Rock Engineering
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Lecture - 59
Bearing Capacity Based on Plate Load Test; Treatment of Foundations

Hello, everyone. In the previous class, we discussed about the determination of bearing capacity based on classification approaches and the core strength or the uniaxial compressive strength. We saw that how using RMR, one can get the safe bearing pressure and how using the value of UCS, one can obtain the safe bearing pressure. In case of the UCS, we saw that it was depending upon the joint spacing, width of the footing etc.

So, today, we will see that how we can determine the bearing capacity based on the plate load test. And then, in case of the foundation, which are pretty weak, how these can be treated in order to have the better bearing capacity of the foundation on these. So, let us first start with our discussion on the determination of bearing capacity based on the plate load test. So, this plate load test is not a new term for you, if you have done the courses on the soil mechanics.

You know that square plate is placed in a pit at a depth wherever you want to carry out that test and then we apply the load in increments. And we wait for some time for this plate to get settled under the application of that load. We note down that settlement and then only we apply the next increment of the load and this process is repeated till either there is a shear failure or there is the settlement which is more than the 25 millimeter.

So, that is how we carry out the plate load test in case of the soils. So, the procedure for carrying out this plate load test on the rocks or rock masses is exactly the same as that in case of the salts.
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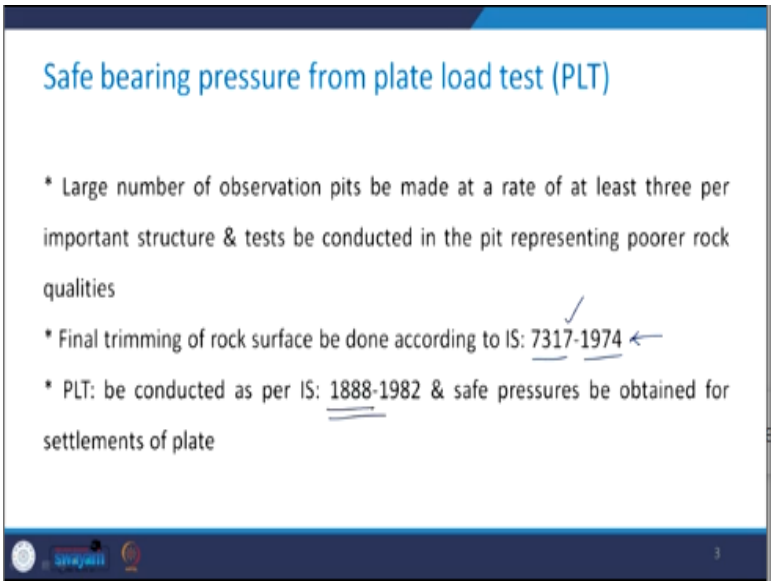

So, the plate load tests, although it has many limitations, but it is still the most practical and the proven test for recommendation of the bearing pressures. These plate load tests should be conducted on poor rocks, where safe bearing pressure is suspected to be less than 100t/m^2. If you recall our discussion of the previous class, I showed you a table that in which case this plate load test would give us the reliable value of the safe bearing question. So, this is what is the condition that one needs to keep in mind.

A frequent mistake which is committed in ignoring the fact that the rock mass is quite heterogeneous material as compared to that of the soil. Although soil has its share of heterogeneity, but that is much, much less as compared to what we have in case of the rock mass. So, that should be taken into account. And in order to get this aspect, one needs to go for large number of observation pits at a rate of at least 3 per important structure and test should be conducted in the pit representing poorer rock qualities.

So, since, this rock mass has more heterogeneity, so, what we do that in an area where this exploration has to be carried out, we make 3 pits per important structure as compared to one which we do in case of the soils and we inspect that pit and whichever pit is representing the poor rock qualities, the test will be conducted in that. The final trimming of the rock surface should be done according to this IS code which is IS 7317. So, it has some specification.

So, one can look at it and then that trimming of the rock surface should be done according to this code. The PLT should be conducted as per IS 1888. This is the same way that you carry out in case of the soils and the safe pressures can be obtained for the settlements of plate The procedure, the conduct of the test, the analysis, everything is same as you have done in case of the soils. Now, for a given settlement of footing, the settlement of plate can be obtained by using the following expressions.

