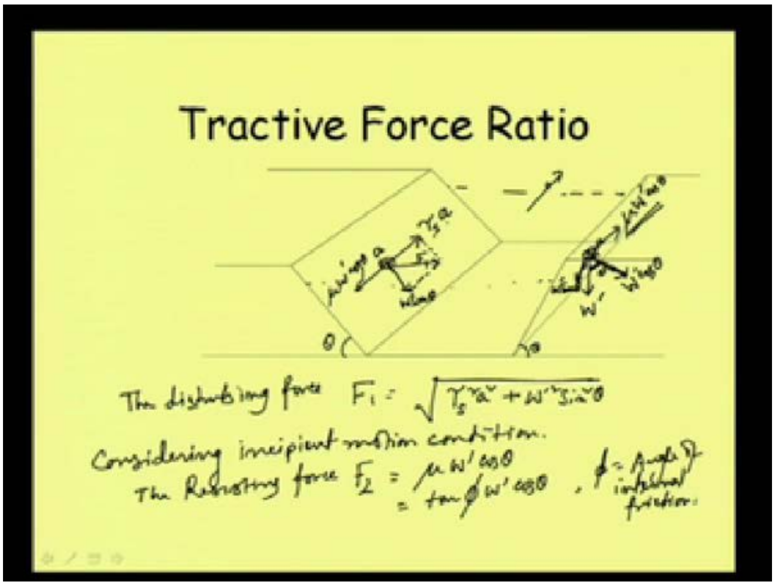

So, to just see that, let us take a channel. Well, let us consider 1 channel, say this is our channel and the water is flowing in this channel, water is flowing in this channel and then, when water will be flowing, let me just show, that suppose this is the water level and it is flowing, I am not drawing it because something else I will have to draw, but well, for just to appreciate, that say water level is there, you just imagine that, we have water level at this level, we can draw a line to show just very small, draw some dot, say this is a what the water level, oh I can draw it here, I can draw it here, say here the water level and then the water is flowing, so there, that will not create any problem. So, that way, water is flowing with a particular depth and then, in this channel, here is our, say, side of the channel, we are digging it. And then, this way after digging it, it is making, we are making the channel.

Now, let us see that, say, side slope of this channel is suppose theta; it is suppose theta. Well, just to analyze, let us consider, say we have a small area, let us consider a small area, say a; let us consider a small area a. And then, when water is flowing in this direction, when water is flowing in this direction, then the tractive force exerted on this area, say area is a and let the tractive force exerted on this area is say tau s, that is, tractive force means, we are always, we are meaning, by unit tractive force means tractive stress. So, tractive stress exerted by the fluid on this particle is say tau s, then if we say, that this area is a, this area is a, this small area, then the tractive force on these area will be on this particular area, will be tau s into a; this area will be tau s into a, fine.

Now, let us see, whether this area or that area, if we talk about a very small portion, then it may ultimately come down to a sediment particle, whether this is getting subjected to some other forces also. Well, the weight of this particle is acting vertically downward; weight of this particle will be acting vertically downward. If I draw the same area here, then it is convenient to show, that it will be acting vertically downward. Say, this is also area a and this weight of this will be acting vertically downward, and let me write that weight as, say w dash. This is I am not writing unit weight, I am writing the complete weight of the sediment of that particular portion a, and that is why I am writing w dash because this is under water. We are considering the force exerted, tractive force exerted means, this is under water, it will be submerged by the water. So, weight of the particle will be basically submerged weight and that is why we are writing this as w dash, well. So, this w dash is the weight and then this particle or particles, or the area itself will be having a tendency to slide down along the slope, or rather we can say, that there is another force, which is acting in this direction and because of which our interest is to know, that what are the forces acting to move this particle from its location, move this particle from its location rather. So, one is the tractive stress and now we are talking is a tractive force, which is tau s into a; another is the force, that is trying to move it along the slope in the downward direction because of the gravity, and that gravity is basically this weight of the particle.

And then, what that angle is? We know that this angle is theta. So, between this line and that line, so if I draw this line and if I draw a normal to this particular slope, then this angle will be theta. So, the angle just acting in this direction will be, say force acting in this direction will be w sine theta, theta is away from this part. So, this is theta. So, and theta is the angle between this line and that line, and this line is perpendicular to this plane means this line, and then it is perpendicular to this. So, this is theta and this is our w sine theta, w sine theta, that particular force we can write w sine theta, and here I am writing this as w sine theta.

