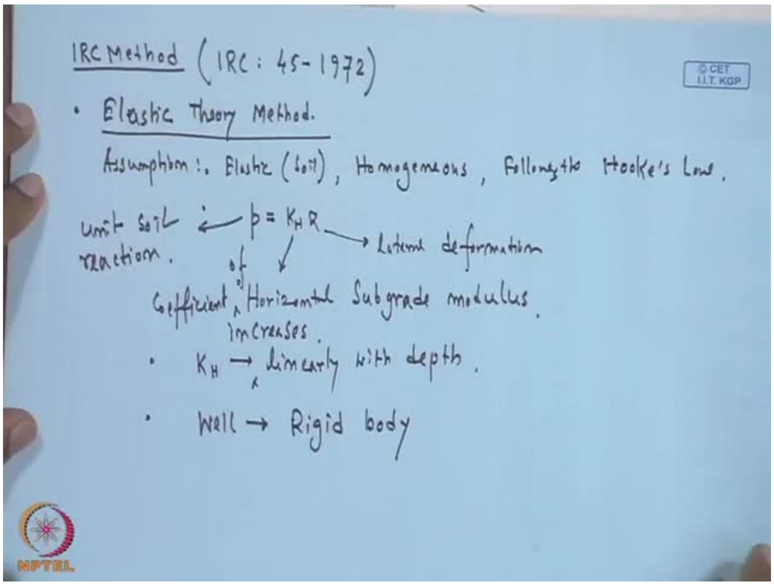
Advanced Foundation Engineering
Prof. Kousik Deb
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture - 22
Well Foundation (Contd.)

So, in the last class I have discussed about various components of the well, well foundation and how we can determine the depth, what are the forces acting on the well foundation, what are the methodology by which we can determine the stability of the well.

(Refer Slide Time: 00:37)

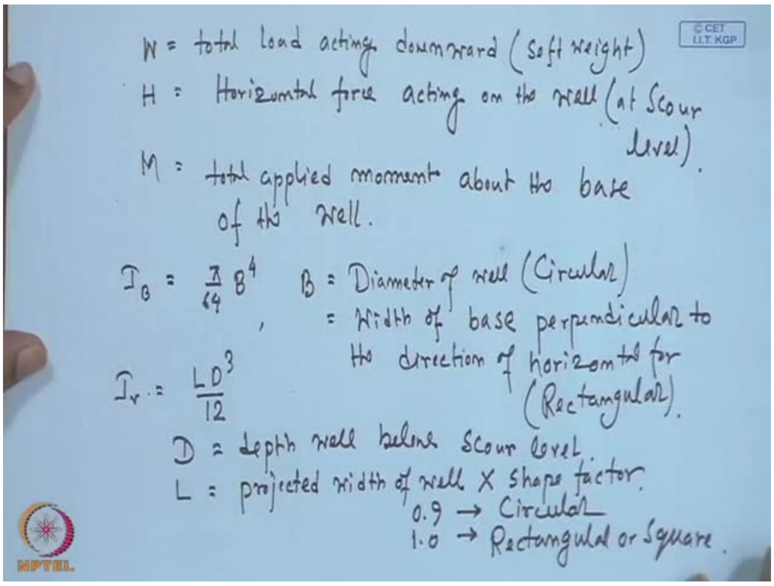


So, now today I will discuss about the IRC methodology, IRC method by which we can determine the stability of the well foundation. So, in the IRC methods the based on that the stability is given by the passive earth pressure resistance of the side soil. Now, and that that resistance we are getting at the at the base of the well as well as the side of the well. Now the, is this method first is first method or first part that is the elastic theory method. So, that means the here assumptions which are considered that this is the soil is perfectly elastic homogeneous, and follows Hooke's law that means soil is surrounding the well is perfectly elastic, the soil edge is homogenous and is follow the Hooke's law.

So, this is first assumption the surrounding soil is a perfectly elastic, homogeneous and follows Hooke's law and then the next assumption is that the unit pressure p which is equal to K H and z. So, that means the where z is the lateral deformation, K H the horizontal, coefficient of horizontal subgrade modulus and p is the unit soil reaction. So, next assumption the unit soil reaction p is equal to coefficient of horizontal subgrade modulus into the lateral deformation. So, then the third assumptions is K K H varies linearly with depth. So, that means the K H value value increases linearly with depth.

So, this is increases linearly with depth, this is the third assumption and another well, that well foundation which behave as a rigid body and acted by the horizontal force H and the moment M A at the base. So, these are the assumptions of this elastic theory method which is proposed by IRC IRC that is IRC 45 1972, now next one that how we can check the stability of this well.