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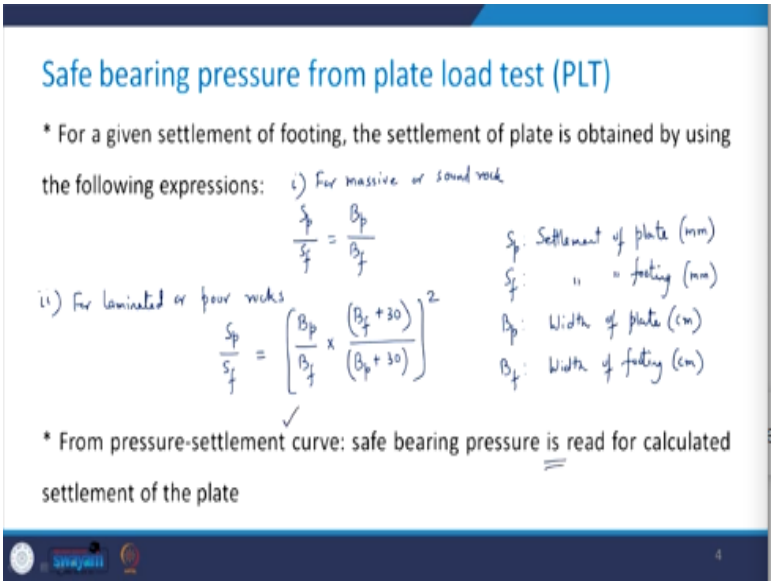

And these expressions are again same as that of the soils. So, in this case, you have the first expression which is applicable in case of the massive or the sound rock. So, you have $\frac{S_p}{S_f} = \frac{B_p}{B_f}$. I will tell you what all these terms are, but let us first see that in case if you have laminated or poor rocks, then how you can get the settlement. So, for laminated or the poor rocks, we have

$$\frac{S_p}{S_f} = \left(\frac{B_p}{B_f} \times \frac{B_f + 30}{B_p + 30}\right)^2$$

So, where you have S_p as the settlement of the plate in millimeter; S_f is the settlement of the footing in millimeter; B_p is the width of plate in centimeter and B_f is the width of the footing in centimeters. So, from the pressure versus settlement curve, you can obtain the safe bearing pressure for this calculated settlement of the plate. So, here, we need to know the settlement of the footing which can be taken as let us say the permissible value and you can find out that what is the value of the plate settlement.

And from the pressure versus settlement curve, whatever is the settlement of the plate that you get. You read from the pressure settlement curve and you can obtain the safe bearing pressure. It is recommended that you carry out 3 plate load tests on different sizes of plates on the rock mass of same quality and if you want, you can check the validity of these equations as well. So, from the pressure versus settlement curve, in case if you are able to obtain the failure point, then the footing can be checked in shear failure also.

But, keep in mind that this plate load test is more towards the settlement criteria rather than the shear failure criteria. Now, there are few correction factors which should be applied in order to obtain the allowable bearing pressure. So, whatever is the safe bearing pressure that you obtain either from the classification approach or UCS or plate load test, these should be multiplied with the correction factor according to the geological conditions. Here, a word of caution is there that these corrections should not be applied for the classification of the RMR method.

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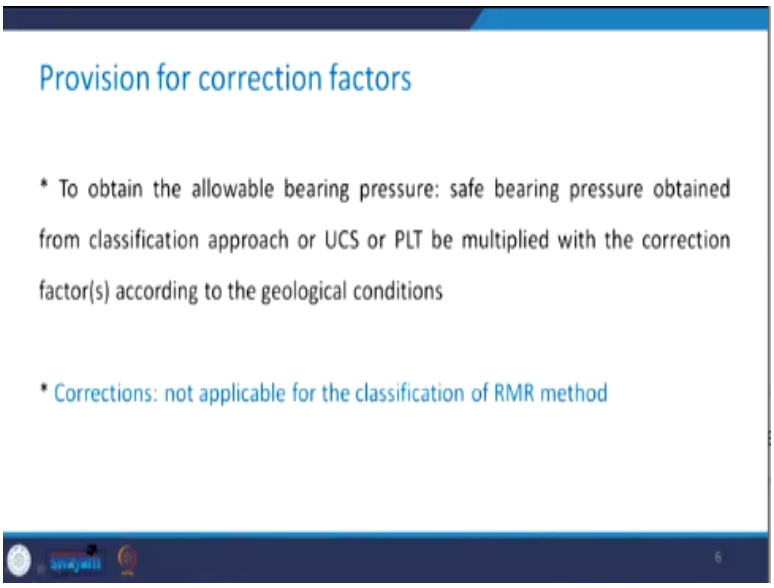

