Advanced Foundation Engineering
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Lecture - 56
Pile Foundation: Under Lateral Load and Uplift - VI

So, last class I have discussed that how we can determine the ultimate lateral load capacity for free-handed or fixed-headed pile if it is in cohesive soil or cohesionless soil. Now, this class I will discuss about the settlement response of laterally loaded pile because settlement response for laterally loaded pile is also very important.

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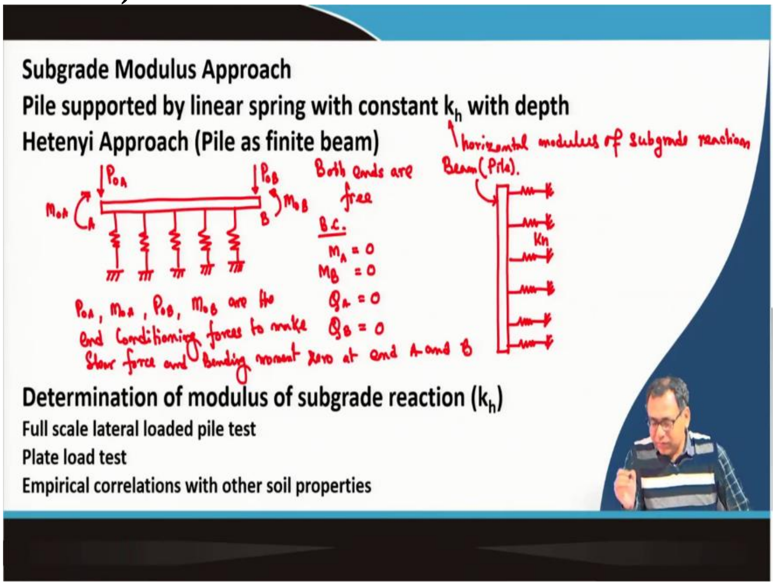

So, for this settlement response of laterally loaded piles, the first approach that I will discuss is the subgrade modulus approach, because this approach I have already discussed during the topics on concept of beams on elastic foundation. So, I have already discussed this concept for shallow foundation when a beam is placed over springs. So, in that case that springs were vertical springs.

The beams are resting on those vertical springs, that concept will be used here for laterally loaded piles where the springs will be the horizontal springs. So, first we will assume that this approach will be applicable for the pile supported by linear spring with constant k_h with depth. Now, what is k_h? k_h is the modulus of subgrade reaction or we can say, horizontal modulus of subgrade reaction.

So, this k_h is basically the horizontal modulus of subgrade reaction or simply I can say it is a horizontal subgrade modulus. So, in this approach here the piles will be connected with horizontal springs and the pile will be treated or will be modeled as beam. So, these are the springs, those are connected with the pile and pile will be modelled as beam. So, this is the spring which modulus of subgrade reaction is k_h and this is the beam which is basically the pile, so, this is the concept of this approach.

So, in this approach the first case we will assume that pile as a finite beam, because as I have already discussed, there can be the short pile there can be a long pile. So, definitely for the short pile you have to go for the finite beam, but for the long pile you can go for the semi-infinite beam and later on I will give you that when you will go for the semi-infinite beam when a beam is called the long beam or the short beam because that I have already given during my presentation of shallow foundation.

But that also I will give later on that how the pile will be treated as long pile or the short pile based on that we have to consider as a finite beam or semi-infinite beam. So, here the first concept of pile as a finite beam and when I discuss about the finite beam solution process here then I discuss that suppose if this is your beam which has finite length for in case of shallow foundation, this is the beam which is resting on the vertical springs.

So, the same thing if I rotate this total beam with spring system then that will represent as these beams or the piles are with connected with the horizontal springs. So now if we model this one and I have already discussed that for different end conditions we have to consider some end conditioning forces the P_0 M_0 or P_{0A} M_{0A} so that the boundary conditions can be satisfied.

So, first condition in this finite beam problem, we are assuming that both ends are free. So, both ends are free. So, when you apply any load in this particular beam, then this is both end finite beam, but we will treat this beam as an infinite beam and then we will determine the bending moment and the shear force at end A and the B due to the external load and then to nullify that bending moment and shear force to make the net bending moment and shear force at point A and B 0.

We have to apply the conditioning forces and we have to make bending moment and shear force 0 because both ends are free. So, the boundary conditions are that moment at A will be 0, moment at B will be 0, shear force at A will be 0 and shear force at B will be 0. So, these are the four boundary conditions for this finite beam with both ends free.

So, I have already been discussed these things in the beams on elastic foundation concept during the shallow foundation part that first we have to consider this beam as an infinite beam then for infinite beam we will calculate the bending moment and the shear force at both ends that means A and B due to the external load and then these boundary conditions have to be satisfied for the finite beam.

Then you have to apply some end conditioning force like M_{0A} P_{0A} or M_{0B} P_{0B} so that the net bending moment and the shear force will be 0 at point A and B or end A and end B. So, that is why these end conditioning forces P_{0A} and M_{0A} we have to apply to make net bending moment and shear force 0 that is the concept. So, that means this P_{0A} M_{0A} P_{0B} M_{0B} are the end conditioning forces to make shear force and bending moment 0 at end A and B. So, this is the concept.

