# LESSON 7

# TOPIC 2

## Spread Footing Design - Settlement

***SPREAD FOOTING DESIGN***

***Lesson 7 - Topic 2***
***Settlement***

**Slide 7-2-1**

Header

***SPREAD FOOTING DESIGN***
***Settlement***

*1. Perform Settlement Analysis in Cohesive and Granular Soil*
*2. Name Solutions to Reduce Settlement Amount or Time*

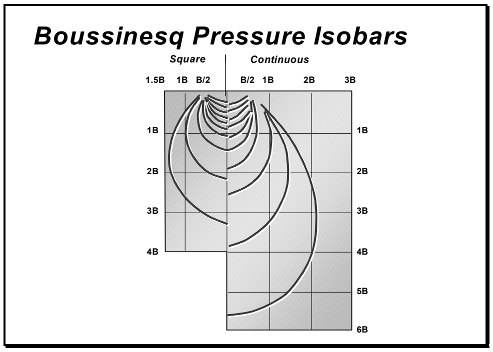
*ACTIVITY: Settlement Analysis*

**Slide 7-2-2**

Objective

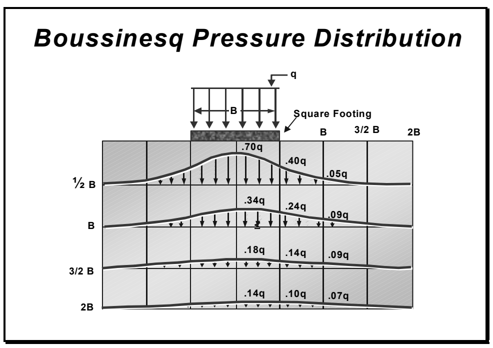
**Slide 7-2-3**

Case history of settlement of bridge abutment at site where no borings were taken. This bridge was placed on spread footings at a site where no borings were taken and the design was done to “match the design of a bridge down the road as the soils in this area are all the same”. Note that a large shim has been produced under the bearing plate because of continuing settlement of the bridge. The maintenance problem was so bad that a boring was taken at the location to find out what soils existed. The boring found a shallow layer of sand underlain by a thick layer of soft soil. Subsequent settlement analyses indicated that over a foot of additional settlement could be expected over a 10 year period.



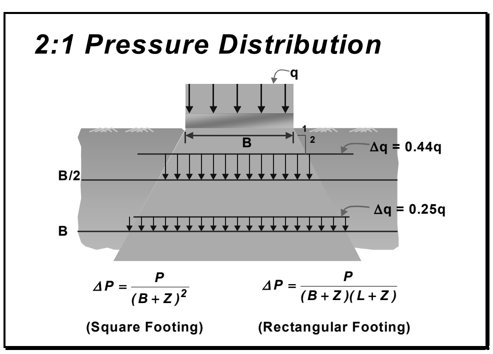

**Slide 7-2-4**

Re-emphasize that size of loaded area controls pressure distribution. Note difference in the penetration of pressure with depth between square and continuous footing of same width.



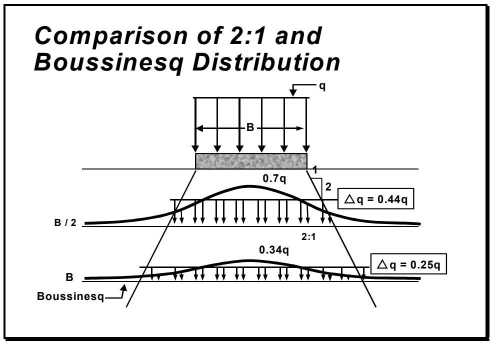

**Slide 7-2-5**

Explain the Boussinesq concept of pressure distribution.



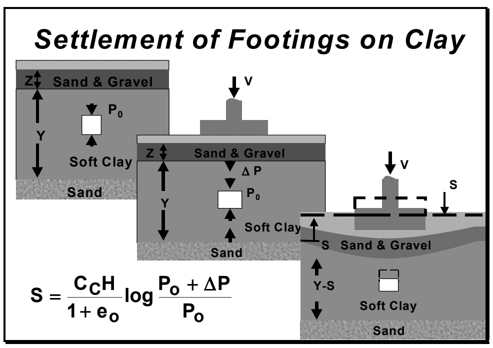

**Slide 7-2-6**

Explain the simplified concept of 2 to 1 distributions.