(Refer Slide Time: 04:39)

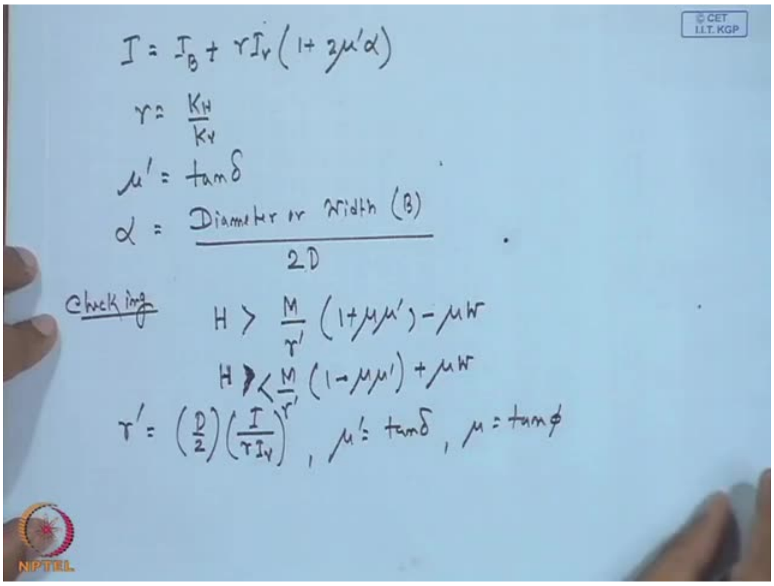


So, that means where we first we consider that W is the total force which is acting in down, downward direction, total force or load acting downward including the soft weight. Next, we can we have to determine the horizontal force acting at the scour level, horizontal force acting on the wall well at scour level. So, next we should know the, what is the net moment or the total applied moment about the base of the well the well. So, the that means we should know the weight total vertical load or downward vertical load acting downward direction including the soft weight that means we should know the vertical load, we should know the horizontal force acting on the well at scour level what is the and we should know the moment moment applied the base of the well.

So, once we know these three components then total load and the moment then we can check whether the well is laterally stable or not. So, first we are checking, we have to calculate that what is the value of I B? The moment of inertia that is acting for the base about a axis passing through the center of gravity and perpendicular the horizontal resultant force. That means the I B we can calculate pi by 64 into B to the power 4 where B is the so this is the moment of inertia acting as the base which is about an axis passing through the gravity center of gravity of the well and perpendicular to the horizontal resultant force.

Now, first we, that means we have to calculate I B. So, I B is pi by 64 B to the power 4 where B is the diameter of well if it is a circular. If it is a rectangular then this is the width of base perpendicular to the direction of horizontal force if it is a rectangular. Then next, one we have to calculate the I v L D cube by 12. So, that is also I v is also moment of inertia about the horizontal axis passing through the center of gravity of the projected area in elevation of the soil mass offering resistance. So, that means we have to calculate the I v which is L D cube by 12. Now, here the D is the depth of the well below scour level and L we have to calculate the projected width of the well.

(Refer Slide Time: 10:14)



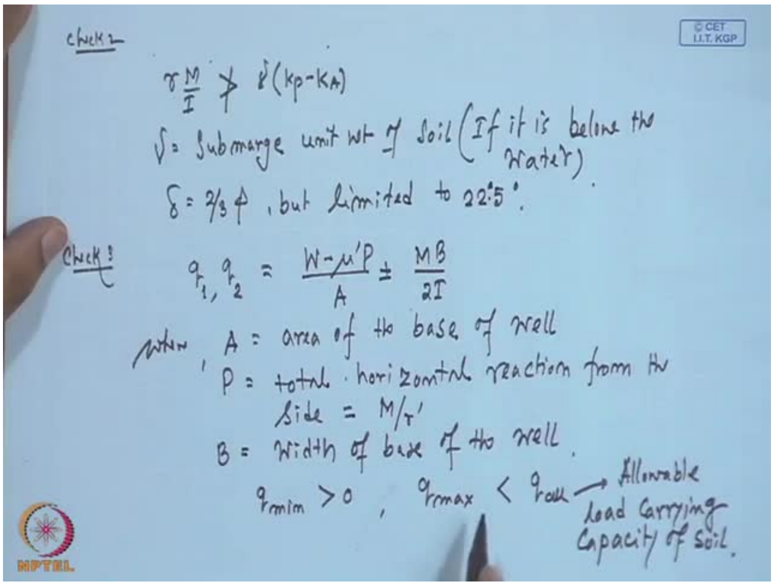
So, where from this expression D is the depth of well below scour level and L is the projected width of the well into we have to apply a shape factor. So, this is 0.9 this shape factor for circular and 1 for rectangular or square.

So, once we calculate the I B and I v then we have to calculate the total moment of inertia I, that is I B plus r into I v 1 plus 2 mu dash into alpha. So, where r is the ratio between K H by K v where K H is the coefficient of horizontal modulus of subgrade reaction, K v is the coefficient of vertical modulus of subgrade reaction. And mu dash is taking the coefficient of friction between the side wall, and the soil which is taken tan delta and alpha is taken as diameter or width of the well width of the well that means B divided by twice D.

And checking that we have to once we calculate this I value then the check, checking that we have to check that whether the horizontal force that should be greater than the moment acting divided by r dash 1 plus mu mu dash minus mu W. So, here and another one that H should be greater than that value also M by M dash 1 minus mu mu dash plus mu W. So, that means first check we have to consider that that mu and mu W that we have to calculate. So, once we calculate the mu value is given, mu dash is given tan delta.