So, now, for the laterally loaded piles what are the forces that will act. So, it is a free-headed pile. So, first condition will be the free-headed pile then I will discuss the fixed -headed pile. So, how we can determine these k_h because I have already discussed how to determine the k_h or the subgrade modulus. So, k_h unit is kN/m^2.

So, this determination of subgrade modulus reaction or subgrade modulus or the modulus of subgrade reaction or subgrade modulus k_h can be full scale lateral loaded pile test we can do the lateral loaded pile test and we can determine the k_h we can do the plate load test or we can use the empirical correlations with other soil properties.

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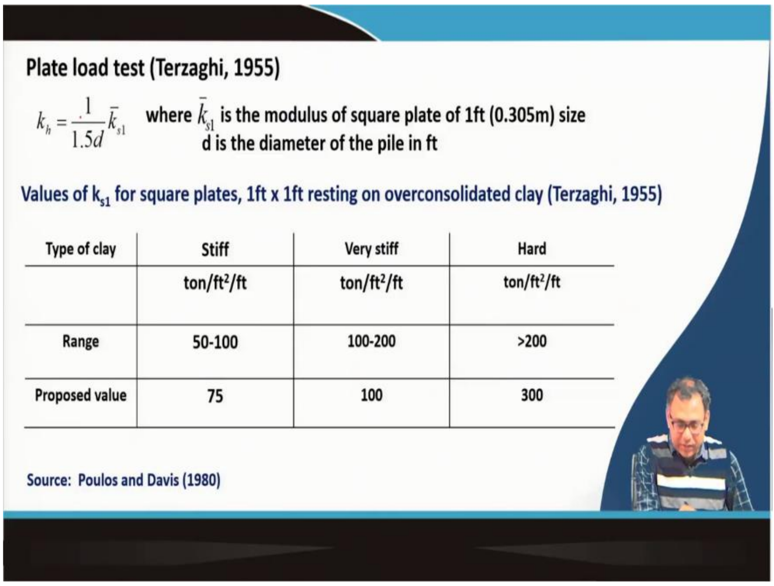

So, based on the plate load test Terzaghi in 1995 proposed the relationship between the k_h and the $\bar{k}_{s1}$, where, $\bar{k}_{s1}$ is the modulus for a square plate of 0.305 m × 305 m square size and d is the diameter of the pile. So, that means this $\bar{k}_{s1}$ is the modulus of subgrade reaction determined by using a square plate of 0.305 m size and that is used here to determine the k_h for the pile.

Here, we will get k_{s1} from the plate load test and that k_{s1} values are given for different types of clayey soil. So, for stiff clay, very stiff clay, hard clay it is given in ton/ft^3. So, this range is given and this is the proposed value that means for stiff clay, this proposed value of k_{s1} is 75 kiloton/ft^2/ft. So, that 75,000 ton/ft^2/ft we will use here and then we will divide it with 1.5 times d, where, d is the diameter of the pile in feet.

So, and then finally, we will get the k_h, which will be your horizontal subgrade modulus. So, this is the one relationship which is given here. So, this is based on plate load test you will get the value.

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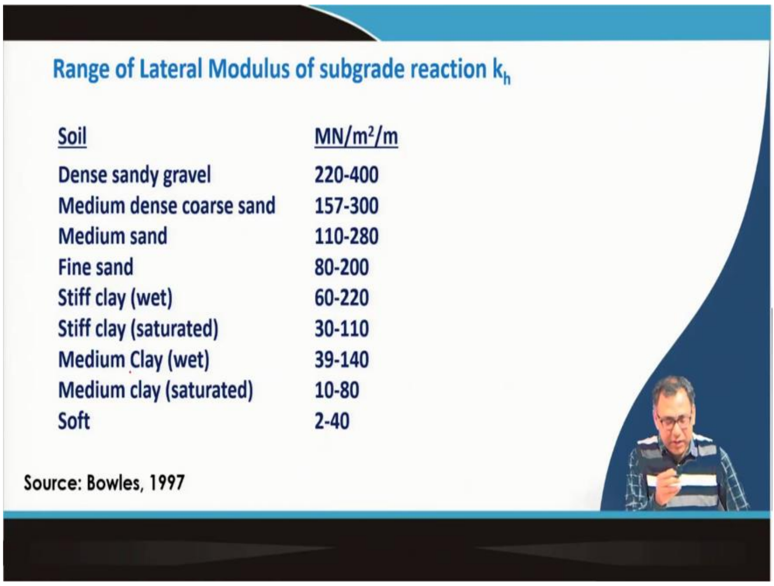

Next one that Bowles has given some lateral modulus of subgrade reaction ranges for different types of soil. So, these k_h values are given. So, for different types of soil these are the ranges. So, for dense sand to soft clay, medium clay, medium clay wet, saturated stiff clay, stiff clay wet, saturated fine sand, medium sand medium dense sand dense sandy gravel.