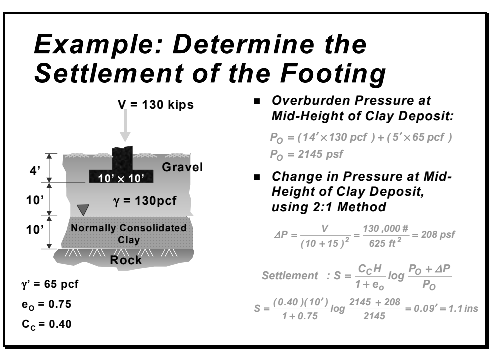

Slide 7-2-7

Compare both methods and use the simpler method for teaching.



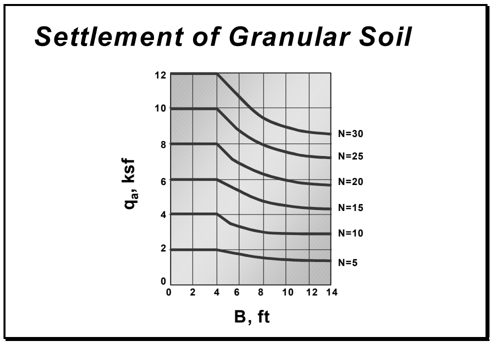

Slide 7-2-8

Review the concept of settlement of cohesive soils.



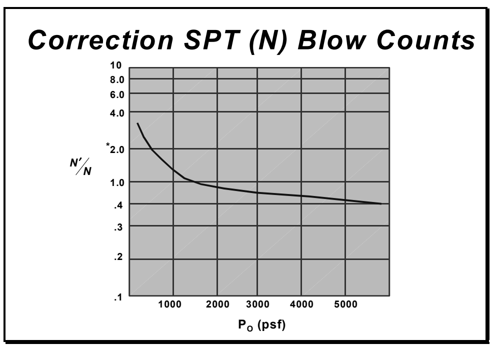

Slide 7-2-9

Apply the concept in an example to illustrate the computational process.



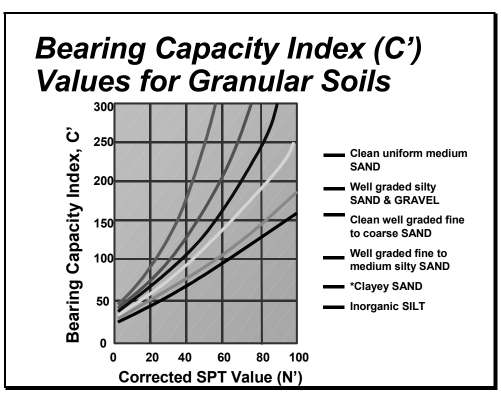

**Slide 7-2-10**

Show a simplistic chart for settlement estimation in granular soils that gives the allowable bearing pressure which will cause less than 1” of settlement. Ask what are the problems with this chart (answer is that the chart is overly simplistic and was developed on very limited case history information that was concentrated in small footing sizes and moderate bearing pressures. Higher bearing pressures have resulted in unconservative predictions of footing settlement). Then show the next two slides, which contain the correct process.



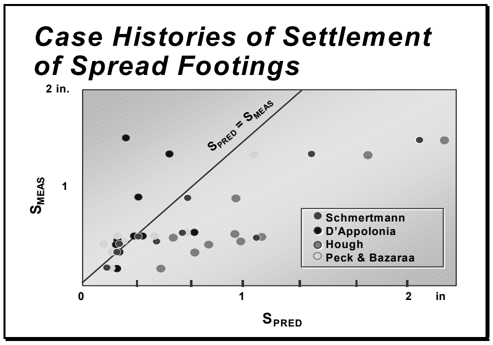

**Slide 7-2-11**

The correct procedure, as previously discussed, first involves correction of SPT blows for overburden pressure.




**Slide 7-2-12**

The second step is to consider the granular soil type to find the compressibility. And then use the actual distributed pressure and previous settlement equation to find the settlement.