Similarly, mu is given as a tan phi and here this is not, this is less than that. That means H, one check is H greater than M by r dash 1 plus mu mu dash minus mu W and another H should be less than to M by r dash 1 minus mu mu dash plus mu mu w and so once we check this value then we have to calculate what is r dash? r dash is D by 2 into I by r I v. So, this is r dash and mu dash as it is mentioned that tan delta, similarly, mu is taken tan phi. This is this is between the soil and the base of the well and it is taking equal to phi because of the roughness of the concrete pile plug. So, once which, this is one checking.

(Refer Slide Time: 13:48)

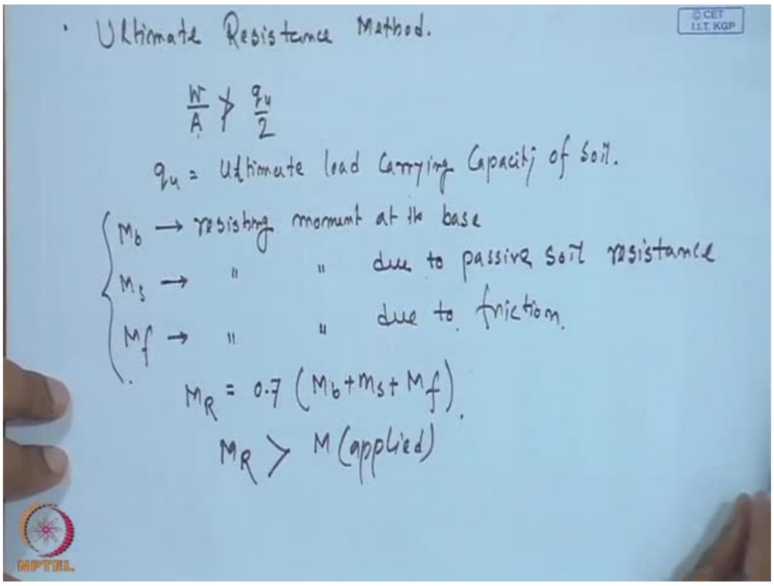


So, next checking is that the check 2 is at r M by I that should not be greater than gamma K p minus K A where gamma is taken as submerge unit weight of soil if it is below the water below the water and K p and K A are the active and passive earth pressure coefficient which can be determined based on the Coulombs theory and delta we can take two-third of phi, but limited to 22.5 degree. So, this is the second check we have to perform then the third check or the check 3 that we have to calculate the soil pressure, what is the stress which is acting on the soil?

So, this we can calculate W minus mu dash p by area plus minus M B divided by twice I. Now, where A is the area of base of well, P is the total horizontal reaction from the side of the well and that we can determine by M divided by r dash. So, p is M divided by r dash and B is the width or diameter of base of the well.

So, this is the third check and then we have to consider then the maximum stress here we will get one is maximum and this is minimum stress. So, that means that next one once we calculate this q 1 and q 2 then we have to check the minimum one or q minimum that should be greater than 0 and q maximum that should be less than the allowable or q allowable means the allowable load carrying capacity of the soil load or stress carrying capacity of soil. So, that means the minimum stress that should be greater than 0 and maximum one should be less than the allowable load carrying capacity of the soil.

(Refer Slide Time: 17:44)

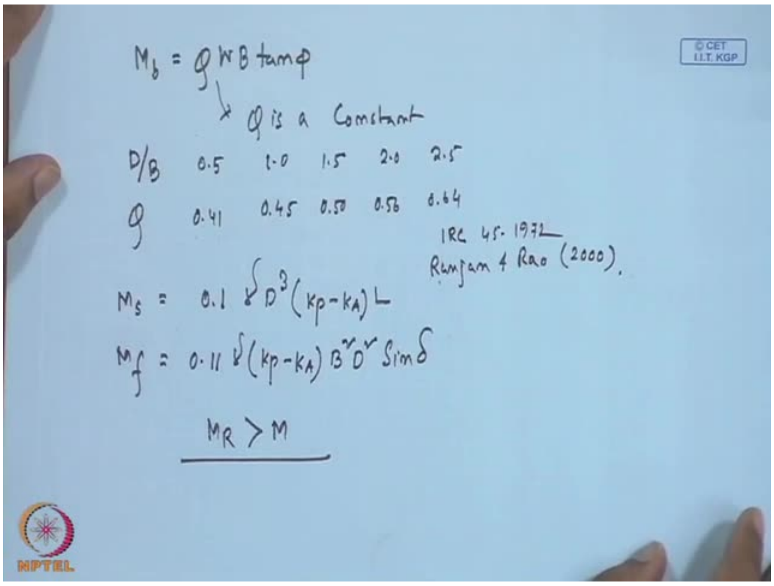


So, next check that we have to do for the ultimate resistance method and first one the elastic method then this is the ultimate resistance method. So, here we have to calculate that W by A that should not be greater than q u by 2 where W is the net vertical force acting or total vertical force acting and A is the area of the base and q here, q is the ultimate load carrying capacity of the soil.

So, next one we will calculate the resisting moment at the base. So, there is the three moment that we are getting that one is M b, that is the resisting moment. So, this is the resisting moment at the base. We have to calculate the M s that is the resistive moment due to passive soil resistance.