So, all the ranges are given and one thing here that these are empirical equations, so, that is why these unit is again kN/m^2/m, but k_{s1} has also the same unit because these are the empirical relationships. So, we can use these relationships and then the proper unit we have to use as suggested because remember that here *d* is in feet.

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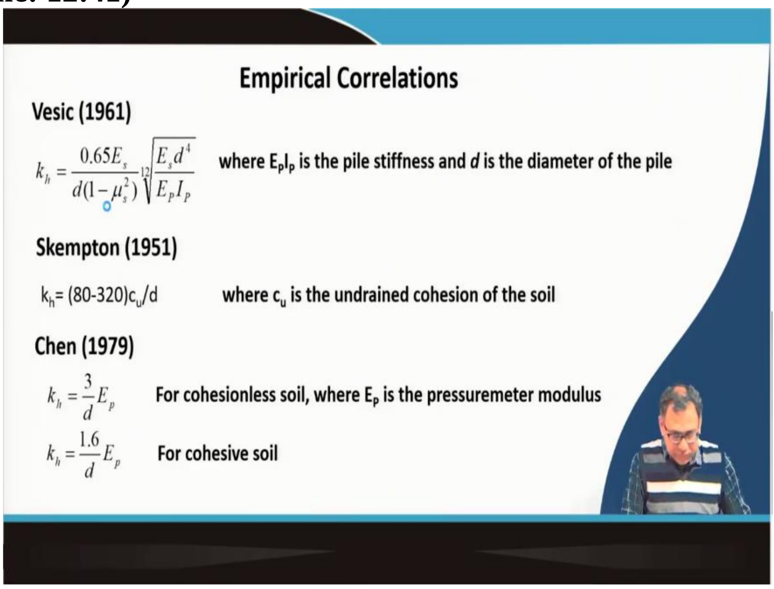

So, and then we will go for a few more empirical correlations. So, Vesic has given one empirical correlation were $E_P I_P$ is the pile stiffness that means E_P is the elastic modulus of the pile material I_P is the moment of inertia of the pile cross section and *d* is the diameter of the pile and E_s is the elastic modulus of the soil, μ_s is the Poisson's ratio of the soil, d is the diameter of the pile as I mentioned.

So, by using correlations also you can determine what would be the k_h value. Skempton has given a correlation based on your undrained cohesion, c_u value for the clay and that correlation can be used for the clay and these are ranges are given. Chen has given some correlation with respect to the pressure meter modulus, because I have already discussed what is pressure meter modulus and then what is pressure meter test in my soil exploration part.

So, you can see what is the pressure meter modulus. So, that way pressure meter modulus can be used to determine the k_h of the soil that means, we can do the pressure meter test and based on that pressure meter modulus value we can determine the k_h by using this correlation one is for cohesionless soil and another one is for cohesive soil.

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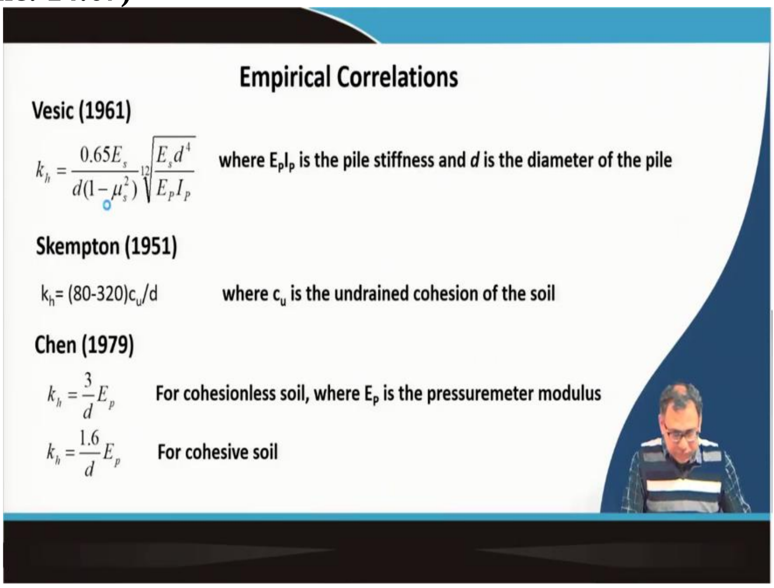

So, again the k_h can be determined by dilatometer modulus also. So, the E_D is the dilatometer modulus and the F_P is the pile shape factor. So, F_P is the pile shape factor which is in between 1.5 to 4 for round pile and 1 for H pile or the square pile and d is the diameter of the pile. So, if we know the dilatometer modulus and then if I apply the shape factor and then divided by 3.7 × diameter of the pile, then you will get the k_h value.

Now, in my previous classes I also discussed that for granular soil, we assumed that the k_h value changes with depth, but for the cohesive soil the distribution of the k_h is uniform along the depth. So, as I mentioned that for the stiffer clay uniform k_h is observed, but for the sandy soil or the granular and very soft clay, the k_h is not uniform along the depth k_h generally increases linearly with depth.