These 2 forces are, forces are acting, w dash, well we are writing w dash. So, what are the net forces that are acting on this particular area to disturb this sediment? Well, there are some other forces, which will try to resist this motion, but now we are talking about or we are looking into the forces, which are trying to disturb this, I mean particles. So, these 2 forces, that is, w dash sine theta and this tau s a are the forces, that is trying to disturb the particle from its position. And then, the, what is the resultant of that? We can draw the resultant of that just by completing this and then joining this. So, this is what the resultant and that resultant if I write as f1, say disturbing force, so that how we can write? This will be d square, I mean tau s into a, tau s square a square plus w dash square sine square theta and then taking root of that, we will be getting this force.

So, we can write the force disturbing or we can write this disturbing force, the disturbing force. Well, the disturbing force f1 is equal to root over, say, tau s square a square plus w dash square sine square theta, well. So, that is what our disturbing force, so I am writing this as f1. Well, then when there is a disturbing force, then if it is not moving means, there is a resisting force also. And at the time of just incipient motion condition, these 2 forces, what we mean by incipient motion condition, that particle are just in the verge of motion; it is just in the verge of motion.

So, what is that? The disturbing force is just equal to the resisting force and our interest is to find out permissible stress, means, up to that point when our force is, when our particles are not moving, then we are fine, our channel design is fine. So, that way, we are talking about that situation and of course, our permissible force may be little less than this particular force, but when it is just in the verge of motion, then we can call that as a critical condition. And the permissible condition should not be the critical condition, it should be little less than that, but anyway let us see, what is the expression for this critical condition. And so, considering incipient motion condition, what we can have, say considering incipient motion condition, we did discuss about incipient motion condition earlier also, that we will equate, but the resistance force, the 1st we have find out the disturbing force, then resisting force, the resisting force because why we are writing this, that considering incipient motion condition. Now, resisting force, as we know, that it is coming from the frictional resistance here and the cohesion part, we are not counting in this point. So, for resisting because we are talking about alluvial channel, because we are talking about alluvial channel, and this resisting force will be proportional to suppose, your, your, force exerted is increasing proportionally, there frictional resistance is increasing, and of course, beyond a particular limit it cannot increase and that is the limiting condition, well.

So, at incipient motion condition, this will be at its maximum and what we can see, that suppose this is the bed, this is the not bed, this is the side, then this will be opposing this motion and frictional motion, opposing this particular force, that will be the normal weight or normal reaction. So, this will be having a normal force in this direction, let me draw on this phase because we are seeing it from the backside, that is fine, we can see.

So, in this direction, in the normal direction, what will be the component? This is w cos theta and as we know, the frictional resistance, frictional resistance will be in any direction. We can say the frictional resistance is equal to mu into the normal force; mu into the normal force. So, the, not that normal force is cos theta, weight is this one, so reaction will be like that and then it is mu into cos theta, so this mu cos theta is basically opposing this forces. We are, I am not drawing exactly the direction here, but we can say, that this is, say mu cos theta.

Now, what is mu? That is again we need to refer to the frictional property of the soil, so, but let me write here as mu cos theta, here itself I am showing on this phase, it is easy to show, and here just I am drawing it because that is, we cannot see the backside from this side, that is why I am drawing it here, well. So, this is equal to mu cos theta resisting force, say f2, if I write, this is equal to mu cos theta.

Now, if angle of internal friction of the soil is say phi, then what the mu is? That we all know that mu is nothing but the tan phi. If the angle of internal friction is phi, then it is tan phi, so we can write that. Well, this, sorry, this is not cos theta, this is w cos theta, this I did a mistake in writing here, this is not cos theta, this is w dash cos theta. Again, dash is always coming, w dash cos theta, this effective weight of the, I mean, soil will be significant there. So, this will be, this I should write as mu w dash cos theta; this will be w dash cos theta, well. And this mu, we can write, as I have explained, that this is equal to, tan, tan of phi into w dash cos theta, where phi is, phi is nothing but angle of internal friction; angle of internal friction.

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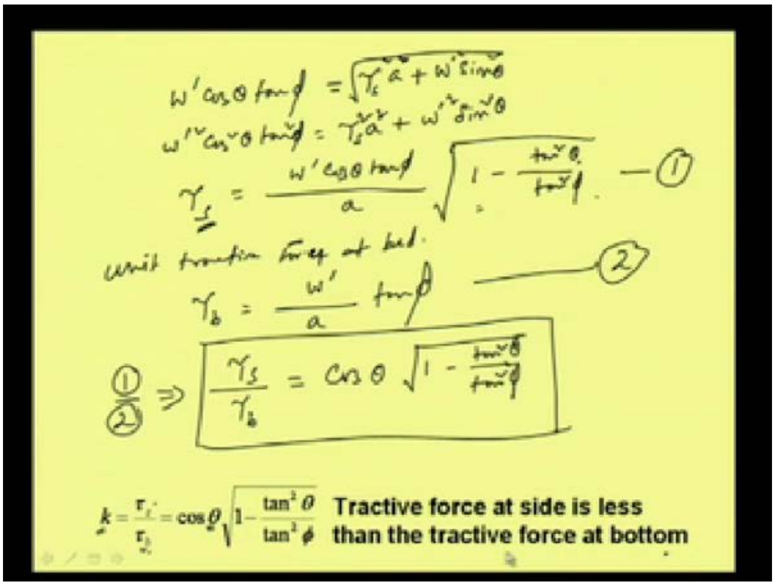