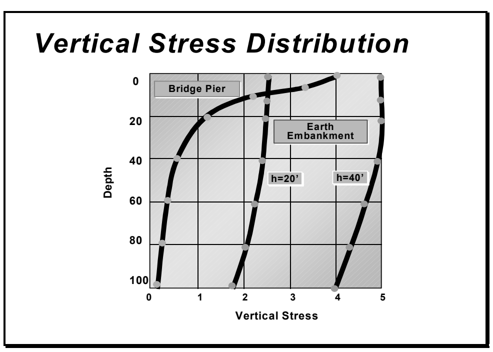



**Slide 7-2-13**

Show the results of research on the current settlement method and explain how the method is conservative. Note the original publication is discussed on page 7-14 of the reference manual Recommend other methods in other FHWA publications for project work.

**Slide 7-2-14**

Contrast the amount of load applied to the soil at the location of the abutment to the load applied at the pier. The settlement of soils beneath the abutment is caused by the weight of fill more than the small abutment load. The lesson learned is that we need to take care of the embankment settlement before considering the use of spread footings at the abutment.




**Slide 7-2-15**

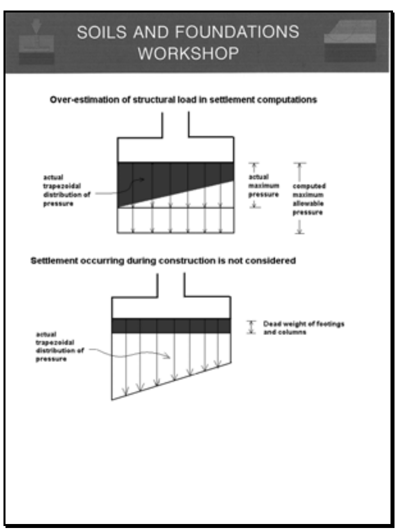
Compare the differences in pressure distribution for a pier and an embankment and ask the group why the great difference (the answer is that the width of the embankment is much greater than the structure footing and therefore the pressure extends to greater depths).

Slide 7-2-16

Case history of large settlement causing structural problems at an abutment. In this case the high approach fill was constructed over very soft compressible soils without any attempt to mitigate the settlement. Then the piles were immediately driven for the bridge and the structure built as quickly as possible. The 6' of approach embankment settlement that subsequently occurred in the following months resulted in severe damage to the structure including shearing off the piles under the abutment. Also the water and gas mains were severed that were carried under the bridge structure and through the backwall. The important point is that the weight of the embankment is very large and when downward movement begins, the force will shear off the foundations.

Slide 7-2-17

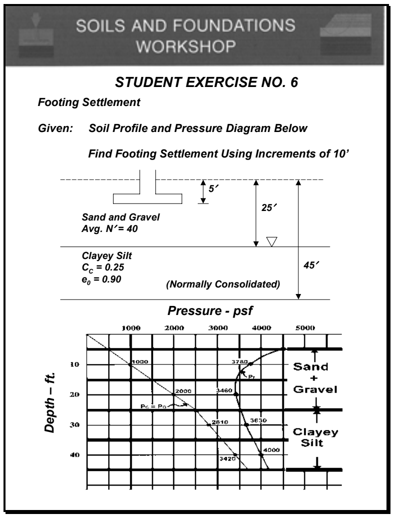
Case history to demonstrate that piers in end fills can be subject to tilting if the differential settlement is not accounted for. Note that the rock fill is 80' high and the end slope constructed on a 1 to 1 slope. The proposed 80' high pier column with a 24' wide footing, which is in the end slope, has been built in the two stages with the first stage shown. Ask the group why the designer chose this method of construction. The answer is because of the last job when the pier columns titled toward the fill and the beams id not fit. This is due to the 24' of differential fill height that is over opposite ends of the 24' wide pier footing.




Slide 7-2-18

Explain why communication with structure's office can improve settlement prediction by geotechnical engineers. Remind the audience that the settlement computation commonly occurs long before the structure design is finalized. Focus on the three aspects shown here; the lack of knowledge of both the actual magnitude and distribution of the footing load and the fact that most granular soil settlement occurs during construction. In the absence of information geotechnical engineers tend to assume the maximum allowable bearing pressure will be used by the structural designer. This is usually an erroneous assumption that will lead to computation of unrealistic settlement for the footing.