So, in such case k_h can be represented as $\eta_h \times \frac{z}{d}$. z is at any depth from the ground surface d is the diameter of the pile and η_h is called coefficient of subgrade modulus or unit subgrade modulus. So, for normally consolidated clay η_h the range of values is given and for sandy soil also η_h ranges are given. So, that ranges for η_h values for sandy soil and the normally consolidated clay are given.

And it is clay means very soft clay because in soft clay only this variation will be noticed otherwise, for the cohesive soil the k_h is more or less uniform along the depth of the pile or along the depth of the soil. For the dry or moist sand and the submerged sand all ranges are given for loose medium and dense soil. So, we can take that η_h from here, then we will put these η_h value here and d is the diameter of the pile. So, for any depth if I change the z value for any depth, I can calculate the k_h for the pile.

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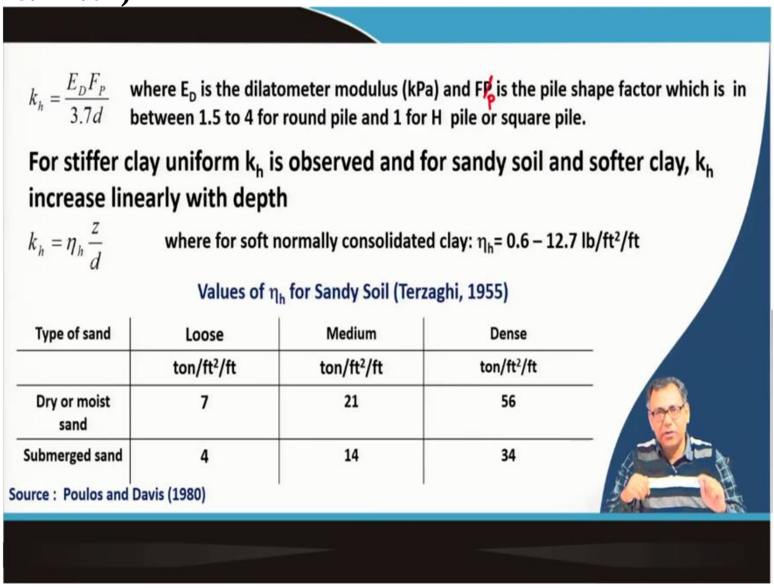

Now, I will go back to that finite beam concept. So, you are talking about that finite beam concept we have to apply the end conditioning forces. So, now first case is for the free-headed pile. So, first case free-headed pile which is modeled as finite beam. So, it is a finite beam. So, there will be a horizontal load H acting on the pile.

So, that means because of that H now, if I rotate this total orientation of the system then this is the finite beam and these are the springs and the spring constant or modulus of horizontal subgrade reaction is k_h. So, suppose H is acting here. So, H is acting here the same thing I am drawing here. So, H is acting here, but now due to the H, we have to determine what is the shear force and the bending moment at both ends, then you have to apply end conditioning forces.

So, that net shear force and bending moment will be 0 for free-headed pile. So, this is for the free end. So, both ends are free. So, we will apply the end conditioning forces. So, this is P_0 say this is A this is B, P_{0A}. Then next one is the M_{0A}. Then here P_{0B}. This is M_{0B}. So, these are the loads which are acting on this finite beam. So, these are the end conditioning forces and H is the actual applied load.

So, after solving this condition, so, I am not giving you the detailed description, I am writing the final expressions of the settlement, shear force, bending moment and slope. So, after solving these conditions, so, we will get the deflection y. So, this is the deflection at any point within that beam will be $\frac{2H\lambda}{k_h d} \times K_{\rho H}$. So, where λ will be equal to this is $\sqrt[4]{\frac{k_h d}{E_P I_P}}$, because in my beam case that was $\sqrt[4]{\frac{k}{EI}}$.

So, that case E will be the kN/m and k will be the kN/m^2. So, but here I am writing k_h which is in kN/m^3, so, we have to multiply with the d, but in the case of shallow foundation that was multiplied with the width of the beam, so, here the diameter of the pile is multiplied. So, k_h and then for $E_P I_P$ when E_P is the elastic modulus of the pile.

The I_P is the moment of inertia of the pile section and $K_{\rho H}$ is a value which I will give in tabular form that for different depth of the pile or depth of the beam how the k_h value will change. So, similarly, the deflection and slope. This is for the slope, $\theta = -\frac{2H\lambda^2}{k_h d} K_{\theta H}$. So, then the bending moment, $M = -\frac{H}{\lambda} K_{MH}$.

Similarly, shear force, $Q = -HK_{QH}$. Now, the similar expression I can develop for another case if a bending moment is applied. So, this is the pile with spring. So, now, if this bending moment is applied, then the equation of the pile will be that mean this bending moment is applied.

