Soil Structure Interaction
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Lecture - 10
Soil – Structure Interaction for Shallow Foundation:
Concept of Subgrade Modulus (Continued)

So in the last class, I have discussed about the plate load test to determine the sub-grade modulus reaction, then we discussed that how to determine it by using different plate size. Now, today I will discuss that what are the factors affecting or what are the factors affect these sub-grade modulus and then the first one I have discussed that how to determine that k value. Then once you get the k value, then you have to apply some corrections, so depending upon the different cases.

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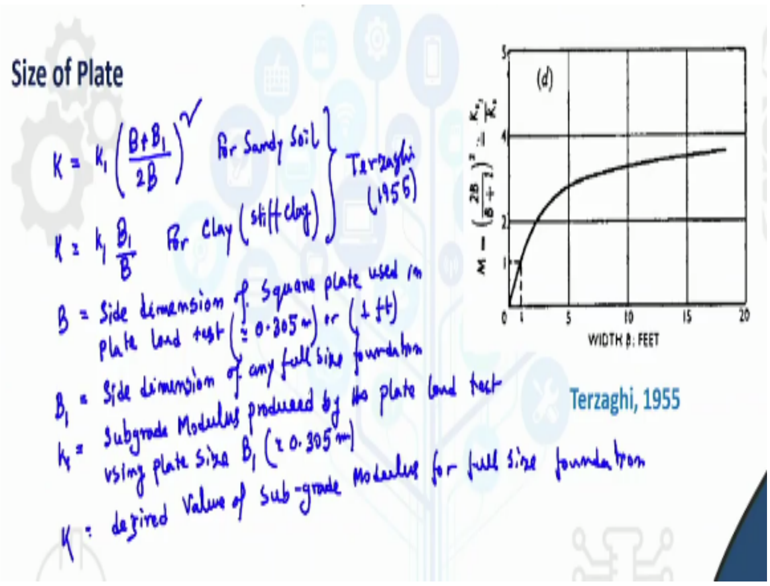

Now first one is the size of plate. So, what is the size of plate affect the modulus of sub-grade reaction. So, that if our modulus of sub-grade reaction at any point at any condition is k, then you can correlate it = $k_1 \times (\frac{B + B_1}{2B})^2$ Now this expression is for sandy soil okay. Now for the clay soil, the similar kind of expression will have that k is $=k_1 \times \frac{B_1}{B}$. So this is for clay or specifically stiff clay okay. So these expressions are proposed by Terzaghi in 1955 okay.

Now, what is k or what is k_1 and similarly the B is the side dimension of a square plate used in plate load test. So, Terzaghi recommended that this value B value is 0.305 meter or it is 1 feet. So, that means here B value is the plate used in the plate load test and that dimension is 0.305 meter or it is a square plate. Similarly B_1 is the side dimension of any full size foundation okay and k_1 is the sub-grade modulus produced by the plate load test using plate sides B_1 and that is your 0.305 meter and k is the desired value of sub-grade modulus for full size foundation okay.

So, that means, these expressions we can use for a plate load test of plate size 0.305 m and k_1 is the sub-grade modulus determined from the plate load taste with a square plate size of 0.305 m. Remember that that here your space size is 0.305 m, So, k we are getting by using a plate of size 0.305 m and it is a square plate. So, now if you can determine for any plate size or any real foundation what would be the k value.

So, first we determine the sub-grade modulus by using this plate size 0.305 m square plate okay, note and then we can use this correlation and you can get sub-grade modulus at any dimension of foundation or plate, so k_1 will be your obtained sub-grade modulus and then k is the sub-grade modulus at any condition, any dimension of plate or foundation. Similarly this chart is giving the same thing that width is the B is in feet and this is the ratio. So, this expression and this chart are same okay. So, this is the expression.

So, for sandy soil, this is the expression and clay soil, the k = $k_1 \times \frac{B_1}{B}$ and this specifically is valid for the stiff clay okay. So, next one that I will discuss about the shape of plate. So, previous one was the size of plate, now next one is the shape of plate okay.

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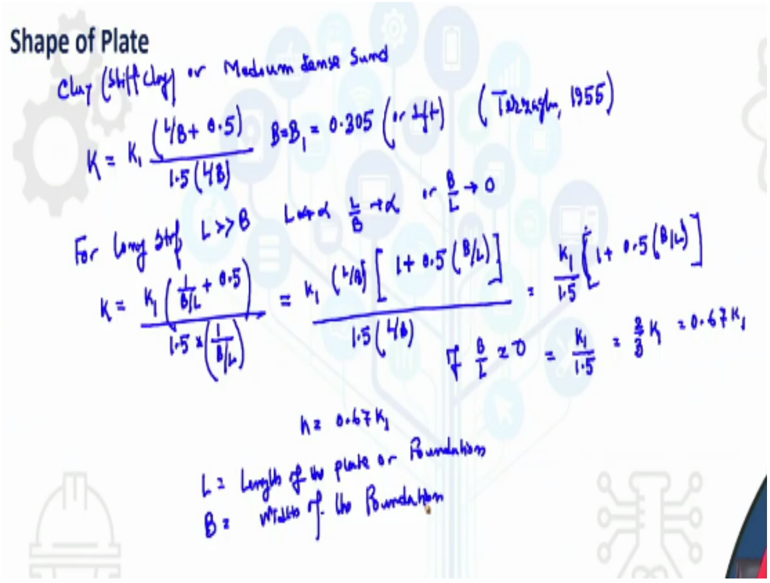