At this point go to the reference manual and cover the important items that were shown in the slides with emphasis on the sections that show how settlement is computed. Then ask if everybody is ready to calculate footing settlement and show the student exercise.



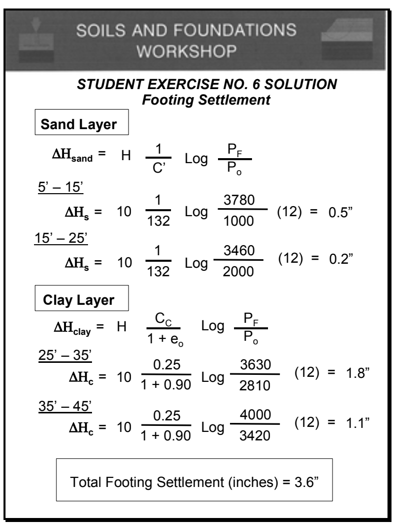

Slide 7-2-19

Instructor should use overhead transparencies for the remainder of this topic.

Student exercise on settlement of spread footings. Purpose is to test learning of the computational process and reinforce concepts of pressure distribution and need for good data. Ask students to do exercise by using 10' depth increments as shown in the profile for each soil layer. This will involve 4 computations to get to the total settlement. Instructor should assign one computation per team. Write equations for settlement of both cohesive and granular soil on flip chart and reference page where C' chart is located. Chose team to present solution. Ask why settlement in the second 10' sublayer is less than top 10' layer settlement.

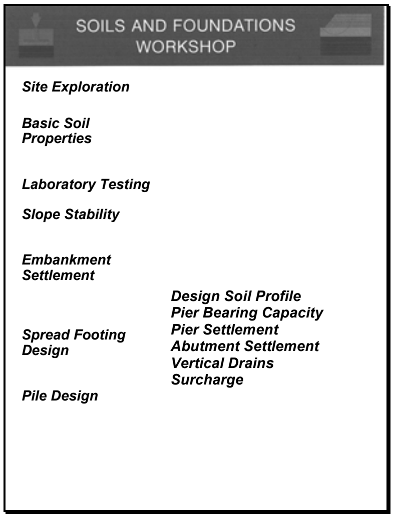
Also ask why settlement in bottom clay layer is greater than upper sand/gravel layer (answer is that clays are one of the problem soils where large settlements may occur under even small loads.

Please refer to the end of the lesson for this exercise.



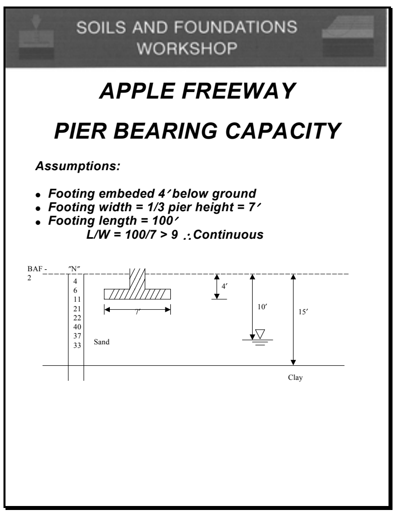

Slide 7-2-20

Please refer to the end of the Participant Workbook for the solution to this exercise.



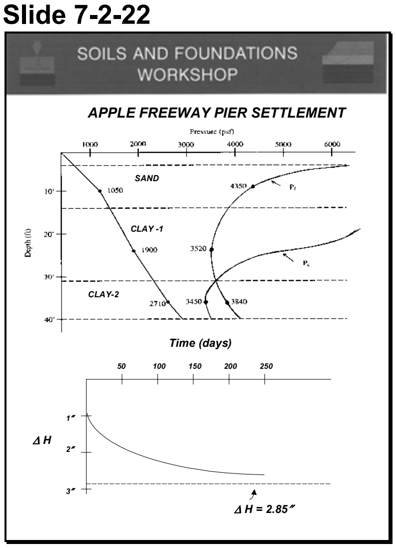

**Slide 7-2-21**

Show Apple Freeway status of design. Use following visuals to test learning of both bearing capacity and settlement for real project application.