So, for the M_0 bending moment, the similar type of expression y will be equal to this is for the horizontal force this is for the force H and these expressions for the moment M_0. So, deflection equation will be $\frac{2M_0\lambda^2}{k_h d} \times K_{\rho M}$ when $\theta = \frac{4M_0\lambda^2}{k_h d} \times K_{\theta M}$ because initially it was for the H that is why H is written now it is for M_0.

Now for the bending moment this is $M_0 k_{MM}$ and for the shear force it is $-2M_0\lambda K_{QM}$. So, these equations are given. So, that means for M_0 also similar kind we have to apply for in the end conditioning forces such that the net shear force and bending moment will be 0. So, based on that we have developed 4 equations for the moment M_0 and for the force H.

So, now for the free-headed pile, so, suppose the pile is subjected to H only then I will get the deflection of the pile at any point if I use the expression of deflection, y, but this is for the free-headed pile.

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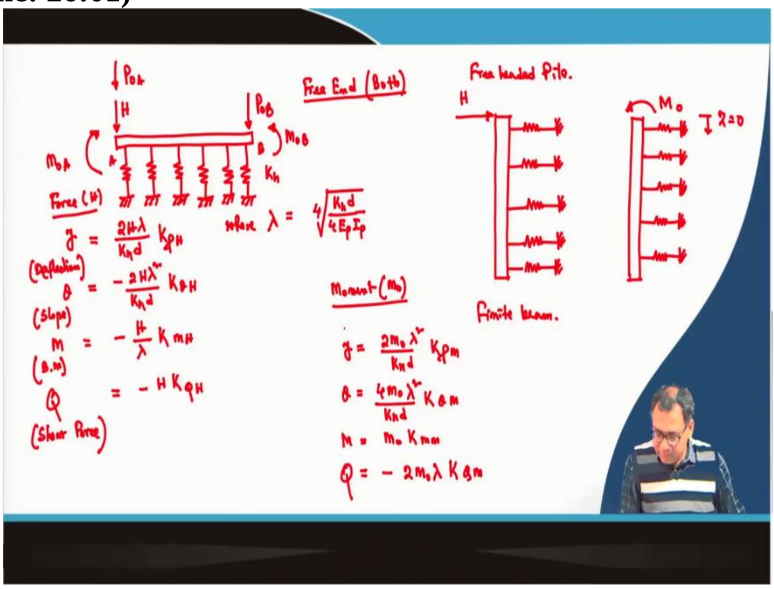

Now, for the fixed-headed pile how this equation will change now for fixed-headed pile because when we derive these equations, we assume that both the ends are free. So, these equations I can use only for the free-headed pile not for the fixed-headed pile, because our assumptions are both the ends are free, but the fixed-headed pile, so, your top or the head of the pile is fixed, but the bottom is free.

So, that means the top head or the top of the pile or one end of the beam is fixed and another end is free and for free-headed pile both the ends are free so, what is the condition by which these equations are developed. So, for free-headed pile directly we can use these equations, but for the fixed-headed pile we cannot. So, for fixed-headed pile what to do so, fixed-headed pile, the solutions of the free-headed pile equations or the equations for the free-headed piles can be used, if we apply our fixity for the free fixed end.

So, for example, suppose if we apply a horizontal force on a fixed-headed pile. So, because of the fixity of the head, so, our movement will generate on that head of the pile. So, and for the fixed-headed pile, what is the in pile one end slips what would be the slope. So, slope will be 0. So, that means, this free-headed pile equation, one to use for the fixed-headed pile and how we will use that.

So, that means, we will use in such a way that first we assume that the pile is free-headed. So, if I apply H for the free-headed pile, we will get a slope of this value for the free-headed pile. Now, actually, the slope at the fixed end will be 0 for fixed-headed pile. So, that means this slope that will develop due to the free-headed pile that you have to make 0 and how that slope will be 0 because when we apply H on a fixed-headed pile, so a moment will generate.

So, that moment is M_0 say so, that moment will be generated. So that overall slope will be 0. So, that means what will be the thing that means we apply H for a free-headed pile we will get a slope now due to the fixity for a fixed-headed pile a moment in M_0 will be generated and that will act in the opposite side of the H and because of M_0 in your free-headed pile, if there will be a slope which will be generated.

So, that means initially we assume both the heads are free at both the piles under H and moment condition free-headed piles. So, for H for free-headed pile there will be one slope and for the moment applied in the free-headed pile, there will be a slope θ. Now this for the fixed because of these, fixed head, now these both the slopes will be equal then only the net slope will be 0. So, first we have to calculate what will be the moment that will be induced due to the fixity of the point.

So, for example, here we assume that there will be only horizontal forces acting in a free-headed. So, you will get the equations or the solutions for fixed-headed also there will be horizontal force is acting. So, due to that horizontal force there will be a slope and because of the fixity there will be a moment. So, because of that moment there will be another slope.

So, we will equate that, because the next slope will be 0 and we will try to find what will be the value of M_0 and what will be the fixed end moment that will be generated due to the fixity. So, that net slope will be 0 at the head.