That is in case if we have obtained the safe bearing pressure from the RMR method, these correction should not be applied, but otherwise, for UCS for plate load test and for other classification approach that we discussed in the previous class, for all these cases, the correction factors should be applied. Let us see what all are those correction factors.

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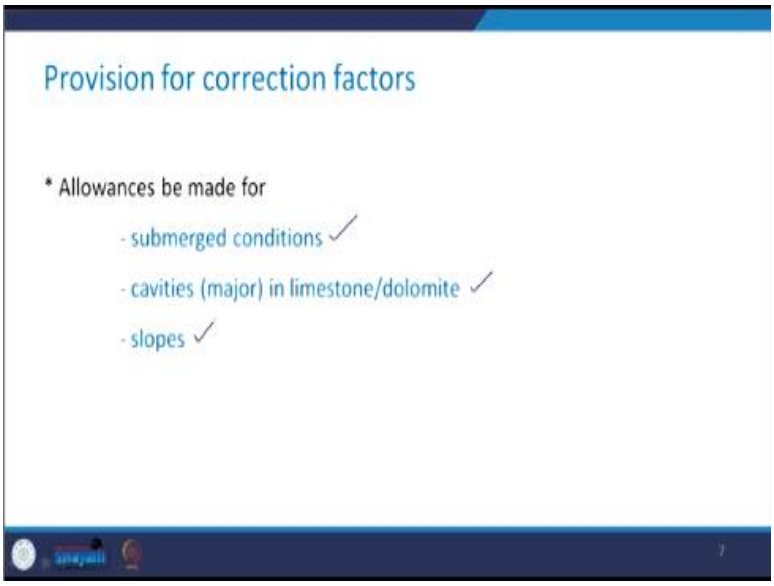

So, the allowance is made for the submerged condition and the presence of cavities which are of course, the major cavities in limestone or dolomite. And in case if you have the footings on the slopes, there also you have to incorporate some correction factor. Let us see what are these correction factors and how these are quantified as per our IS code. So, the first one is the submersed conditions under water table.

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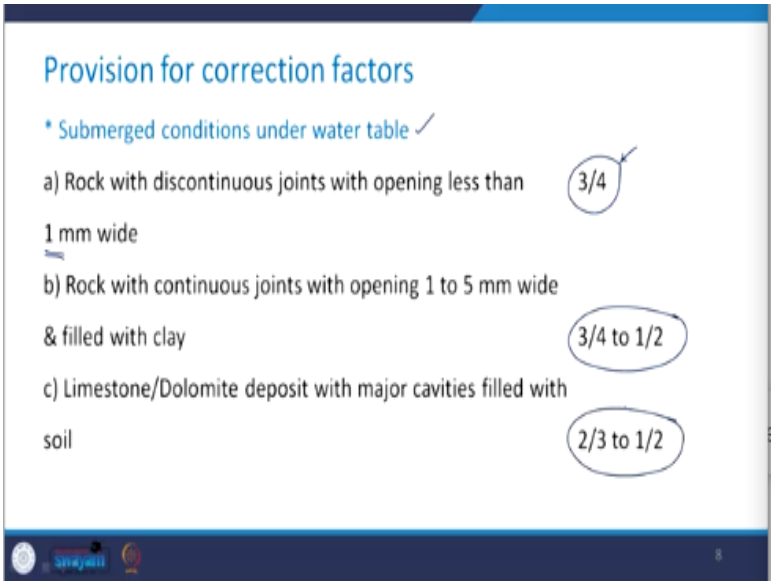

So, in case if you have the rock with discontinuous joints with opening less than 1 millimeter wide in that case, the correction factor to account for the submerged conditions under water table should be taken us ¾. So, whatever is the bearing pressure that you have obtained from the

pressure versus settlement curve from the plate load test data that you should multiply by ¾ in order to obtain the allowable bearing pressure.

