Soil Structure Interaction

Prof. Kousik Deb
Department of Civil Engineering
Indian Institute of Technology- Kharagpur

Lecture 12
Soil-Structure Interaction for Shallow Foundation: Concept of Subgrade Modulus (Continued)

In the last class, the determination of subgrade modulus by IS code method and the corrections to be applied were discussed. Today the methodology described by the IS code will be discussed followed by an example problem related to the determination of subgrade modulus, and then different foundation models related to soil structure interaction.

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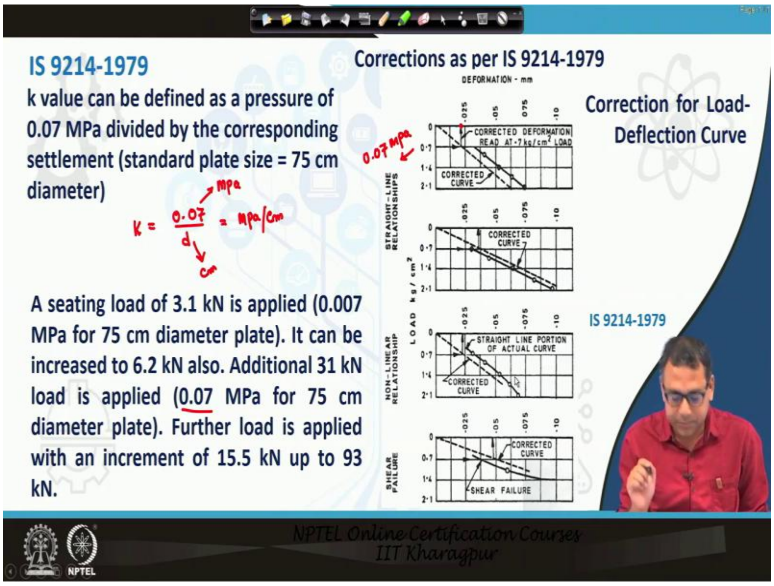

Let us have a brief overview of the method suggested by IS code 2914 1979 to determine subgrade modulus of a soil. The formulation, according to IS 9214-1979 for subgrade modulus is that k is equal to 0.07 (MPa) divided by the corresponding settlement. The plate load test should start only after the application of a seating load of 3.1 kN followed by a load increment of 31 kN which is equivalent to 0.07 MPa for a 75 cm diameter plate.

Further, the load is applied in increments of 15.5 kN up to 93 kN. After this, the load versus settlement curve should be drawn from which the uncorrected k value or the k value from the test can be determined. To this k value, corrections should be applied firstly, for the load deformation curve if it is not linear or doesn’t coincide with the origin or both. A non-linear curve should be first converted to a linear curve, which is parallel to the linear portion of the original curve and then redrawn such that it passes through the origin.

From the linear curve obtained, the corresponding settlement of 0.07 MPa (for a 75 cm plate) should be determined to calculate the new k value.

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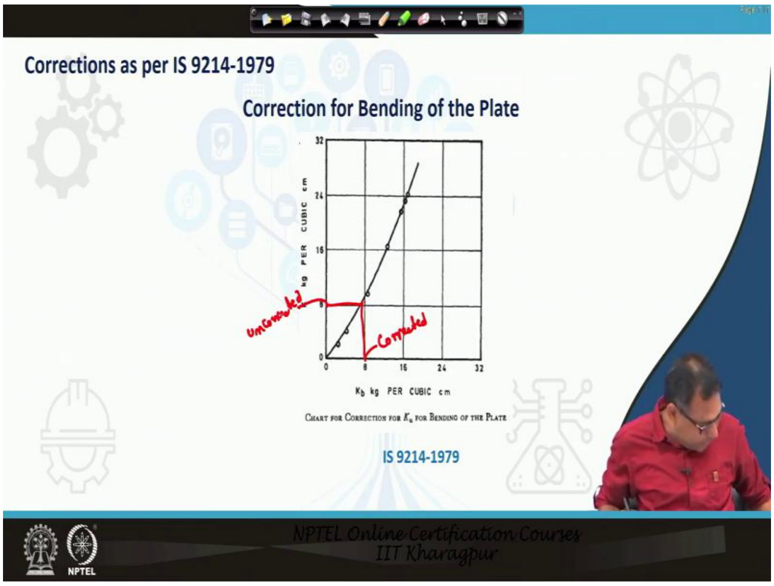

The next correction to be applied is for the bending of plate which can be determined from the graph with uncorrected k value on the Y-axis and the corrected k value (k_b) on the X-axis.