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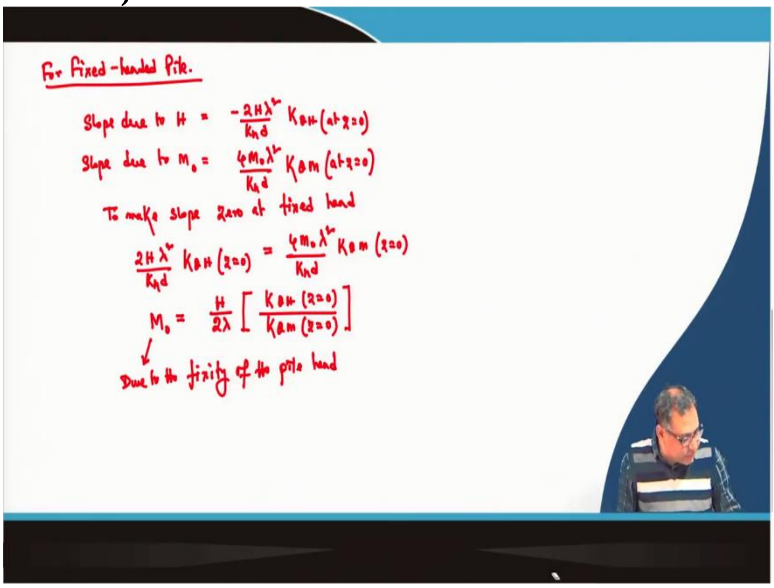

So, under this kind of concept, we will use that slope for due to H is equal to how much $-\frac{2H\lambda^2}{k_h d} K_{\theta H}$ at $z = 0$ because your fixed head is here where $z = 0$. So, now, this is slope due to H now, slope due to M_0 is equal to $\frac{4M_0\lambda^2}{k_h d} \times K_{\theta M}$ at $z = 0$. So, you will equate them and will not consider the sign because these equations are given under these loading and moment direction.

That means, load is acting in this direction and moment is acting in the anti-clockwise direction. So, under these conditions these equations are given. So, if your direction of the load will change this equation sign will also change. So, you have to use these equations under these loading directions loading on the moment are the forces direction. So, that means here moment and H is acting opposite direction which is the actually the to make the net slope 0.

So, we will take only the magnitude of the slopes. So, to make this slope 0 at fixed end we opt to equate this to slope that means $\frac{2H\lambda^2}{k_h d} K_{\theta H}$ at $z = 0$ that will be equal to $\frac{4M_0\lambda^2}{k_h d} K_{\theta M}$ at $z = 0$. So, finally, what is the moment we have to apply should be applied to make this slope 0.

So, that moment is $\frac{H}{2\lambda}\left[\frac{K_{\theta H(z=0)}}{K_{\theta M(z=0)}}\right]$ that means this $K_{\theta H}$ and $K_{\theta M}$ at $z = 0$ you have to determine. So, now, this value we have to put in place of M_0. So, that means this moment will be developed due to the fixity of the pile head. So, these are the equations, so, that we have developed for the pile.

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λL	z/L	$K_{\rho H}$	$K_{\theta H}$	K_{MH}	K_{QH}	$K_{\rho M}$	$K_{\theta M}$	K_{MM}	K_{QM}
2	0.0000	1.1376	1.1341	0.0000	1.0000	-1.0762	1.0762	1.0000	0.0000
2	0.0625	0.9964	1.1200	0.1080	0.7333	-0.8807	0.9519	0.9836	0.1256
2	0.1250	0.8586	1.0828	0.1848	0.5015	-0.6579	0.8314	0.9397	0.2214
2	0.1875	0.7264	1.0298	0.2347	0.3035	-0.4644	0.7178	0.8751	0.2913
2	0.2500	0.6015	0.9673	0.2620	0.1371	-0.2982	0.6133	0.1959	0.3387
2	0.3125	0.4848	0.9004	0.2704	0.0021	-0.1569	0.5192	0.7073	0.3669
2	0.3750	0.3764	0.8333	0.2637	-0.1054	-0.0376	0.4366	0.6173	0.3788
2	0.4375	0.2763	0.7695	0.2452	-0.1868	0.0624	0.3658	0.5119	0.3771
2	0.5000	0.1838	0.7115	0.2180	-0.2442	0.1463	0.3068	0.4262	0.3639
2	0.5625	0.0981	0.6610	0.1851	-0.2793	0.2168	0.2591	0.3379	0.3411
2	0.6250	0.0182	0.6192	0.1491	-0.2937	0.2767	0.2220	0.2564	0.3101
2	0.6875	-0.0571	0.5865	0.1125	-0.2887	0.3286	0.1946	0.1834	0.2722
2	0.7500	-0.1288	0.5628	0.0776	-0.2654	0.3747	0.1757	0.1208	0.2282
2	0.8125	-0.1981	0.5474	0.0468	-0.2245	0.4171	0.1640	0.0698	0.1787
2	0.8750	-0.2659	0.5389	0.0222	-0.1665	0.4572	0.1578	0.0318	0.1241
2	0.9375	-0.3330	0.5356	0.0059	-0.0916	0.4963	0.1554	0.0082	0.0645
2	1.0000	-0.3999	0.5351	0.0000	-0.0000	0.5351	0.1551	0.0000	0.0000

Source : Poulos and Davis (1980)

And then how we will calculate these coefficients because these $K_{\rho H}$ $K_{\theta H}$ K_{MH} K_{QH} $K_{\rho M}$ $K_{\theta M}$ K_{MM} K_{QM}. So, these are the given values for different λL and z/L. So, you have to calculate the λ and the L and then we multiply it. L is the length of the pile and z is any depth. So, at any point you will get these coefficients and if you put these coefficients in the values then we will get the deflections, moment, slope, bending moment, shear force. Now, this is for $\lambda L = 2$.