In case of the rocks with continuous joints with opening from 1 to 5 meter wide and filled with place, then this correction factor varies between ¾ to 1/2 and in case, if limestone or dolomite deposit are there with major cavities which are filled with soil, this correction factor becomes two third to half.

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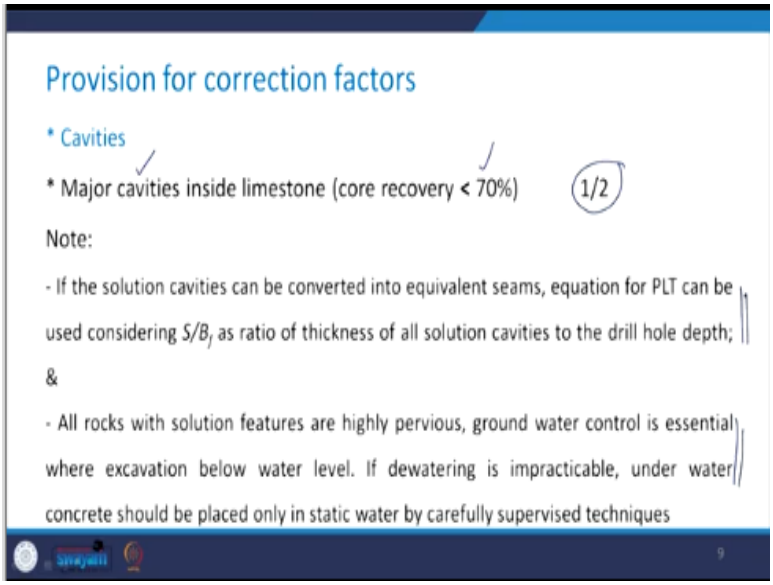

Coming to the second one that is to account for the cavities. So, these cavities involve the major cavities inside the limestone. How can we identify that these are the major cavities? So, in such cases, the core recovery is going to be less than 70%. And to account for such cavities, the correction factor of 0.5 should be applied to the safe bearing pressure values. Now, there are few things one needs to keep in mind which have been given as a part of note here in this slide.

Take a look that if the solution cavities can be converted into equivalent seams. The equation for plate load test can be used considering S upon B_f as the ratio of thickness of all the solution cavities to the drill hole depth. So, instead of S upon B f, you can use the ratio of thickness of all the solution cavities to the drill hole depth. In case, all the rocks with solution features are highly pervious, ground groundwater control is essential where the excavation below the water table is there.

Now, if dewatering is impracticable, then underwater concrete should be placed only in these static water by carefully supervised techniques. So, these things should be kept in mind, when you have these major cavities which are present. In case of the footings on the slope and if you have the fair orientation of continuous joints in the slope, the correction factors, they vary between 1 to half.

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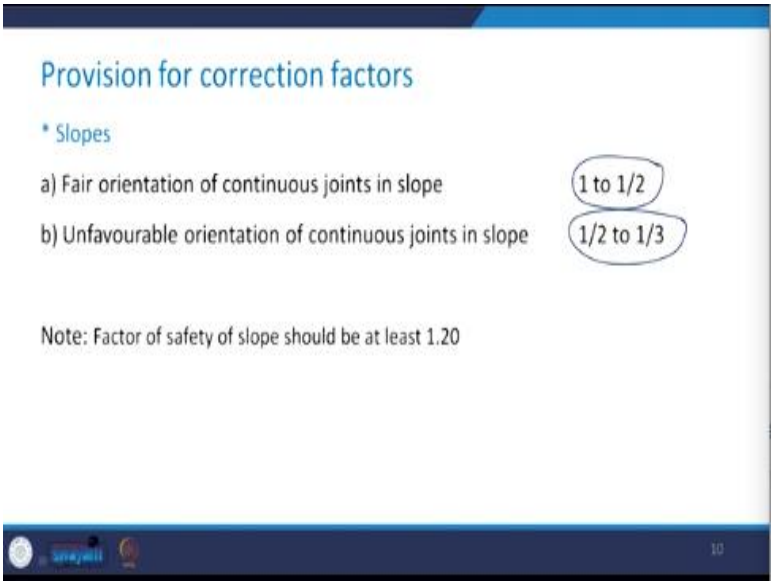

And in case of the unfavorable orientation of the continuous joints in the slope, these get to half to 1/3. Take a note here that in such cases, the slope should be stable and its factor of safety should be at least 1.20. It should not happen that we are designing a very safe footing, but the slope itself is not stable, because if the slope is not stable, there is no point in designing or analyzing a stable footing on that slope.