Well, so now, for incipient motion condition, we can equate these 2; we can equate these 2. So, equating this 2, what we can write? That w dash cos theta and tan of phi, this is what the resisting force, and the other one is, say tau s a plus w dash sine theta with a root sine, then squaring these 2, what we can write, that w dash square cos square theta tan square phi is equal to tau s a. Just to our target is to separate this tau s and then, this is tau s square, these are also square because after taking square only we were taking the roots. So, it will be tau square a square w dash square sine square theta. Well, now this expression, where we got is this one, tau square a square dash square w dash square sine square theta. We are writing the same expression here, then from here what we can write, that tau s, tau s is equal to, that is the side tractive stress, we can write from this part as w dash cos theta tan phi by a. First we are writing tau s is equal to this minus that and then we are taking w dash cos theta tan phi common and then of course, we are taking root and then, if we take the other part here, then it become 1 minus tan square theta by tan square phi.

Well, so when we took tan phi common, then here we are having already, say tan square phi is coming here and then it becomes and we are taking cos theta common. So, it is becoming at, in fact, we took cos square theta. So, that way, it is becoming, cos, sine square theta by cos square theta. So, this tan square theta is coming and then, later when we took root over this, cos square theta become cos theta, tan square phi become tan phi and all are just getting this thing. This one more step we can, we could write in between, well. So, that way we are getting this tau s, the side tractive force, we are getting an expression. Let us give a number one, today's equation.

Well, now, if we talk about the shear stress at the bed, so shear stress or rather, let me use the word tractive, unit tractive stress, unit tractive stress or tractive force, unit tractive force because already we are using the term unit, so tractive force at bed.

Now, what is the difference between this particular expression in bed and side? Well, if we talk about bed, then our theta for the bed is becoming 0, if we just flatten it this become bed. So, in bed other things will be remaining same, this, this force will be there, the reaction force will be there, but the, here if we take a bed, same area, then this force will be there, and there is this tau b into a, then weight component will be directly vertical. So, there will be no component in that direction and then the resistance force will be coming here, it is directly equal to w, means basically, if we make theta is equal to 0, then we get the expression for bed. So, what we can write, unit tractive force at bed tau b is equal to, so if we make theta equal to 0, our expression will become, say we can write it as w dash by a, we can write w dash by a and then, on the w dash by a and then it is tan of phi. This part means, w dash by a cos theta is becoming 0; theta is becoming 0 means, cos theta equal to 1 and then it become tan phi, and what about this part? When theta becoming 0, this part is becoming 0 and that is why it is 1 minus, this means only root over 1. So, finally, this is becoming 1 and we get this expression, so this is what, the expression 2.

Now, our target was to find an expression or to find a relation between this shear stress or unit tractive stress, tractive force at side and unit tractive force at bed. So, we can now do 1 by 2. So, that will give us, say tau s by tau b; tau s by tau b is equal to this and that part will get cancelled and we will be getting only cos theta. Then, root over 1 minus tan square theta by tan square phi, well. So, this is what, very, very important expression, that we use for design purpose; thus, we use for design purpose.

And then, as you can see that cos theta root over this can further be simplified, but of course, we are leaving it in this level, that is, tau s and this ratio. This ratio has a particular name, we call this as k; we call this ratio as k. And then, what we can see? That k is equal to, say tau s by tau b, this is equal to cos theta root over 1 minus tan square theta by tan square phi. That means, name we are giving as k and then one point we should note here, that theta will always be having some value, and of course, for trapezoidal channel and then, this value will be always a fractional less than 1. So, tau s is always equal to some fraction multiplied by tau b; well what it means?

So, this ratio we name as k and so you can see, that k is tau s by tau b and cos theta root over 1 plus tan square theta by phi. And more importantly, that, when we see, that cos theta, theta value will be always, say, a fraction. So, it will be, it is between 1 and 0, so it will be a fraction and I mean cos theta value will be a fraction. So, the highest being 1 now, I mean, so if this is a fraction, then what we can derive from that, that tau s by tau b is always a fraction because tan theta by tan square phi, this will be of course, a positive term and less than 1. So, 1 minus something less than 1, then root over terms. So, this product will be what? Whatever it is, this thing, this product will be a fraction and that way we will be finding, that this tau s is equal to some fraction multiplied by tau b and that way we are getting, the tractive force at side is less than the tractive force at bottom; tractive force at side is less than the tractive force at bottom and this is very important, which help us in proceeding for design.