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λL	z/L	$K_{\rho H}$	$K_{\theta H}$	K_{MH}	K_{QH}	$K_{\rho M}$	$K_{\theta M}$	K_{MM}	K_{QM}
3	0.0000	1.0066	1.0004	0.0000	1.0000	-1.0004	1.0008	1.0000	0.0000
3	0.0625	0.8210	0.9695	0.1543	0.6575	-0.6589	0.8183	0.9690	0.1545
3	0.1250	0.6459	0.8919	0.2508	0.3829	-0.3854	0.6433	0.8913	0.2514
3	0.1875	0.4832	0.7870	0.3018	0.1709	-0.1743	0.4857	0.7862	0.3029
3	0.2500	0.3515	0.6698	0.3184	0.0141	-0.0184	0.3493	0.6684	0.3202
3	0.3125	0.2371	0.5514	0.03101	-0.0956	0.0905	0.2352	0.5491	0.3127
3	0.3750	0.1444	0.4394	0.2850	-0.1664	0.1607	0.1429	0.4360	0.2887
3	0.4375	0.0716	0.3389	0.2496	-0.2063	0.2002	0.0710	0.3339	0.2544
3	0.5000	0.0164	0.2528	0.2091	-0.2223	0.2162	0.0168	0.2458	0.2150
3	0.5625	-0.0242	0.1823	0.1673	-0.2205	0.2147	-0.0222	0.1728	0.1744
3	0.6250	-0.0529	0.1271	0.1272	-0.2057	0.2011	-0.0489	0.1148	0.1353
3	0.6875	-0.0727	0.0864	0.0908	-0.1819	0.1793	-0.0661	0.0709	0.0995
3	0.7500	-0.0861	0.0584	0.0594	-0.1519	0.1524	-0.0763	0.0396	0.0684
3	0.8125	-0.0953	0.0411	0.0340	-0.1178	0.1227	-0.0816	0.0189	0.0426
3	0.8750	-0.1021	0.0321	0.0154	-0.0807	0.0916	-0.0839	0.0069	0.0225
3	0.9375	-0.1077	0.0287	0.0039	-0.0414	0.0599	-0.0846	0.0014	0.0083
3	1.0000	-0.1130	0.0282	0.0000	-0.0000	0.0282	-0.0847	0.0000	0.0000

Source : Poulos and Davis (1980)

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λL	z/L	$K_{\rho H}$	$K_{\theta H}$	K_{MH}	K_{QH}	$K_{\rho M}$	$K_{\theta M}$	K_{MM}	K_{QM}
4	0.0000	1.0008	1.0015	0.0000	1.0000	-1.0015	1.0021	1.0000	0.0000
4	0.0625	0.7550	0.9488	0.1926	0.5616	-0.5624	0.7567	0.9472	0.1929
4	0.1250	0.5323	0.8247	0.2907	0.2411	-0.2409	0.5344	0.8229	0.2910
4	0.1875	0.3452	0.6693	0.3218	0.0234	-0.0220	0.3478	0.6673	0.3219
4	0.2500	0.1979	0.5101	0.3093	-0.1108	0.1136	0.2010	0.5082	0.3090
4	0.3125	0.0890	0.3641	0.2717	-0.1810	0.1855	0.0926	0.3626	0.2705
4	0.3750	0.0140	0.2403	0.2226	-0.2055	0.2118	0.0178	0.2397	0.2204
4	0.4375	-0.0332	0.1419	0.1715	-0.1996	0.2079	-0.0295	0.1430	0.1671
4	0.5000	-0.0590	0.0682	0.1243	-0.1758	0.1858	-0.0558	0.0720	0.1176
4	0.5625	-0.0692	0.0163	0.0843	-0.1432	0.1545	-0.0674	0.0242	0.0749
4	0.6250	-0.0687	-0.0176	0.0529	-0.1084	0.1200	-0.0696	-0.0043	0.0406
4	0.6875	-0.0615	-0.0379	0.0299	-0.0756	0.0858	-0.0665	-0.0178	0.0149
4	0.7500	-0.0505	-0.0488	0.0147	-0.0475	0.0538	-0.0616	-0.0206	-0.0025
4	0.8125	-0.0376	-0.0536	0.0057	-0.0255	0.0242	-0.0568	-0.0166	-0.0122
4	0.8750	-0.0239	-0.0552	0.0014	-0.0101	-0.0033	-0.0535	-0.0096	-0.0148
4	0.9375	-0.0101	-0.0555	0.0001	-0.0016	-0.0296	-0.0520	-0.0029	-0.0106
4	1.0000	0.0038	-0.0555	0.0000	-0.0000	-0.0555	-0.0517	-0.0000	-0.0000