So, these correction factors are associated with the fact that the factor of safety of the slope should be at least 1.20. And since, it is more than 1, this signifies that the slope itself should be stable. Now, there are few precautions for the safe bearing pressure when these are recommended. So, one needs to keep in mind that when the safe bearing pressure should be recommended, always less than the safe uniaxial strength of the lean concrete leveling course of the individual foundations.

Otherwise, richer plain concrete layer should be laid in order to prepare the smooth surface for laying the RCC foundation.

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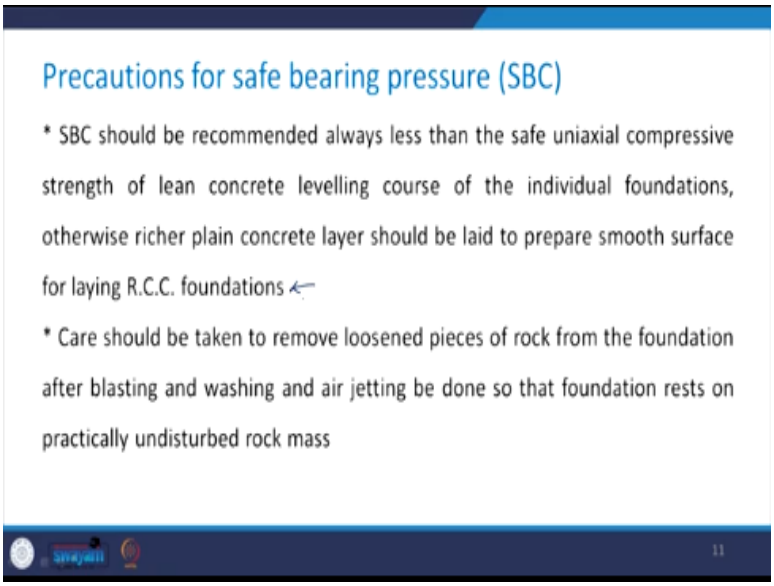

The care should be taken to remove the loosened pieces of rock from the foundation, because what happens that when you are trying to create the excavation in order to place the foundation, some blasting is to be carried out now, because of this blasting, there can be some losing piece of the rock at the surface. So, these should be removed and that area should be washed and air jetting should be done.

So, that the foundation rests on practically undisturbed rock mass. If this is not done, then whatever is the bearing capacity of the foundation that would have been if that was placed on the undisturbed rock mass will not be achieved in this case, if you are not carrying out this particular step that is washing and air jetting. So, one needs to be extremely careful.

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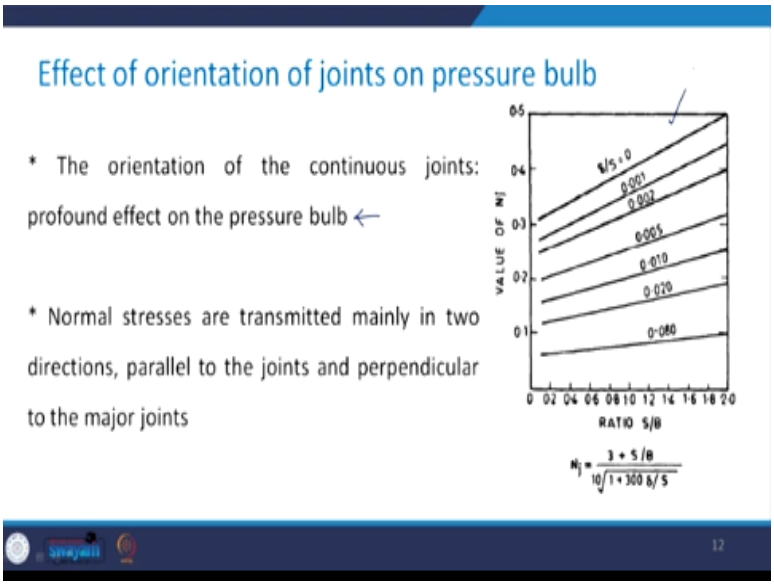

Effect of orientation of joints are there on the pressure bulb. And we have seen that earlier also where I showed you that which type of orientation is very favorable, favorable, fair, unfavorable or very unfavorable. So, the orientation of the continuous joints has profound effect on the pressure bulbs. Normal stresses are transmitted mainly in 2 directions. One is parallel to the joint and another one is perpendicular to the major joint.