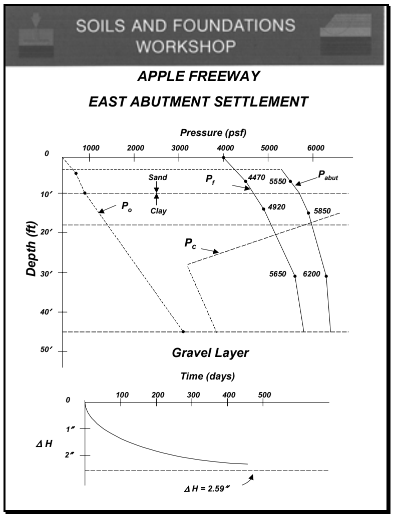

**Slide 7-2-22**

Ask students what problems they identify with the bearing capacity of the pier footing shown (answer should be water table within the failure zone and the clay layer may influence the bearing capacity).




**Slide 7-2-23**

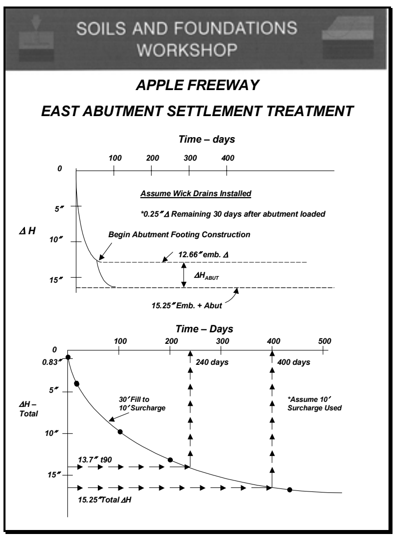
Ask which layers will yield the most settlement at the pier and why (answer is the portion of the clay layer that is not preconsolidated and the top part of the sand layer that is subject to high pressure).




**Slide 7-2-24**

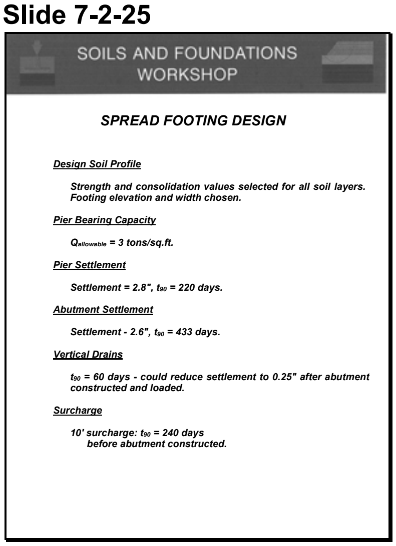
Ask students about the reason for the surprising large amount of settlement on the time settlement plot as the change in pressure is small (answer is that the load above Pc and all in virgin compression).

Also ask if the wick drains decrease settlement magnitude under the structure foundation area (answer is no but time reduced).




**Slide 7-2-25**

Explain wick drain option (note that if wick drains used for embankment the wicks still function when the footing is placed and that the total settlement occurs quickly but could still cause clearance problems under structure if that was an issue) and surcharge option (note that surcharge for embankment could be left on longer until settlement due to both embankment and footing loads have occurred, then application of footing would result in no settlement).




**Slide 7-2-26**

After reviewing the design summary, ask if the differential settlement would be small enough to permit the structure to be built "high" (answer is that differential settlement appears to be only 0.2 inches but that is incorrect as the settlements occurs at different rates and an overlay of the time settlement diagrams would show almost 1.5" of temporary differential settlement.
Instructor asks students to open reference manual to the Apple Freeway problem, overviews the solution, and then promotes NHI Shallow Foundations course.

Go to Reference Manual.


**Slide 7-2-27**

Repeat objectives for lesson 7 topic 2.