Next, one is M f this is also resisting moment that is due to friction. So, we have all three so that means the final resisting moment that is is taken at 0.7 tines of M b plus M s plus M f. So, that means these all are the resisting moment. So, that is resisting moment first at the base that is given from the base (( )) then the resisting moment from the due to the passive soil resistance and the resisting moment due to the friction and the total resisting moment is 0.7 times of M f and this check we have to done that M r should be greater than the moment which is applied. So, M r should be greater than the applied moment.

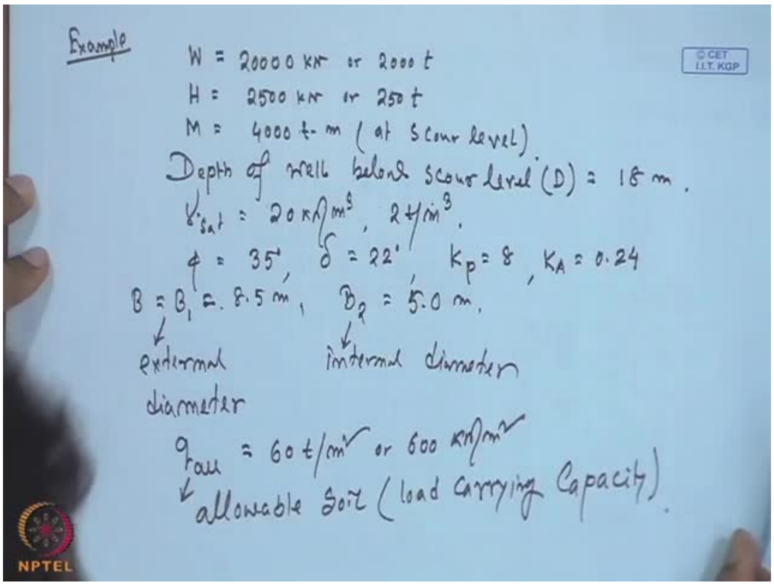
(Refer Slide Time: 20:47)



So, next one that, how to calculate this M b? Now, the M b we can calculate by q W B into tan phi where W is the total vertical weight force, B is the width of the well and then q is a constant. So, here q is a constant whose value we can, that depend on the shape of and the depth of the well so D by B ratio and the q. So, if it is 0.5 then 1, 1.5, 2, 2.5. So, Q value is 0.41, is 0.45, is 0.50, is 0.56, is 0.64. So, this is recommended by IRC and it is 45 1972 and taken from Ranjan and Rao 2000. And the M s value also we can calculate by 0.1 into gamma D cube K p minus K A into L and M f is can be given by this expression 0.11 gamma K p minus K A B square D square sin delta.

So, by this we can calculate the total resisting moment and then that should be equal to the, that should be greater than the applied moment. Now, once we calculate these value then we can complete or check and again as I mentioned that M R should be greater than M. Once, we can complete this check, this check you can say that our this well is laterally stable. Now, we will solve one problem and then we can see how we can use this expression and we can check where the well is, how we can check the well against a lateral load.

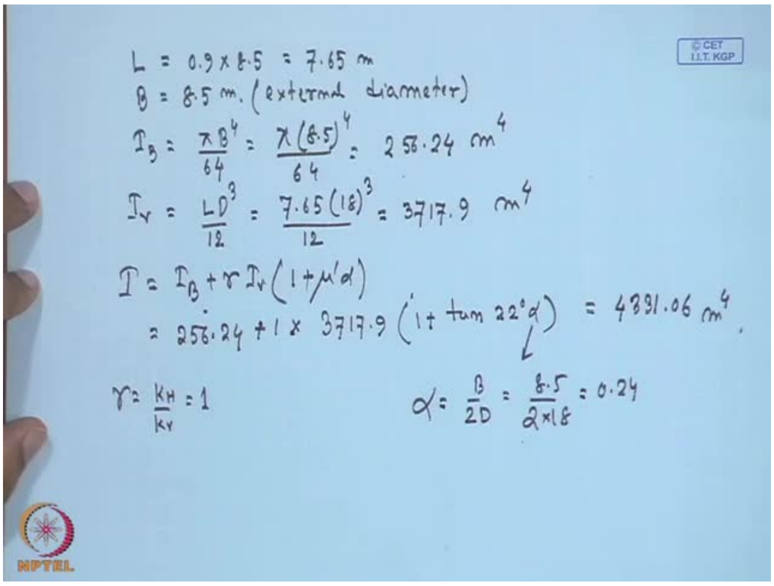
(Refer Slide Time: 23:29)



So but if this is the example that here the W or net weight is taken, I had given was 20 2000 or 20000 kilo newton or we can say this is 2000 ton, the H is given 2500 kilo newton or 250 ton, M is given at 4000 ton per meter. So, these are the given vertical horizontal force and the moment that is at the scour level. Now, depth of the well below scour level that is D is taken as 18 meter. Now, gamma sat is taken 20 kilo newton per meter cube or 2 ton per meter cube, phi value is given as 35 degree and delta value is 22 degree, K p and K A value, K p value is given 8, K A value is given 0.24.