Why I have put disfigure is that depending upon the spacing of the joints and the orientation, you have seen that how the safe bearing pressure gets influenced. And this also, you have seen that the extent of the pressure bulb is more in the direction in which the joints are dipping.

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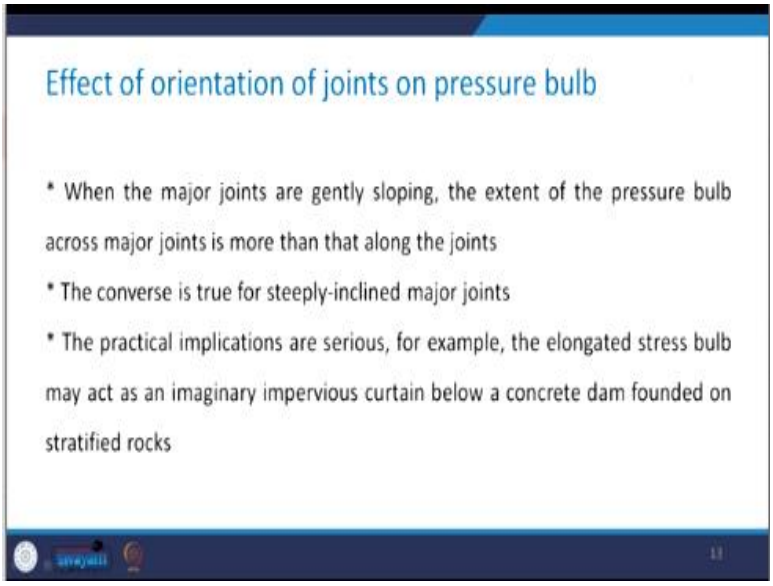

So, when the major joints, they are gently sloping the extent of the pressure bulb across the major joint is more than along the joint and the converse is true for steeply inclined major joints. In case, if you have steeply inclined major joints, the extent of the pressure bulb will be more along the joint as compared to across the major joints. The practical implication of this is quite serious. For example, the elongated stress bulb may act as an imaginary impervious curtain below a concrete dam which is founded on stratified rocks.

So, we need to be extremely cautious about this effect of orientation of the joints which is there on the pressure bulb. The rock mass rating also will be reduced considerably in case, you have unfavorable orientation of the continuous joints as far as the placement of the footing is concerned and accordingly the bearing pressures also should be reduced. Now, there are few considerations which one need to keep in mind, while going for the construction of the footings on the rock.

We need to keep this in mind that the horizontal stiffness of foundations on rock is quite small as compared to its vertical stiffness.

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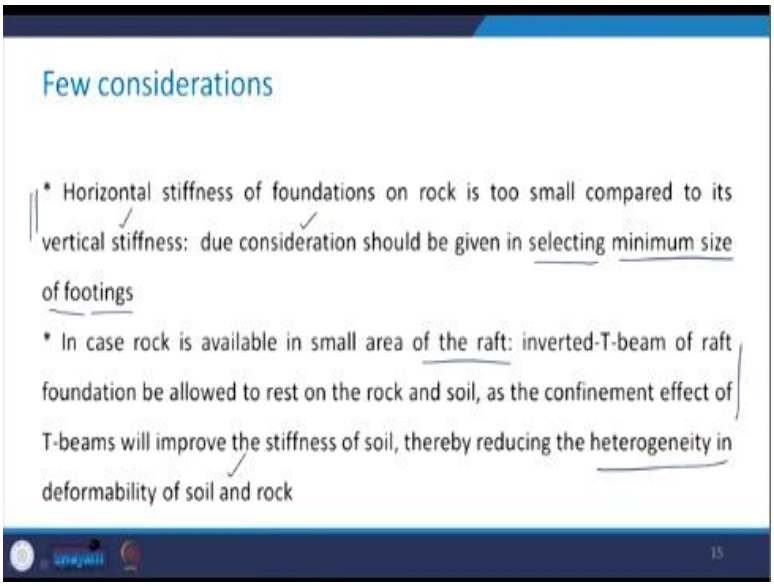