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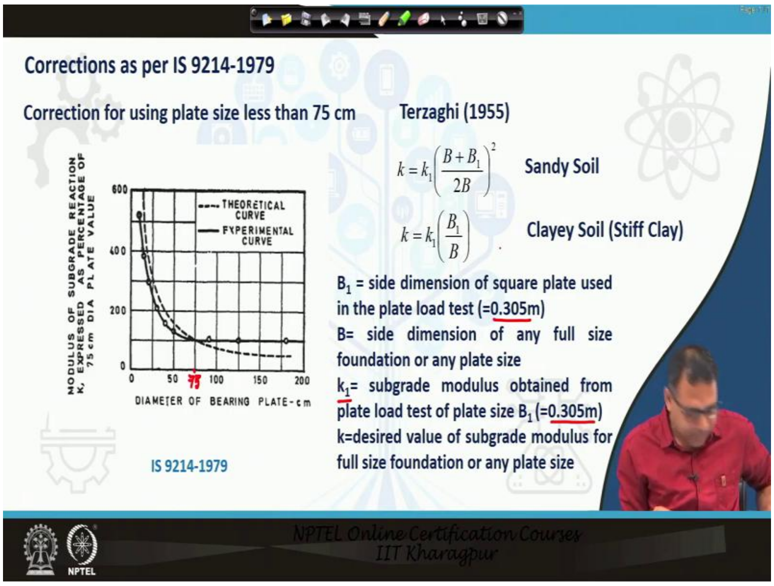

The third correction is for the plate size which need not be applied if the size of the plate is 75 cm. If the size of the plate is less than 75cm, the size correction should be applied. The IS code has recommended with this chart where this dotted line is the theoretical curve and firm line is the experimental curve. From the experimental curve, it is evident that after 75 cm, the k value is constant. But if the plate size is less than 75 cm, the above chart can be used to find out how many times the k value will be to that of a 75 cm plate.

Terzaghi, also recommended a method to incorporate the plate size correction involving the formulae:

$$k = k_1 \left(\frac{B + B_1}{2B} \right)^2 \text{ for sandy soil}$$

$$k = k_1 \left(\frac{B_1}{B} \right) \text{ for clayey soil}$$

where, B1 is the side dimension of the plate used in plate load test, B is the side dimension of the footing, k1 is the measured subgrade modulus from the plate load test and k is the corrected subgrade modulus for a foundation.

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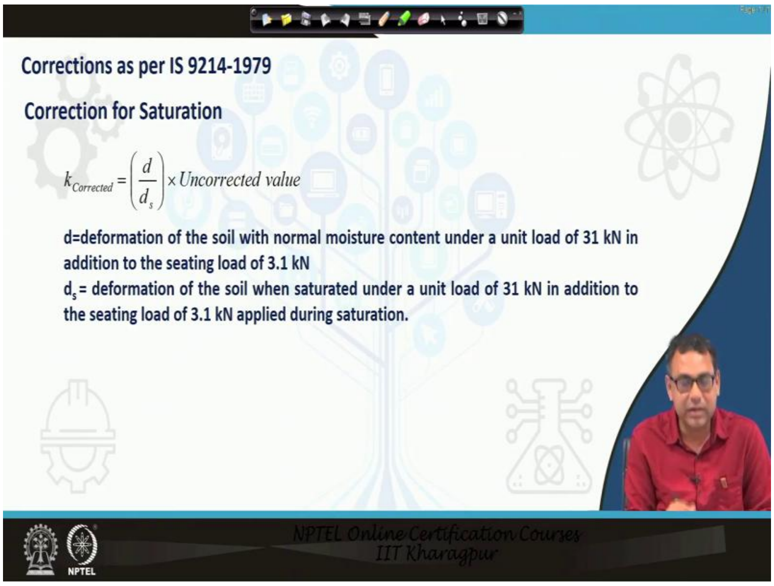