And the or the B external diameter of the well is given as 8.5 meter and internal diameter of the well B 1 is the or B or B 1 that is the external and B 2 is the internal diameter is given as so 5 meter. Now, allowable soil pressure q allowable is 60 ton per meter square or 600 kilo newton per meter square. That is the allowable soil, allowable root carrying capacity of the soil. Now, we have to check the lateral stability of the well.

(Refer Slide Time: 27:01)

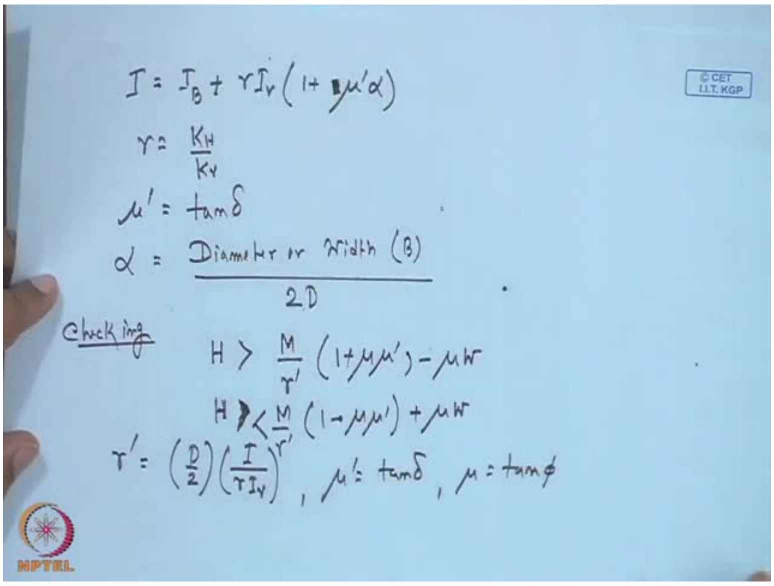


Now, first as we have mentioned that we have to check for the first to calculate the L is equal to as it is the circular well so that the safe factor is 0.9 into the projected base or with this 8.5 that is the external diameter. So, you can calculate L is 7.65 meter.

Next, one is that I B or B value here we have to take the 8.5 meter that is the external diameter or you can take that is external diameter. So, I B we can calculate by pi B to the power 4 divided by 64. So, pi into 8.5 to the power 4 divided by 64 that is 256.24 meter to the power 4 and I v that is taken as L D cube divided by 12. So, L is 7.65 D cube is 18 to the power cube and 12 where D is the depth of well below the scour level. So, that is D cube by 12 so that is equal to 3717.9 meter to the power 4. So, once you calculate I v and I b then total I is I B plus r into I v 1 plus mu dash into alpha.

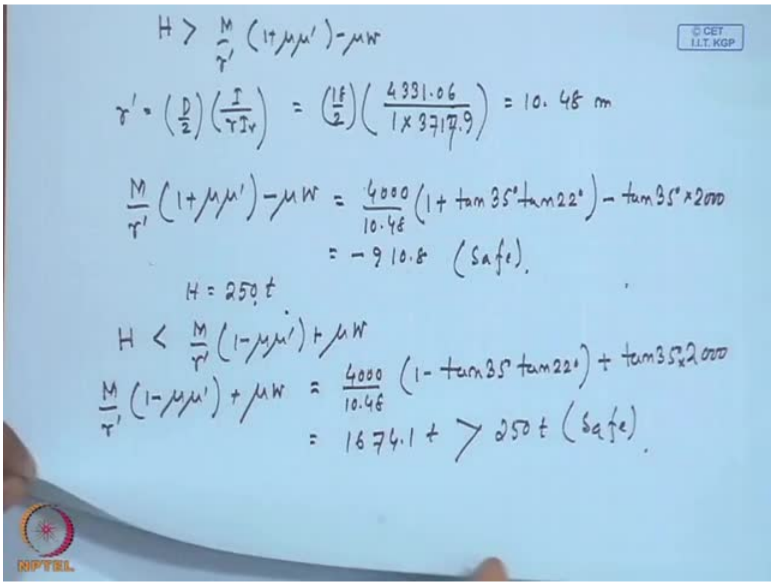
So, once you calculate that 1 plus mu dash into alpha then the total I will be I B is 256.24 plus r we have taken r is taken that is K H is equal to K v that is taken equal to 1. So, I v is 1 into I v value is 3717.9 1 plus this is tan 22 degree into alpha and alpha value we can take as B by 2 D so B is 8.5 2 into 18. So, that is 0.24. So, once we calculate we will get a value that is 4331.06 meter to the power 4. So, these are the value that we are getting from the calculation.

(Refer Slide Time: 30:30)



So, in the last expression that was shown so should not be a 2 that is 1 plus mu dash into alpha. So, we have to correct this equation. So, here also this is I B 1 plus mu dash into alpha. So, that we will get this moment that is this is a moment of inertia I. So, once we calculate the moment of inertia I then we have to conduct some several checks.