Well, now, let us just see how we can have, (( )), now let us talk about design of tractive force method or rather design by tractive force method. And till now, we have discussed about tractive force that is how we can have theoretically a relationship between the tractive force at the bed and tractive force at the side. And that way, once we can have some idea about the permissible tractive force of the bed, then we can know, what will be the permissible tractive force, unit tractive force at the side, permissible unit tractive force of the side. So, this is we have done and we can get it, then how much is the tractive force exerted by the fluid on the side and bottom bed of the channel, that we can get from the curves given by USBR. Well, now, let us see how this information helps us. This information helps us in designing the channel by tractive force method, well.

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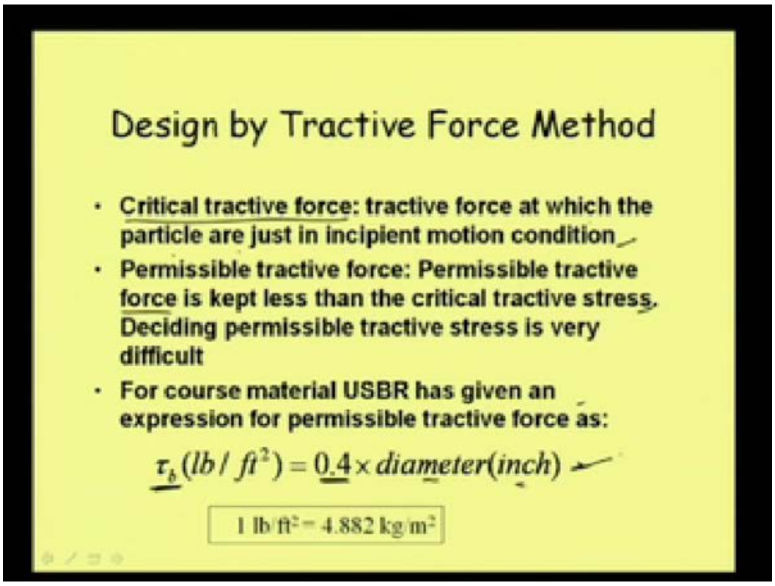

And for design purpose, we define few terms that are important. We call this as a critical tractive force. Well, so what is critical tractive force? The tractive force at which the particles are just in incipient motion condition, this is called critical tractive force, well. Then, definitely, we do not design in engineering any design for the critical condition, we do it for a situation that it is safer or better than the critical condition, we are not generally trying to reach the critical condition. So, when we talk about permissible tractive stress or say, permissible unit tractive force, then we define it in a way, that permissible tractive force is kept less than the critical tractive stress, well.

And now, for what type of soil, what will be the permissible critical stress? This is very, very critical, this is really critical. I mean, we have theoretically derived one relationship between the bed tractive stress and side tractive stress, that is fine, but what will be the critical tractive stress for the bed or for the side, what will be the limiting value, that is a very difficult task. And because, and why it is difficult? Because say, we are talking about alluvial channel, but there also will be some finer fraction and those finer fraction will be changing the value. And then, we, it is of course, generally expressed in terms of the diameter of the particle, it is generally expressed in term of the diameter of the particle, say if diameter of the particle is this much, then tractive stress required is this much. In fact, when we did discuss about the uniform flow in erodible channel, then we were studying those aspect also. We, we, we were discussing silt theory and there we were discussing those aspects, but again say particle size only does not matter, sometimes the, orient, orientation of the particle, then what is the shape of individual particle, how is the frictional resistance, all those factors will be influencing. Well compactness and other things are also coming into play.

So, like that, I mean this deriving, derivation of this tractive force is difficult, but still for our purpose, that we need to design. So, we will be, we will have to follow some methods and the experiences shown, that well, these approach if we follow, it gives us a, say, suitable channel, which we can use for our purpose and it is stable, so that way we go by those method. In fact, USBR also conducted lot of experimentation and they gave, they gave a, a, very, I mean, with quite convincingly they could give the value of permissible tractive force for a bed based on the particle diameter and that relation, what they gave is the tau b, and of course, they gave in pound per feet square, is equal to 0.4. Its relation is very simple, 0.4 into diameter and that diameter is in inch. diameter is in inch.

Now, say, now, it is in India we are using, say diameter in millimetre or say centimetre, we will be talking about and then, we are not talking about pound per feet square, we may be talking about Newton per meter square, kilo-Newton per meter square. So, that way, if we use this equation, then this relation, then we need to convert the unit and this is well known, how we can convert from inch to centimetre, just to give readily, how we can have pound per feet square to kg per meter square, that we can convert as 4.882 kg per meter square, 1 pound feet square is equal to, that we can have. And if we want to convert it to Newton, then we multiply it by 10, like that kilo-Newton, thousand. So, like that we can change these things again.

