SETTLEMENT OF SHALLOW FOUNDATIONS IN SAND AND IN CLAY
Summary findings

CONSORTIUM FOR EDUCATION AND RESEARCH IN GEOENGINEERING PRACTICE
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Background: Estimating the settlement of shallow foundations under load is one of the most important issues in the proper design of shallow foundations. The CERGEP members requested a study of this problem from a very practical and useful point of view.

What the Researchers Did: Two databases of observed shallow foundation behavior under load were assembled: one for sand and one for clay. In sand, 318 cases were collected with the longer-term settlement and the applied pressure. The cases included load tests on smaller footings and observed behavior on large scale foundations. The foundation widths varied from 0.3 m to 135 m and the soil properties included SPT blow counts, CPT point resistance, and PMT modulus. All the data was organized in a spread sheet called TAMU-SHAL-SAND. In all cases, the elasticity equation was used to back-calculate the soil modulus E which would give the measured settlement.

$$S = I\,(1-\nu^{2})p\frac{B}{E}$$

These long-term modulus values were then correlated to the soil properties. In addition, the Terzaghi and Peck chart for footings on sand was populated with the data from the data base to evaluate its precision. Finally, a chart was developed base on the finite element method for the influence of adjacent footings on the settlement of a footing.

In clay, 98 cases were collected with the longer-term settlement and the applied pressure. They included load tests on smaller footings and observed behavior on large scale foundations. They included two building sub-databases, one load test sub-database, and one tank sub-database. The foundation widths varied from 0.3 m to 105 m and the soil properties included consolidation test compression index, undrained shear strength, Vane Shear Test, CPT point resistance, PMT modulus. All the data was organized in a spread sheet called TAMU-SHAL-CLAY. The consolidation equation was used to back-calculate the compression index C_c which would give the measured settlement and the elasticity equation was used to back-calculate the soil modulus E which would give the measured settlement. These long-term values were then correlated to the soil properties. In a separate effort, the influence of the test procedure on the consolidation test results was studied by performing 9 tests on 3 different PI soils. The procedures included no sample inundation prior to testing, inundation but constrained from swelling, and inundation and allowed to swell prior to testing.

What the Researchers Found: The analysis of the database in sand led to the following equations to estimate the modulus E. This modulus E together with the elasticity equation and according to the database will give a settlement larger or equal to the measured settlement 90% of the time.

$$E\ (kPa) = 1000\ N(bpf) \text{ or } E\ (ksf) = 20\ N(bpf)$$
$$E = 4\,q_c$$

$$E = 3\ E_{pmt}$$

$$s = 4.25\ p\ (kPa)/N(bpf) \text{ or } s = 8\ p\ (ksf)/N(bpf)$$

The last equation is based on the Terzaghi and Peck's chart (TP chart). For small footing widths, the measured value of the pressure p(25mm) corresponding to 25 mm settlement is larger to much larger than the TP chart predicted value. However, p(25mm) measured becomes closer to p(25mm) predicted by the TP chart for larger footing widths. As the sand becomes denser, there is an increase in the number of cases where p(25mm) measured is smaller than p(25mm) predicted by the TP chart.

The analysis of the database in clay led to the following equations to estimate the modulus E. This modulus E together with the elasticity equation and according to the database will give a settlement larger or equal to the measured settlement 90% of the time.

$$E = 120\ S_u \text{ (All records except the Tank sub-database)}$$

$$E = 80\ S_u \text{ (Tank sub-database, assuming no hard layer at depth)}$$

Using 2 times the measured value of C_c in the consolidation equation gives a 90% probability that the predicted settlement will be greater than the long term measured settlement (Buildings on Chicago clay). Using C_c gives 50% probability. The inundation of the sample had the following effect on the consolidation test results. When the consolidation procedure goes from no inundation to inundation but constrained from swelling to inundation and allowed to swell, the value of C_c increases, no trend was observed for the initial recompression index C_{ri} and for the recompression index C_r, but the change in strain between 1kPa and 1000kPa ($\varepsilon_{1000} - \varepsilon_1$) increased.