(Refer Slide Time: 31:09)



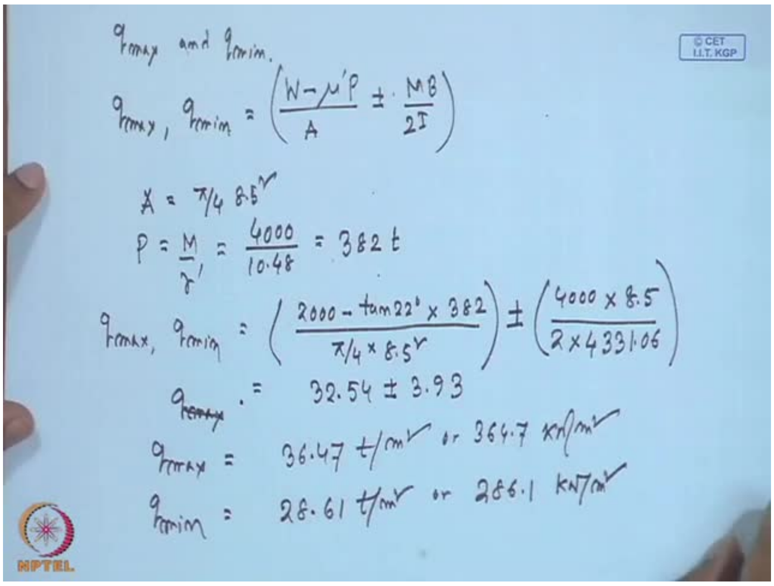
So, first check that we will do that is the check whether H is greater than M by r dash 1 plus mu mu dash minus mu W or naught. So, first we calculate the r dash that is equal to D by 2 into I divided by r I v. So, D is 18 meter divided by 2, I is 4331.07, r is taken as 1, I v is 3717.9. So, we will get a value of 10.48 meter as a r dash. Now, we calculate that M by r dash 1 plus mu mu dash minus mu W.

So, once we calculate these value here M is taken given a 4000 ton per meter and this is 10.48 1 plus mu we have to take tan 35 degree mu dash is tan 22 degree minus tan 35 degree into 2000 ton 2000 is a W value. So, this value is coming out to be minus 910.8.

So, now the H value is 250 ton and which is greater than this minus 1 910.8. So, it is we can say it is safe. So, next one and next check that we have to conduct the H should be less than M by r dash 1 minus mu mu dash plus mu W. So, first we will calculate the M by r dash 1 minus mu mu dash plus mu W.

So, M is 4000 r dash is given by this 10.48 1 minus mu is tan 35 mu dash is tan 22 plus mu mu is tan 35 into 2000. So, this value is coming out to be 1674.1 so that is this ton. So, that is greater than 250 ton so it is safe. So, we can say that this two checks are been done.

(Refer Slide Time: 34:30)

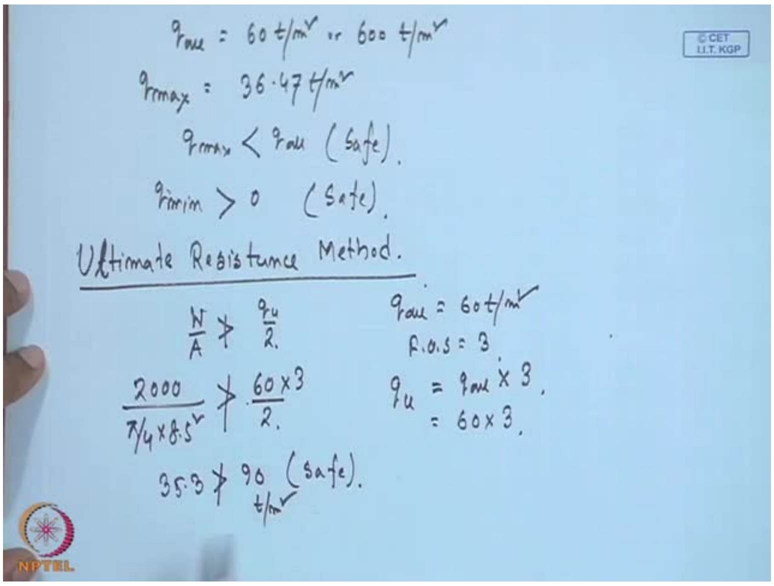


Now, we have to conduct the soil pressure or maximum q max and q min we have to determine. So, we can determine q max q min by given this expression W minus mu dash P divided by A plus minus M B divided by 2 I where plus we have to use for the q max and minus we have to use for q min.

So, once we, so from here the A value will be the area of the base that is pi by 4 into the 5 8.5 whole square. So, that is the projected area of the base 845 square and P we can determine that is P equal to M by r dash, M is 4000 ton meter, r dash is 10.48. So, B value is 382 ton. Now, if now if we put this value in q max and q min then we can determine the W is 2000 minus mu dash is tan 22 degree then P is 382 divided by area pi by 4 into 8.5 square then plus minus M is 4000, B is 8.5 divided by 2 into I is calculated 4331.06.