And hence, the due consideration should be given in selecting the minimum size of the footings. So, when you select the size of the footing, you should keep in mind this fact that the horizontal stiffness of the foundations on rocks, they are quite small as compared to that of its vertical

stiffness. Now, in case, the rock is available in the small area of the raft, what we do is that inverted T beam of the raft foundation should be allowed to rest on the rock and the soil as the confinement effect of this T beam will improve the stiffness of the soil.

And hence, reduce the heterogeneity in the deformability of rock and soil. Because, let us say that the raft is there and in one portion, you have the soil strata and other part, you have the rock. So, since, the deformability of the rock and the soil they are different. So, the raft may experience the differential settlement and this is not desirable because this will cause cracks in the rock. So, therefore, to reduce the heterogeneity in the deformability of rock and soil, this should be adopted.

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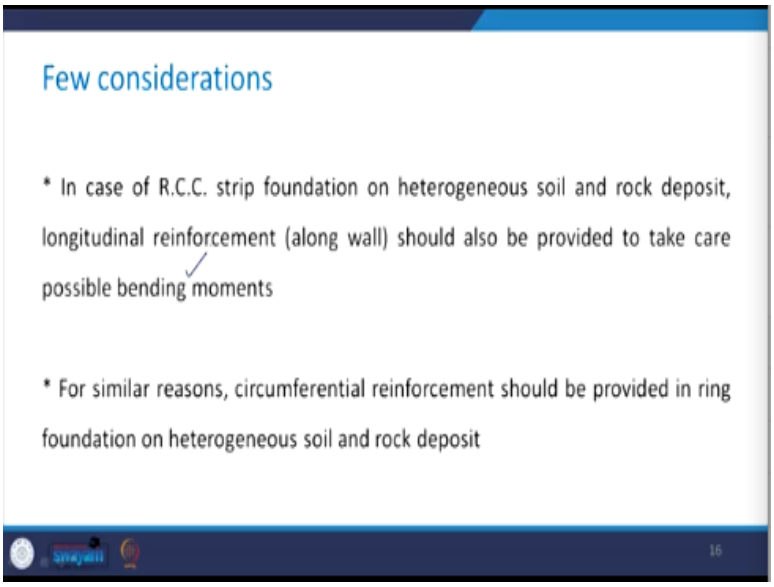

In case of the RCC strip foundation on heterogeneous soil and the rock deposit, the longitudinal reinforcement that means along the wall, it should also be provided in order to take care of any possible bending moments. Now, for the similar reasons circumferential reinforcements should be provided in ring foundation on heterogeneous soil and rock deposit. So, when I say heterogeneous soil and rock deposit, what does that mean is that below the base of the foundation, some part, you have the occurrence of the soil and some part of the foundation is lying on the rock deposit.

So, in such cases because the strength and the deformability characteristic of soil and the rock deposit are altogether different, we need to be extra careful. If we are not getting the adequate bearing capacity of the foundation, when we are putting it on a particular type of rock or rock masses, then in such case, one can go for some kind of a treatment of foundation. Let us see what all those treatment can be.