Well, so that way we can have the value of say, tractive force at bed of the particle, at bed of the channel, by using the relationship given by USBR. This is directly giving us permissible tractive stress, well.

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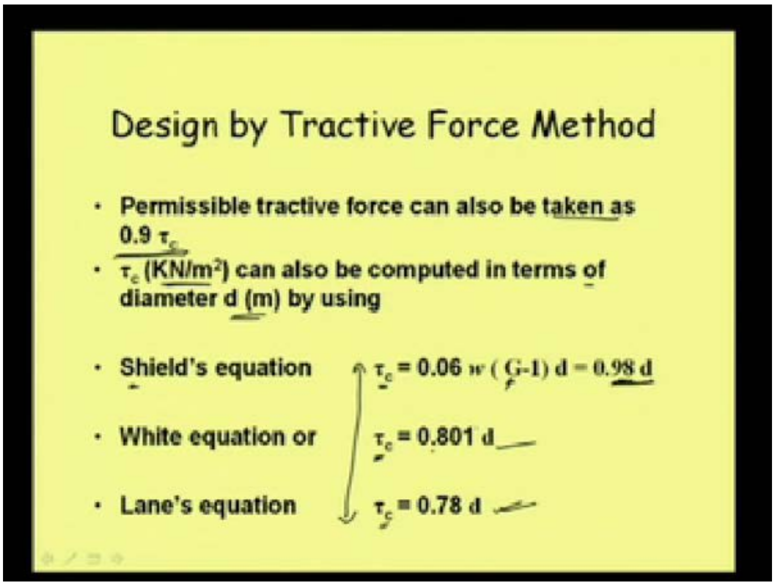

But again, as we have just discussed, that we were discussing Shield's theory also and then from Shield's theory we got a curve, and from that curve, ultimately we could derive that tractive stress, or this we, we gave as critical tractive stress. tau c we were writing by Shield's equation and there with tau c, if we keep in kilo-Newton per meter square and say, diameter of the particle in meter, diameter of the particle in meter, say d, diameter in meter and in tau c is in kilo-Newton per meter square, then we could see, that Shield's equation gave us a relation like 0.06. Then unit weight of water, g, is the specific gravity of the soil and then, minus 1 into diameter of the particle, that simplified equation we could get and that equation, if we simplify further by taking the standard value of w and by taking the standard value of say, soil, may be 2.65, like that soil is specific gravity, then we can get a value tau c is equal to nearly 0.98 into d.

Well then white equation is another equation that gives us critical tractive force or critical tractive stress tau c as 0.801 into diameter the unit is same and a Lane's equation is another equation, which is generally applied when the flow is a, when it is a fully developed turbulent flow. In that case, our tractive force is, I mean, at a little lesser tractive force, the particle starts moving for a fully developed turbulent flow and then tau c is given as 0.78 into d. So, these values can also be used for determining the permissible tractive force or permissible unit tractive force, other permissible tractive stress at the bed, and what is that?

That is permissible tractive force, can also be taken as 0.9 of tau c. Here, we are getting tau c and then by this method if we calculate the value, and then we take the 0.9, that is, 90 percent of that value, then that we can take as permissible tractive stress. And then, if you just try this calculation, then from this calculation if we do, if, if we just try this calculation putting for standard values, then we find, that this gate, we get almost expression of 0.76 d. This will also ultimately lead us to a value. If we change this unit, it will lead us to a value of, say, 0.76 d around and then, here it is tau c and then, we need to take 0.9 times of that. So, more or less, we are at almost, I mean near value, that we are getting and so we can see, that to be on safer side for our design purpose, we can take a tau c as say, 0.76 tau b permissible tractive stresses, 0.76 d or 0.75 d, around that we can take.

Of course, if we have confidence, if we know the soil in a much better way and flow condition, we are sure about that it will not be the turbulent, and then we can take our tractive force little higher value. Then, our, if we take the tractive force little higher value, that this permissible tractive force little higher, our size of the channel will be lesser. So, I mean, if we do not want to be that much conservative, then we can take little higher value or otherwise, we can go for lesser value. Well, that depends on experience and knowledge of the soil formation.