The shape of plate similarly for the clay soil specifically stiff clay or medium dense sand, the expression is k is = $\frac{k_1 \times \frac{L}{B} \times [1 + 0.5\frac{B}{L}]}{1.5(\frac{L}{B})}$. So here that means, we are using a rectangular or square plate, then we can determine it for any plate dimension and then we can convert it for other dimension also. So, that means here this L by B is the ratio of length versus B. So, now we can change this L by B ratio by changing B keeping L constant or changing L keeping B constant, but here this expression is valid by changing L keeping B constant okay.

So here, your B_1 is equal to or B is equal to constant and that is equal to B_1 and that value is again 0.305 or 1 feet okay. This expression is also given by Terzaghi in 1955 okay. So, again the k_1 is the same obtained sub-grade modulus from the plate load test of a square plate of dimension 0.305 okay. So k_1 is same as we explained in the previous case. Now, by using that k_1 value, we can determine the k for any plate size, it can be a rectangle also or any foundation with rectangle shape okay.

So, that is the effect of the shape of plate. Now, for long steep okay, when your L is very large than the B okay or you can say your L tends to infinity or close to infinity okay, then your = $\frac{L}{B}$ value will be also infinity okay or you can say my $\frac{B}{L}$ value which is close to 0 okay. So now, if your $\frac{L}{B}$ value is close to 0, then we can write that k is equal to your, this is k_1. Now, if I convert this thing by writing that, this is $\frac{k_1 \times \frac{L}{B} \times [1 + 0.5\frac{B}{L}]}{1.5(\frac{L}{B})}$.

So, now if I take $\frac{B}{L}$, $\frac{B}{L}$ or I can form this expression also, I can take your $\frac{L}{B}$ out. So, then this will be, first let me take $\frac{L}{B}$ out, so this will be $\frac{(1 + 0.5) \times B}{L}$ okay and this will be your . So $\frac{L}{B}$, will be canceled out. So this is k_1 by 1.5 x $\frac{L}{B}$ and this is $\frac{(1 + 0.5B)}{L}$. Now if your B by L is 0 or close to 0, now if my $\frac{B}{L}$ is close to 0, then this expansion will be k_1 divided by 1.5 or we can write this will be 2/3 of k_1, which is 0.67 x k_1 okay.

So now for the long steep, your k value is point, so that means k value is 0.67 x k_1 okay. So, here your L is equal to length of the plate or foundation and B is equal to width of the foundation okay. So, this way we can incorporate the shape effect of a plate.

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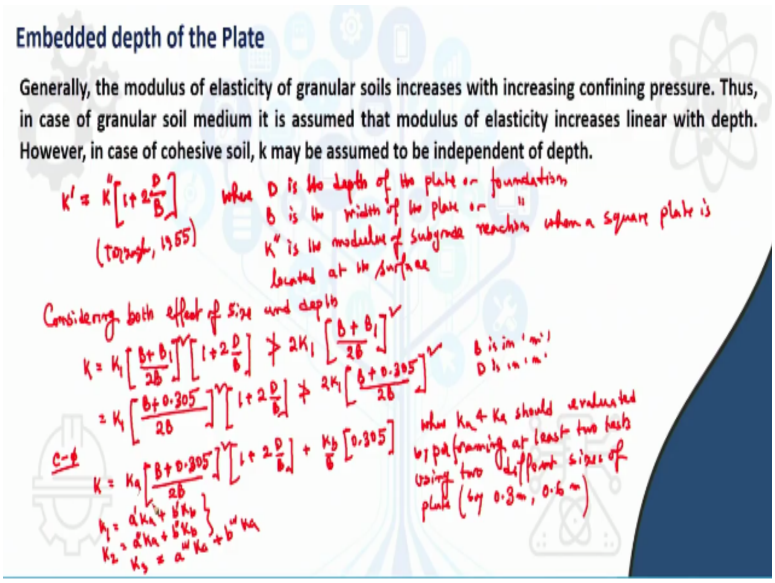

The next one is the embedded depth of plate. Now, generally the modulus of elasticity of granular soil increases with increasing confining pressure. Thus in case of granular soil medium, it is assumed that the modulus of elasticity increases linearly with depth, but in case of cohesive soil, k maybe assumed to be independent of depth. That means this depth effects for the clay soil, the modulus of sub-grade reaction is generally independent to the depth of the soil, but for the granular soil, it is not independent to the depth, it is dependent on the depth.