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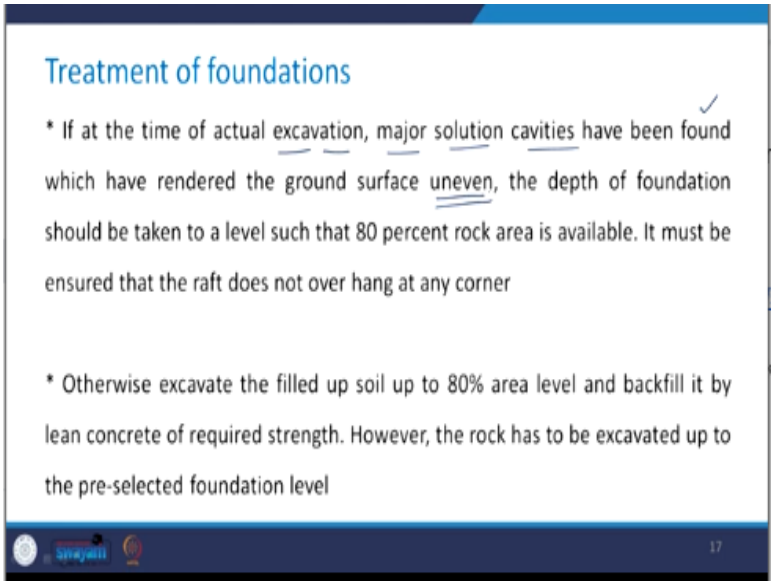

So, if at a time of the actual excavation, the major solution cavities have been found, which have rendered the ground surface as uneven, then the depth of the foundation should be taken to such a level where the 80% rock area is available. This means that at the base of the rock 80% should be in contact with the rock. Further, it must be ensured that the raft does not overhang at any corner. That means throughout the support is available at all the corners of the raft.

And in case if you are not able to ensure this particular situation, then what you need to do is excavate the filled up soil up to the 80% area level and then backfill it by the lean concrete of the required strength. However, in this case, the rock has to be excavated up to the pre-selected foundation level. That means wherever you are planning to place the base of the foundation that should be planed; there should not be any differential settlement because of this rock and the soil deposits.

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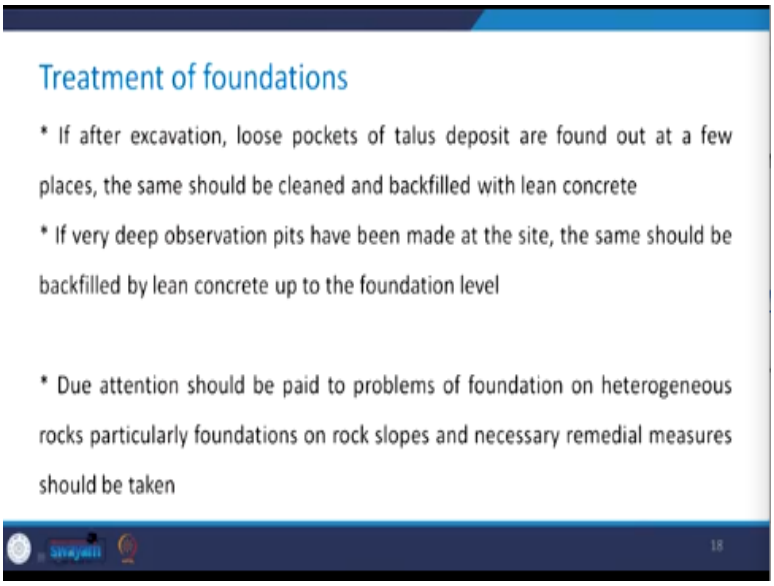

Now, if after the excavation, say loose pockets of talus deposit, if they are found out at a few places, these should be cleaned and backfilled with the lean concrete. In case, if very deep observation pits have been made at the site, these also should be backfilled by lean concrete up to the foundation level. You need to give a lot of attention towards the problem of foundation on heterogeneous rocks, particularly if the foundations are lying on the rock slopes and one should go for the necessary remedial measure.

Now, what are these necessary remedial measure that we discussed when we were discussing about the stabilization of the rock slope. These include the shear key, then the placement of the rock anchors, then buttresses. So, all those aspects that we discussed there. They will also be applicable in case of the treatment of the foundations, if they are to be laid on the sloping kind of brown. So, this is what that I wanted to discuss with you as far as the determination of the bearing capacity of the shallow foundation is concerned using the plate load test.

Then some of the consideration that one needs to keep in mind while going for the construction of these foundations. In case of some different and a special kind of issues like loose pockets of talus deposit or the cavities which are present at the site, some treatment of the foundation should be done and specially if the foundations are resting on the sloping ground there, whatever are the measures that we adopted for stabilizing the slopes that also can be used in the treatment for the foundation.

So, in the next class, we will discuss some aspects related to dam foundations. Thank you so much.