Now, if I consider the plus value then q max is so from here we can write that this is 32.54 plus minus 3.93. So, we can say that q max will be 32.54 plus 3.93. So, it is coming out to be 36.47 ton per meter square or third 364.7 kilo newton per meter square and q minimum will be 32.54 minus 3.93. So, q minimum value will be 28.61 ton per meter square or 286.1 kilo newton per meter square. So, we can, we have determine, that what is the maximum stress which is acting on the soil and which is the minimum stress which is also acting on the soil. So, that means we will consider the maximum one to check whether this stress soil can able to carry or not.

(Refer Slide Time: 38:03)

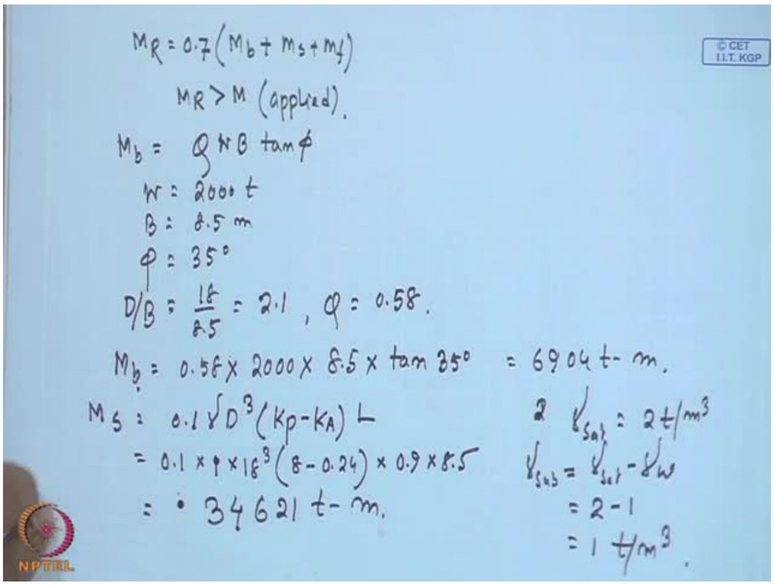


So, we can consider that allowable stress q allowable is given 60 ton per meter square or 600 ton per meter square whereas, q max is given 36.47 ton per meter square. So, that means we can say that q max is less than q allowable so safe. So, we can say that the maximum stress which is acting which is coming on the soil is 36.47 ton per meter square whereas, soil can able to take a load soil load allowable load carrying capacity is 60 ton per meter square. So, it is safe.

Another one is q minimum which is greater than 0. So, that is also, that means that is also safe, I mean no tension zone force is occurred in the soil. So, next check that we have to conduct is for the ultimate resistance check. So, for the ultimate resistance check method or check here first we have to calculate W by A that should not be greater than q ultimate by 2.

Now, here that q allowable is given 60 ton per meter square and generally the factor of safety which is applied is 0.5 to 3. So, here if we consider a factor of safety is 3 then q ultimate will be equal to q allowable into 3. So, we can consider this will be 60 into 3. So, now we can calculate that W is 2000 area of the base is pi by 4 into 8.5 square that should not be greater than 60 into 3 divided by 2. So, we will calculate, we will get that this value is 35.3 and that is not greater than equal to 90. So, it is safe. We can say so this is safe 90 ton per meter square. So, this is also safe.

(Refer Slide Time: 41:31).



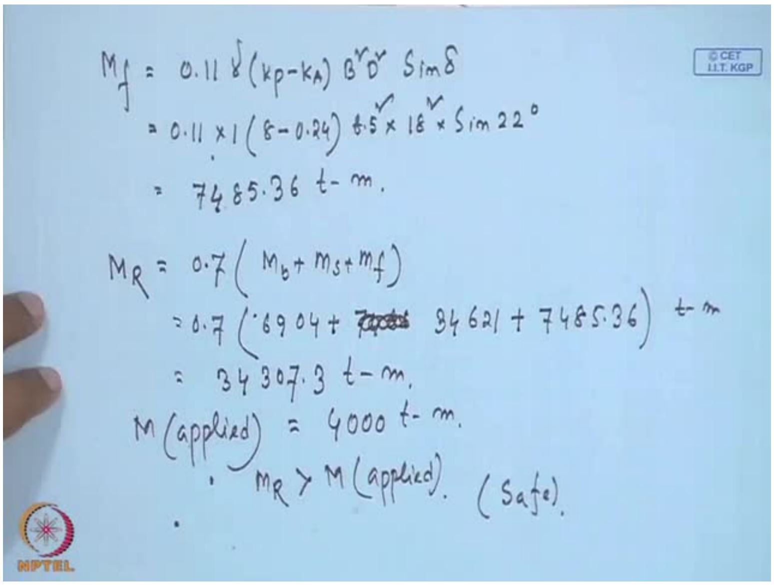
Now, we have to calculate the all resisting moment and this expression we have to determine that M r is 0.7 of M b plus M s plus M f and M r should be greater than M which is applied. So, first we will calculate what is the value of M b? So, M b is Q W B tan phi. Now, the W value is given, W is equal to 2000 ton, B is 8.5 meter and phi is 35 degree. Now, Q value we have to calculate.