Then next correction, as suggested by the IS code is the correction for saturation. The equation for this correction is shown above where d is the deformation of the soil under normal moisture condition when a unit load of 31 kN in addition to the 3.1 kN is applied (a total load of 3.1 kN + 31 kN), d_s is the deformation of the soil under saturated condition when a unit load of 31 kN in addition to the 3.1 kN is applied.

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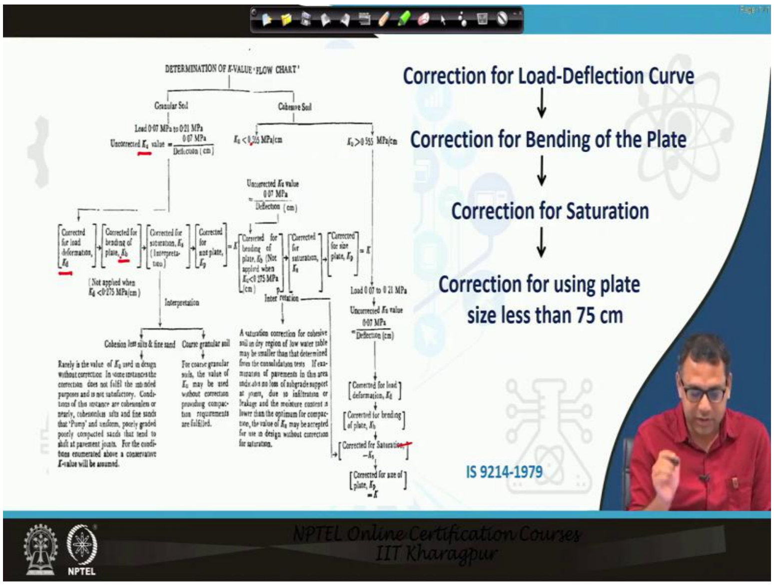

This is the summary of all the corrections discussed so far. For an uncorrected k value, the first correction to be applied is the correction for load-deflection curve followed by the bending of plate correction, and the correction of state of saturation and finally the correction for plate size if plate size used is less than 75 cm.

To detail the flowchart shown above, firstly the soil type should be identified if it is granular or cohesive. If the soil is granular, calculate the uncorrected k value (k_u) for 0.07 MPa stress divided by the corresponding deformation settlement. Then this k_u will be used to determine the corrected k value after applying the correction for load deformation k_d. This k_d will be applied with the correction for bending of plate and find out the corrected k value for bending (k_b). It should be remembered that if k_d is less than 0.275 MPa/cm, the correction for plate bending is not required. Once k_b is calculated, it will be further corrected for saturation which gives k_s. The k value corrected for saturation (k_s) will be used to determine k_p, corrected k value for plate size or the final k value, k.

So, first k_u will be corrected for load-deformation that gives k_d, which is corrected for the plate bending to get k_b, followed by the correction for saturation to get k_s. The k_s will be corrected for plate size and k_p will be determined which will used as the final corrected k value, k. (k_u to k_d; k_d to k_b; k_b to k_s; k_s to k. This is the sequence of correction to be followed.

If the soil is cohesive, with an uncorrected k value (k_u) less than 0.555 MPa/cm no load-deformation correction is required. The bending of plate correction is also not required if k_u is less than 0.275 MPa. The correction for saturation followed by correction for plate size can be applied directly to get the corrected k value. But, if k_u is greater than 0.55 MPa/cm, all the corrections need to be applied.