Source : Poulos and Davis (1980)

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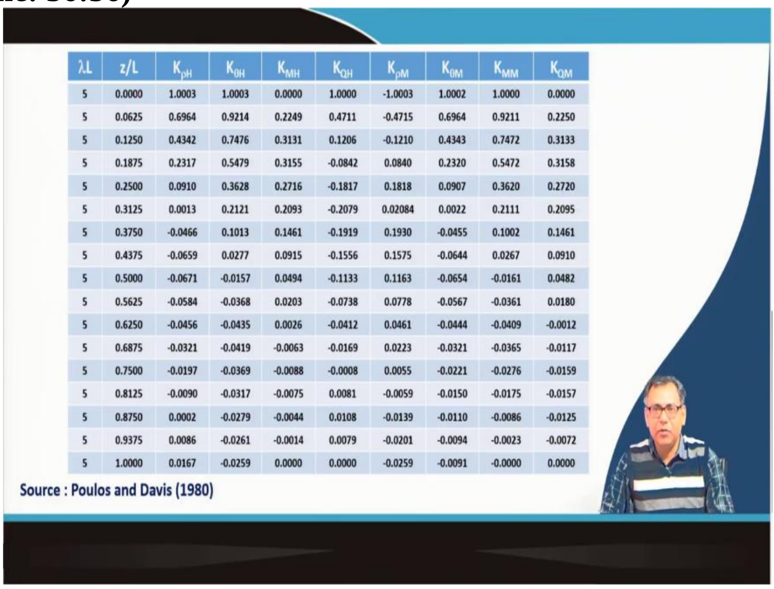

λL	z/L	$K_{\rho H}$	$K_{\theta H}$	K_{MH}	K_{QH}	$K_{\rho M}$	$K_{\theta M}$	K_{MM}	K_{QM}
5	0.0000	1.0003	1.0003	0.0000	1.0000	-1.0003	1.0002	1.0000	0.0000
5	0.0625	0.6964	0.9214	0.2249	0.4711	-0.4715	0.6964	0.9211	0.2250
5	0.1250	0.4342	0.7476	0.3131	0.1206	-0.1210	0.4343	0.7472	0.3133
5	0.1875	0.2317	0.5479	0.3155	-0.0842	0.0840	0.2320	0.5472	0.3158
5	0.2500	0.0910	0.3628	0.2716	-0.1817	0.1818	0.0907	0.3620	0.2720
5	0.3125	0.0013	0.2121	0.2093	-0.2079	0.02084	0.0022	0.2111	0.2095
5	0.3750	-0.0466	0.1013	0.1461	-0.1919	0.1930	-0.0455	0.1002	0.1461
5	0.4375	-0.0659	0.0277	0.0915	-0.1556	0.1575	-0.0644	0.0267	0.0910
5	0.5000	-0.0671	-0.0157	0.0494	-0.1133	0.1163	-0.0654	-0.0161	0.0482
5	0.5625	-0.0584	-0.0368	0.0203	-0.0738	0.0778	-0.0567	-0.0361	0.0180
5	0.6250	-0.0456	-0.0435	0.0026	-0.0412	0.0461	-0.0444	-0.0409	-0.0012
5	0.6875	-0.0321	-0.0419	-0.0063	-0.0169	0.0223	-0.0321	-0.0365	-0.0117
5	0.7500	-0.0197	-0.0369	-0.0088	-0.0008	0.0055	-0.0221	-0.0276	-0.0159
5	0.8125	-0.0090	-0.0317	-0.0075	0.0081	-0.0059	-0.0150	-0.0175	-0.0157
5	0.8750	0.0002	-0.0279	-0.0044	0.0108	-0.0139	-0.0110	-0.0086	-0.0125
5	0.9375	0.0086	-0.0261	-0.0014	0.0079	-0.0201	-0.0094	-0.0023	-0.0072
5	1.0000	0.0167	-0.0259	0.0000	0.0000	-0.0259	-0.0091	-0.0000	0.0000

Source : Poulos and Davis (1980)

This table is for $\lambda L = 3$ or $\lambda L = 4$. So, this table is given then next is $\lambda L = 4$. So, similar table is given, so, this is the $\lambda L = 4$ then this is for $\lambda L = 4$. so, for different λL values these tables are given and then for different z/L we will get this coefficient and once we get this coefficient, we will get the required deflection, slope bending moment and shear force at any depth of the pile. So, this class I have discussed that pile is treated as a finite beam.

So, next class I will discuss if pile can be treated as a semi-infinite beam and then here I have discussed that k_h is uniform throughout the depth or the length of the pile. So, next class I will discuss also that if k_h varies linearly with depth of the pile. Thank you.