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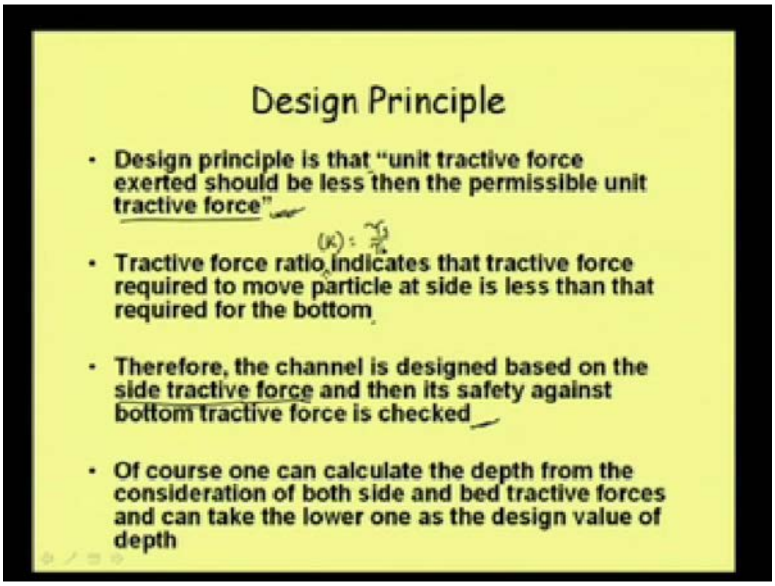

Well, then, what is design principle; what is design principle? So, design principle, let me just explain it step by step, you can refer to the slide. The design principle is that unit tractive force exerted should be less than the permissible unit tractive force. That we have already explained, we are repeating, but as a design principle, the main steps we must say, that this is the 1st principle.

Well, then starting with this principle, then we could see, that tractive force ratio, we calculated one, that we name as k tractive force ratio; k is equal to say, tau s by tau B and this ratio, this ratio indicates, that tractive force required to move particle at side is less than that required for the bottom, that required for the bottom. Well, and therefore, for design purpose what is done, that the channel is designed based on the side tractive force. This is the standard procedure we follow, for design is done based on the side tractive force because in the side, the force required is less. And of course, there is another point, that we, we are getting, that at the side, the force required is less. So, this is more critical, more critical if the side is safe, generally bottom will be safe. But another point we need to note, that if we just go back to our this curve, that we did discuss, we are discussing this curve, then if our B by y ratio is high than the, the force exerted, the bed is higher and for otherwise also, normally these, these are steeper in bed, the tractive force exerted is also higher than tractive force exerted in the side.

So, we know that tractive force, resisting tractive force of the side is less, but at the same time, force applied is also less. But of course, for high value of B by y is, this is significant, but for low value it is not that much significant. So, generally, we design it 1st for, say, tractive force at the base and then, sorry, tractive force of the side, side tractive force we design it first. We see what the value is coming and then we are getting a size, and then its safety against bottom tractive force is checked, it is the conventional practice we follow. However, when we have a computer, then these calculations will not take much time and in fact, if we have the curve and then we can just represent the curve also by some equation, and then this can be done very quickly. And then, what we can see, of course one can calculate the depth from the consideration of both side and bed tractive force, that means, depth we can calculate from both side considerations. We can get one depth from bed consideration, we can get one depth by using both the tractive force value, one is permissible, another is what is exerted.

So, from both these value we can get 1 depth and then, of course, 2 depth we will be getting out of that. What is the smaller one, that we can consider for our design purpose, but conventionally we find, that for a side, what depth we will be getting, that is the smaller because the side is more critical. Still, we can go by this way also, what I have mentioned in the last.

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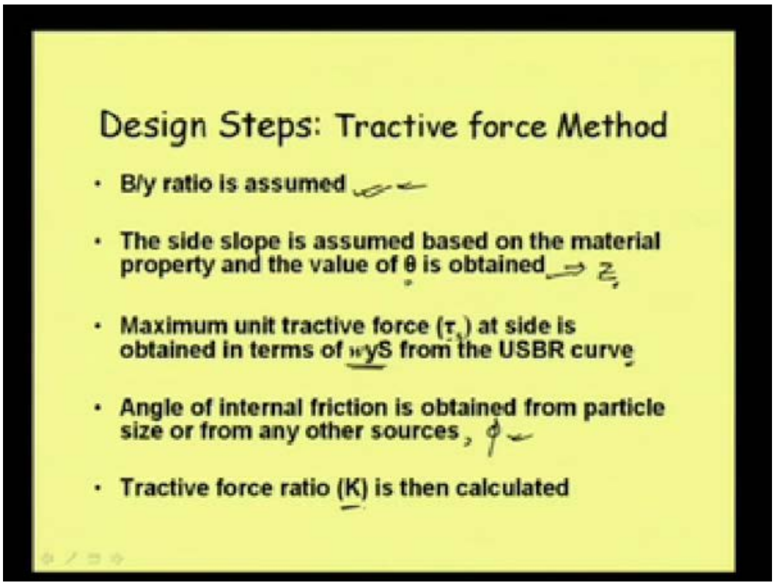

Well, then we need to follow some design step for tractive force method. First, what we do, that we consider a B by y ratio. Well, we need to assume a by y ratio based on the availability of space and with some of our understanding, the depth will be this much. Suppose, we know, that this is the discharge and for that discharge, this much will be the depth around we want to flow in the channel, then well, that should be the B.