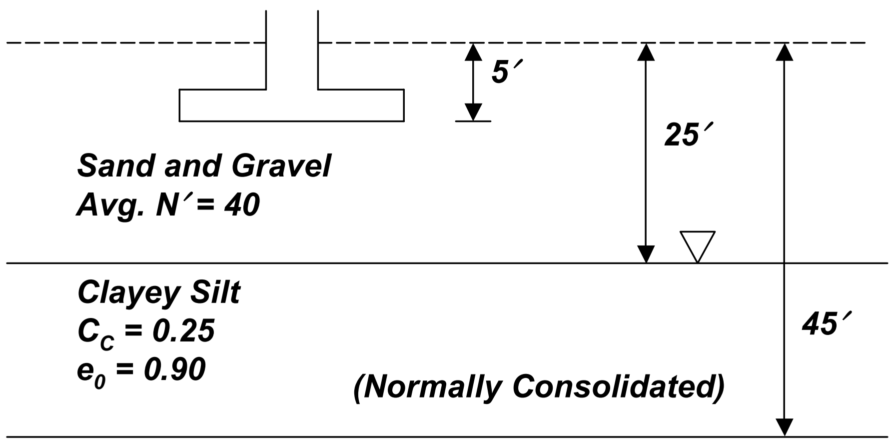
# SOILS AND FOUNDATIONS WORKSHOP

## STUDENT EXERCISE NO. 6

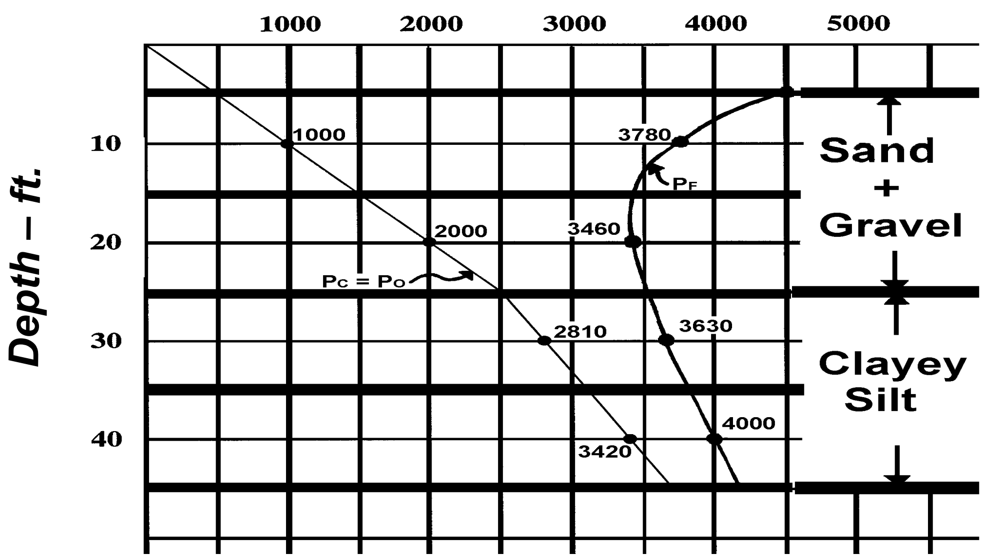
***Footing Settlement***

***Given: Soil Profile and Pressure Diagram Below***

***Find Footing Settlement Using Increments of 10'***




***Pressure - psf***



SOILS AND FOUNDATIONS WORKSHOP

## *STUDENT EXERCISE NO. 6 SOLUTION*
## *Footing Settlement*

**Sand Layer**

$$\Delta H_{sand} = H \frac{1}{C'} \text{Log} \frac{P_F}{P_o}$$

5' – 15'

$$\Delta H_s = 10 \frac{1}{132} \text{Log} \frac{3780}{1000} (12) = 0.5''$$

15' – 25'

$$\Delta H_s = 10 \frac{1}{132} \text{Log} \frac{3460}{2000} (12) = 0.2''$$

**Clay Layer**

$$\Delta H_{clay} = H \frac{C_C}{1 + e_o} \text{Log} \frac{P_F}{P_o}$$

25' – 35'

$$\Delta H_c = 10 \frac{0.25}{1 + 0.90} \text{Log} \frac{3630}{2810} (12) = 1.8''$$

35' – 45'

$$\Delta H_c = 10 \frac{0.25}{1 + 0.90} \text{Log} \frac{4000}{3420} (12) = 1.1''$$

Total Footing Settlement (inches) = 3.6"