So, for the granular soil, we have to apply the corrections. So, that correction we can write in this form that if your $k^{/}$ is written $k^{/}= k^{//}[1 + 2 \times \frac{D}{B}]$ okay, so where D is depth of the plate or foundation okay and B is the width of the plate or foundation and k is the modulus or you can write this is key double dash, so $k^{//}$ double dash is the modulus of sub-grade reaction, reaction when a square plate is located at the surface okay.

So that means here, if your plate depth is or the depth of the plate is 0, that means the plate is located at the surface, and when you obtain the k value from that plate load test that is written as here k double dash, so then we can determine the k value at any depth by using this expression okay. So, D is the depth of the plate and k double dash is the modulus of sub-grade reaction obtained by conducting a plate load test of square plate placing it on the surface okay.

So now considering both depth effect and the size effect, considering both effect of size and depth, we can write that our k $=k_1[\frac{B + B_1}{2B}]^2[1 + 2 \times \frac{D}{B}]$, okay, but remember that this value should not be greater than $2k_1[\frac{B + B_1}{2B}]^2$. Now, when I discuss about the size of it, then I mention that B1 value is 0.305 meter. k $=k_1[\frac{B + 0.305}{2B}]^2[1 + 2 \times \frac{D}{B}]$.

So, remember that here this expression as $B_1$is mentioned as 0.305, so you have to use B as in meter, D and B both will be in meter okay as your B_1 is given as in meter. So, remember that you B is in meter and D is in meter okay. So, this is considering both the effect. Now as I mentioned, so this is also proposed by Terzaghi in 1955 okay and this expression it is valid for the granular soil because as we mentioned the depth effect is significant in the granular soil, in cohesive soil k is assumed to be independent of depth okay, but for c-phi soil, then what will be the effect, but c-phi it has some effect.

So c-phi soil we can write our k is equal to ka the combined one =

$$. k_a[\frac{B+0.305}{2B}]^2[1+2\times\frac{D}{B}]+\frac{K_b}{B}\times 0.305$$

So in the previous expressions also, remember that B is in meter if B1 is in meter okay. So here, we combine the effect of granular soil and the cohesive soil. So, that means your c-phi soil, this is the k here for the granular part and the cohesive part combining both shape effect because here, the depth effect is not incorporated in the cohesive part because the cohesive soil k value is independent to depth, but in the granular part, the deep effect is incorporated, so this is the expression.

So but how we can calculate ka and kb where k_a and k_b should be evaluated by performing at least two test using two different sizes of plate, say you can use 0.3 meter plate or 0.5 meter plate, 5.6 meter plate okay. So that means in this equation, we have basically two unknowns okay, that is k_a and k_b, because others are you should know the B value, may be know on which dimension you want to determine the k or you should know the D value because at what depth you have placed your foundation, but k_a and k_b are unknown.

So, this kb and ka are determined by using two plates of different sizes, that means for the c-phi soil, you conduct a plate load test of using 0.3 mm plate size, then you will get one k value that you put here, for different plate you can use these expression. Then also you conduct another plate load test. So, there also you will get a k value that you put here, then you have two unknowns, two equation, you solve them. So, you will get the ka and kb value okay. So, that kb and ka value you put here, you will get the expression.

So, that means you have to conduct at least two plate load test to determine ka and kb. By plate load test you will get one k value, that k you put in corresponding depth and b value you put in these expressions, so you will get one expression of say k_1, so you will get for the first plate load test k_1. So, if I say this is the one constant into (k + b x k_b), then you conduct another plate load test, then you get this is $a^{//}$ k_a + $b^{//}k_b$.

So, this a dash, b dash, a double dash, b double dash these are known value because these dimension or the depth and B you should know. So, you have two equations, so you solve them, your k_1 and k_2 is also known. So, you form here, you will get k_1 and k_b, that k_1 kb you put it here, you will get a complete equation okay. If you conduct more tests, then you will get more value of, that means value of k_1. Suppose you conduct another plate load test, then you will get another expression, k_3 is equal to $a^{///}k_a + b^{///} + k_b$.

Then you have three equations, but two unknowns okay. Then you take pair of any two, that means either you take one and two, then you solve, then you will get k_a and k_b. Then you take two and three, you solve, you will get k_a and k_b. Then you take one and three, you will get k_a and k_b. Then you can take the average value of these k_a and k_b and that you put in this equation, then you will get the complete equation of clay. So, I have discussed this effect for granular soil and c- phi soil and for the c soil, cohesive soil, it does not have any effect, depth does not have any effect okay.

So, in the next class, I will discuss another way of determination of modulus of Sub-grade reaction, that is as per IS code, and then also I will discuss some corrections those are required as per the IS code. Thank you.