So, we can try with B by y ratio from our experience and then we are assuming a B by y ratio, and the side slope is assumed. So, this first B by y ratio we are getting, then side slope is assumed based on the material property, and the value of theta is obtained. Well, a side slope as we did discuss that for this particular material, this will be like that, although it is alluvial, but still based on our understandings, still there will be some variation. Alluvial means, the particular size may be still larger and smaller. Well, that way we decide what should be the side slope and then, once we decide the side slope, well, we will be getting what is the angle theta.

Well, then, once we get this theta, that is z value is known, z value is known, this will give us the z value, then maximum unit tractive force tau s at the side can be obtained in terms of wyS from the USBR curve. We have just shown that particular curve from the side tractive force and bed tractive force, we have sets of curve for different z value, we can find those tractive force, that is at side and bed of course, that will be in terms of wyS, that is, some fraction multiplied by wyS.

And then, another important value we need to know is that angle of internal friction phi. So, that angle of internal friction we need to calculate, rather calculate means we can have our analysis in the laboratory or there are some standard curve, which provide the value of angle of internal friction. In fact, USBR gave some curves, which gives us the value of angle of internal friction based on the diameter of the particle. Well, those curves can be used, we can do experimentation in the lab, we can find the value of phi. So, that way, somehow we need to find the value of phi, then we need to calculate the tractive force ratio k, which we know, that there is an expression we can find that.

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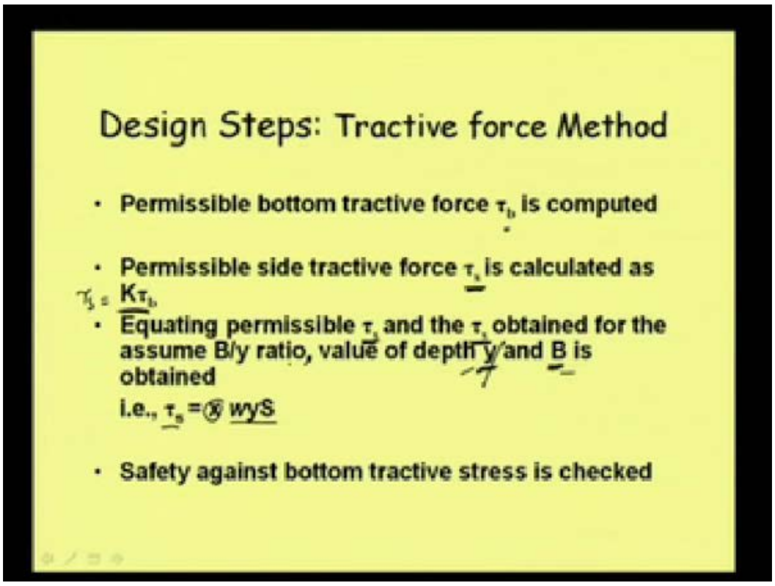

Well, the next step will be permissible tractive force tau b is computed. So, tau c, we can use the expression of USBR or we can use tau c for that, Shield's equation or White equation, Lane's equation, then we can, I mean, from any of these we need to calculate finally, the permissible tractive force at the bottom. So, once we get the permissible tractive force at the bottom, we can get the permissible tractive force of the side by the equation, that it is, tau S is nothing, but is equal to k into tau b.

Well, then, equating permissible tractive stress at the side and the tractive stress exerted, which we have obtained from the assumed B by y ratio and value of depth B by y ratio, so that we can equate and from that we can get the value of y, depth y and b. Why first we will be getting the value of y and then, we know the B by y ratio. So, we can have the value of, I mean, this B directly from them and that we are getting tau s. How we are getting this tau s? That we can get tau s is equal to that fraction multiplied by wyS and after that we are getting the depth and B value. So, this is what is our required design, but of course, this is not the final design. Then, safety of this design we need to check against the tractive force at the bed.

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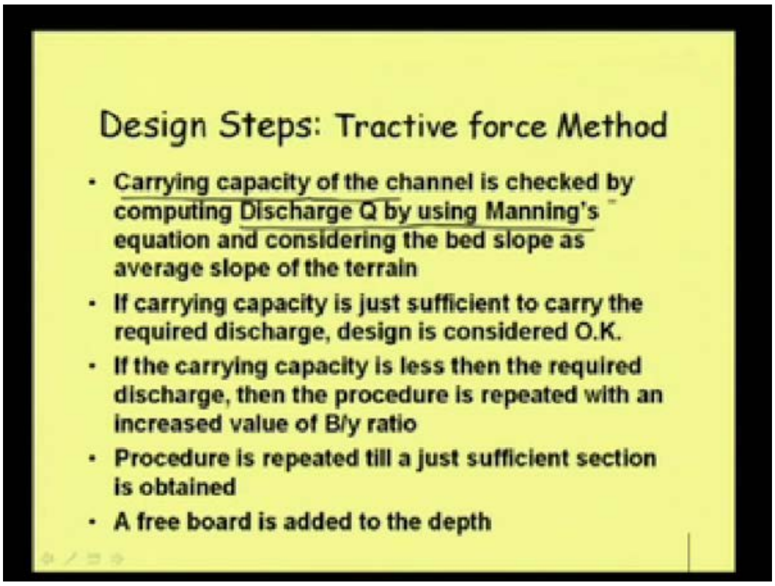