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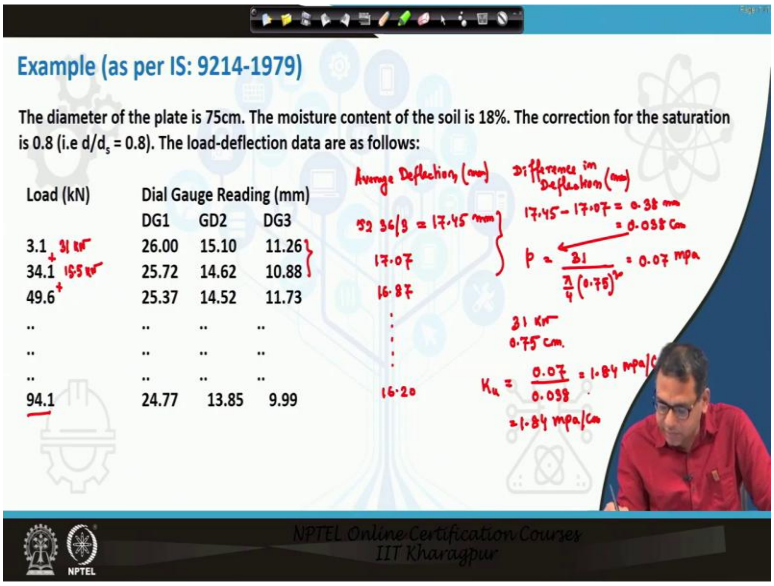

Now a problem involving the determination of subgrade modulus from a plate load test results and applying the appropriate corrections to it will be solved. The test was done on a plate of diameter 75 cm, moisture content of the soil was 18% the correction for saturation is 0.8 (d/d_s = 0.8). The load-deflection data is mentioned in the table. Since the plate is 75 cm, no plate size correction is required. It is given that first, seating load of 3.1 kN is applied. Further, 31 kN load was applied which means that the total load in the second column will be 34.1 kN (3.1 kN + 31 kN). The readings are in millimetre. After this, as discussed earlier, the load increment is of 15.5 kN up to a maximum additional 91 kN. So, the final load would be 94.1 kN from which, when the seating load of 3.1 kN is deducted, 91 kN would be there. Three dial gauges were used: DG1, DG2 and DG3 and the readings from all the dial gauges are given (in mm) in the table shown.

The readings after applying the seating load of 3.1 kN will be treated as zero readings, because the original load-deformation curve starts from after the seating load. So, the load that is applied after seating load will only be treated as actual load.

So, the readings in the first row against the first load entry should be treated as initial readings. This implies that the difference of the first and second row readings will give the deformation corresponding to 31 kN load because the first readings are against seating load which are treated as initial condition. So, after application of the 31 kN load, the difference in reading will give the additional deformation due to the application of the 31 kN load.

So, the readings from all dial gauges should be summed up and then the average deflection should be calculated against each load entry. For the 3.1 kN load, the sum of deflections from all three dial gauges is 52.36 which, when divided by 3 gives an average deflection value of 17.45 mm. So, for a load of 31 kN, the average deflection of the plate is 17.45 mm. Similarly for the third row, (46.5 kN load) the average is 17.07 then the next row it is 16.87 and it goes on till the last row with an average of 16.20 mm.

After calculating the average deflection values against each load, the difference of two consecutive readings should be calculated. So, the difference in the average readings against first and second rows will give the deflection corresponding to 31 kN load. So, the deflection corresponding to 31 kN load is the difference, 17.45 - 17.07 that is equal to 0.38 mm or 0.038 cm. The deflection of 0.38 mm is the deflection corresponding to 31 kN load.

As the plate used in the test was of diameter 75 cm, a load of 31 kN induces a stress of 0.07 MPa $\left(\dfrac{31\times10^3}{\dfrac{\pi}{4}\times750^2}\right)$. So, for a stress of 0.07 MPa, the deformation is 38 mm and hence the k_u value will be equal to the ratio between the stress and the corresponding deformation that is, 0.07 divided by 0.38 mm or 0.038 cm. So that value of the uncorrected subgrade modulus, k_u will be 1.84 MPa/cm.