Now, for for Q value D by B is 18 divided by 8.5. So, that is 2.1. So, once we get this B value where D by B then from the table we can determine what would be the value of this Q, because Q has this table is given. So, that means from here in this value D by B is 2.1. So, D by B is rounding this one and this is 0.56 and this is 0.64. So, in between this so that Q value is coming out to be around 0.58.

So, the Q value from here we can get 0.58. Now, if we put this value M b is equal to 0.58 into 2000 into 8.5 into tan 35 degree. So, it is coming out to be 6904 ton meter. Similarly, the M s is given 0.1 to gamma D cube K p minus K A into L. So, this is 0.1 gamma is given as a, because 1 because the gamma sat is given 2 ton per meter cube and as gamma submerge we have to consider because it is below soil. So, gamma sub is equal to gamma sat minus gamma water. Gamma sat is 2, gamma water is 1. So, this is 1 ton per meter cube.

So, this is 1 into D cube is 18 cube, K p is 8, K A is 0.24, L is 0.9 is a safe factor into 8.5. So, we will get a total resistance due to the passive force or passive resistance. This is 34621 ton meter. So, this is the moment due to the passive resistance.

(Refer Slide Time: 45:15)



Next, one we will calculate what is the value of M f? So, this is the resisting moment due to the friction. So, M f that is 0.11 gamma K p minus K A into B square D square sin delta this is for the friction. So, we will have 0.11 into 1 K p is 8, K is 0.24, B square is 8.5 square into D square is 18 square into sin 22 degree.

So, we will get a total resistive moment due to friction 7485.36 ton meter. So, we can calculate the total moment that is the M r 0.7 of M b plus M s plus M f. So, this is 0.7, M b value is 6904, M s is 7485 sorry M s value is 34621 plus M f is 7485.36. So, this ton meter. So, ultimately M r total resistive force or moment is 34307.3 ton meter and M applied applied load at the scour level which is given 4000 ton meter where this is 34307 ton per meter. So, we can say that M r is greater than M applied. So, this is safe.

So, this way we can check that the dimension that we have chosen based on the loading condition that is the vertical load, horizontal load and the moment at the base, the, this well is checked for all the possible condition and all the checking's are okay so that means it is safe for lateral stability checking. That means we can say that under this condition this well is safe against the laterals; that means this well is lateral checking that means this well is laterally stable.

So, that means we this one we have we have done the checking for the moment, resisting moment that is applied then we have checking for the stress which is acting on the soil that means the q max and q min. Now, the q max should be less than the allowable load carrying capacity of the soil and also we have checked the horizontal stress or horizontal force actually that is acting on the well that we have to also check whether that due to that horizontal force is the stability will be disturb or not, whether well is also stable under that horizontal force.

So, that all the checking's are done and it is passed all the checking's. So, it is safe against the lateral stability. So, that means here first basic is that we should know the what is the vertical load acting so based on that the load which is acting on the base of the soil that we can determine. So, that is the purpose to for the for that checking we should know the vertical load, we should know the lateral load or that means that will also help you to check the whether this is safe against lateral condition or not. Now, we should know the moment which is acting in the base of the soil so that means whether base of the well.

So, that means that moment also disturb the lateral stability of the well. So, we should know the, these all three components before we start the checking of the well against the lateral stability. And as well as we should know should know the the properties of the soil and based on that we we have to determine what is the scour level and what is the scour depth, and then we should know what is how much foundation, how much depth of the foundation will provide below the scour level. So, that we can determine what would be the depth of the foundation below scour level, and based on that we will determine the that level the soil stress will determine. And then we will check whether that soil stress is good enough, soil condition is good enough to resist the stress which is coming on the soil.

So, that means we should know the external load or the moments that means the vertical load horizontal load and the moment, we should know the soil properties or based on that we have to decide how much diameter or the depth of the well will provide. So, what would be the diameter, what will be the depth of the well below the scour level? So, those things we have to determine.

So, now in this way we can check this well foundation and then we have to design this well. Now, this part in today's class I have discussed about the this IRC method and how we can check the lateral stability of a well by using the IRC method and previous class I have discussed about how we determine the depth and that depth depth is also here required to check this lateral stability. Then what would be the diameter of the well and then how much minimum amount of the depth or the grip length because this grip length is also required to determine how much depth will provide.

So, how much required grip length I have to provide, what would be the minimum depth of the well that things also we explained here. So, based on that we should provide the particular depth of the well below the scour level and then based on that we will decide the, we will check the lateral stability of the well.

So, now in this class or in the in in this course we have discussed various component of the foundation that we have discussed about the shallow foundation, we have discussed about the defoundation that means of the pile under define loading condition then the well foundation. We have discussed about the a reinforced earth, how we can design the reinforced retaining wall then I have discussed about the, I have discussed about the soil foundation interaction that means how soil can be modeled to interact with the foundation and as well as the soil properties whichever very important things. And then how we can determine the soil property by the exploration so those things also we discussed here and the we have also designed that retaining wall not only the our reinforced retaining wall also the the normal or traditional retaining wall which is cantilever retaining wall or gravity retaining wall. So, those things also been discussed in this course.

So, this is the complete or this is the last lecture of this course, and here so I have tried to incorporate all the basic components of the foundation and how to analyze these things and how to design these things.

Thank you.