So, then, once we check the tractive force at the bed, suppose we have found it to be safe, then we need to check, whether this size is enough to carry the required discharge or carrying capacity of the channel is checked by computing the discharge by Manning's equation.

Now, our size of the channel with us, then slope is there. So, we can calculate how much discharge it can carry. If this is the depth y, then if it is just sufficient from our required discharge, then this is our final acceptable design, and if it is less than our required discharge, then we need to repeat the entire procedure by increasing the B by y ratio. So, we need to increase the B by ratio y ratio and then we need to carry out the entire process to get a new dimension for our channel. So, that way we get the channel dimension, we check and if it is sufficient, when it is just sufficient, then we stop. Suppose, in a 1st trial we have found, that it is sufficient, but it is much more than the sufficient, then we can reduce the B by y ratio, rather we should try with smaller B by y ratio, so that we can just get from insufficient than we are moving into just sufficient. So, that is what we can do and once the computer program is developed, then we can do it very easily.

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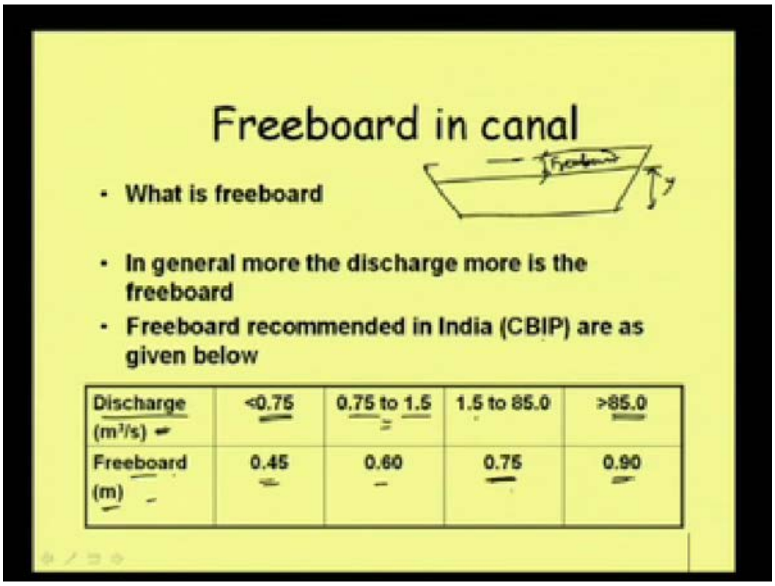

Well, then, after designing the channel, we need to a, a freeboard to the channel. What is meant by freeboard? Say, our design depth is this one, then we need to keep some extra over this for our safety, that is called freeboard; that is called freeboard. So, that extra depth we need to provide. And Indian standard and USBR also suggest that, saying that standard mean, basically, Central Board of Irrigational Power has suggested some value, that if discharge is less than 0.75 meter cube per second, the freeboard required is 0.45. Why I am giving this value? Because freeboard is not that negligible. Suppose, sometimes we may get our depth of y, water is 0.5, but above that we need to, it is 0.45, almost 100 percent freeboard, I mean.

Then suppose, for a depth of 0.75 to 1.5, not depth for, a depth of 0.75 to 1.5 meter cube per second discharge of this value, we can have freeboard of 0.6 and then, for there is a large range now, from 1.5 to 85 meter cube per second, that range is very large and for that we need to 8.75. And then, if it is greater than 85, then we need to 8; almost 1 meter is 0.9 meter. So, what we should get, that it is not uniformly with the increase of discharge, it is not proportionately increasing, but it is increasing definitely. But for a very large range of discharge we may keep the freeboard as 0.75 meter. So, that is how we get the freeboard and finally, we get our required design for the channel.

Well, here we are concluding our discussion on alluvial channels and we are not taking up any numerical of course, we did not take any numericals and I hope that we have tried to explain the steps very well, so that there will not be much problem in doing some of the numerical example, but this practice is essential. A nd I hope that we will be able to have better understanding of all this method, Kennedy’s, Lacey's tractive force by taking some hands on and by doing some practical example.

Thank you very much.