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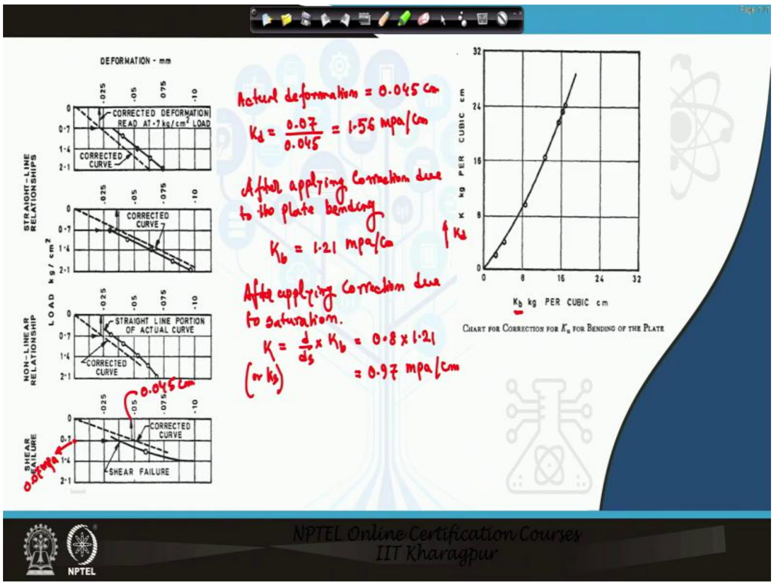

As discussed, the first correction to be applies is the load-deformation correction. In the question given, the load-deformation curve was not given and so the shape of the curve is unknown to us. So, for an example say that our curve resembles the fourth curve shown above. A parallel straight curve that passes through the origin should be drawn and the settlement corresponding to the 0.07 MPa stress should be considered as the corrected deflection reading for that stress. So, now this is my .07 MPa, now I will use this curve so this will be my actual settlement. The actual deformation or deflection that is read from the curve is about 0.045 cm.

It should be remembered that now, the fourth curve is used based on a mere assumption that the response given in the question fits that curve. But, a load-deformation curve should always be plotted from the plate load test results and then the appropriate curve out of the given four should be used.

Assuming that the fourth curve fits the load-deformation response given in the question, the actual deformation value is found to be 0.045 cm. The k value corrected for load-deformation will be 1.56 MPa/cm (k_d = 0.07/0.045). This k_d value will used to determine the k_b, k value corrected for plate bending.

To apply the correction for bending the k_d value should be converted to kg/cm^3 as the chart that gives the corrected k value, k_b is in that units. First the k_d value (uncorrected) should be converted to kg/cm^3 and the corresponding k_b value (corrected) should be read from the graph which can then be converted to MPa/cm again. So, for a k_d value of 1.56 MPa/cm, the kb value will be around 1.21 MPa/cm.

The next correction to be applied would be the plate size correction but that would not be applicable in the present case, as the plate used for the test described in the question is 75 cm. The plate size correction should only be applied if a plate of diameter lesser than 75 cm is used. Although, the correction for the saturation should be used as the test was done on a partially saturated soil.

The subgrade modulus corrected for saturation may be called as k_s or simply k because this is the last correction to be applied $\left(k_s = \frac{d}{d_s} k_b \right)$. Here, k_b is the uncorrected k value that is obtained by applying the plate bending correction. Usually this uncorrected value will be k_p, where the k value is corrected for plate size but as the test was done using a 75 cm plate, the k_b value can be directly used without applying the plate size correction. The d/d_s value is given as 0.8 and k_b value is 1.21 MPa/cm which gives a k_s value of 0.97 MPa/cm ($k_s = 0.8 \times 1.21$). This is the procedure to determine the uncorrected k value, apply all the corrections and find out the corrected k value.

To summarise entire procedure of applying corrections, the first correction to be applied is the load deformation correction, then the correction for plate bending. Then, the correction for plate size should be applied only if the plate size is less than 75cm. After that, the correction for saturation should be applied that finally gives the corrected k value. This procedure is as suggested by IS code. In the next class different models to idealize soil for the soil structure interaction problem will be discussed. Thank you.