DMM TREATMENT PATTERNS

Deep mixing techniques can be used to produce a wide range of patterns in the treated soil structure. The selected pattern depends on the construction location (land or marine), the purpose of the DMM applications, and the characteristics and capabilities of the method used. The treatment patterns can be single element (column), rows of overlapping elements (walls or panels), grids or lattices, or blocks.

DRY AND WET MIXING METHODS

Deep mixing is carried out using either the dry method or the wet method. Dry mixing is possible when the natural moisture content of the *in situ* soil is quite high, so the cement hydration reaction can take place for strength development. Deep deposits of organic and peat soil (with high water content) can be effectively stabilized with the dry method. The column diameter is typically 0.6 to 0.8 m with the depth of treatment reaching up to 25 m. Release of dry binder and the soil mixing occur during the withdrawal of the mixing rod, where the rotational direction is reversed compared to the direction during penetration. The binder dosage is maintained as desired by controlling the air pressure and the amount of binder during construction.

Wet mixing is more appropriate when the natural water content is low. Soft clays, silts, and fine sands are suitable for this method. The binder is introduced in a slurry form through a nozzle placed generally at the end of the auger. The specialized mixing tool contains transverse beams and can move vertically along the column length to achieve homogeneous mixing. The composition and the amount of slurry can be controlled to achieve design specifications. The column diameters are typically 0.4 to 2.4 m, depending on the application. Steel reinforcements can be inserted into the soft columns to improve bending resistance.

Cement injected in the wet method is typically in the range of 100 to 500 kg/m^3 of untreated soil (Bruce and Bruce, 2003). In the dry method, this range is 100 to 300 kg/m^3, provided the natural moisture content is in the range of 40 to 200%.

5.19 Summary

When the soil conditions at the site are not suitable or when the project can be constructed more economically by improving the ground conditions, the geotechnical engineer has several alternatives. The different ground improvement techniques discussed in this chapter include field compaction, vibroflotation, blasting, precompression, prefabricated vertical drains, chemical stabilization, stone columns, and dynamic compaction. Every technique has its limitations, and it is necessary to understand them before selecting the most suitable method for modifying ground conditions.

PROBLEMS

5.1 From the test specifications given in Table 5.2, show that the compactive energy in method C is 2700 kN·m/m^3.

5.2 In a sandy soil, the maximum and minimum void ratios were determined to be 0.725 and 0.465, respectively. The specific gravity of the soil grains is 2.65.

- **a.** What would be the relative density of this sand compacted to a dry unit weight of 16.46 kN/m^3?
- **b.** Assuming the maximum dry unit weight of the sand determined from the compaction is the same as the one corresponding to $e_{\min}$, determine the relative compaction of the soil.

5.3 For a cohesive soil with LL = 45 and PL = 25, estimate the difference in the w_{opt} and $\gamma_{d(\max)}$ values between standard and modified compaction tests. Use Gurtug and Sridharan (2004) correlations.

5.4 Repeat Problem 5.3 using Osman et al. (2008) correlations.

5.5 The undisturbed soil at a given borrow pit is found to have the following properties: $w = 15\%$; $\gamma = 19.1$ kN/m^3; $G_s = 2.70$. The soil from this borrow is to be used to construct a rolled fill having a finished volume of 38,500 m^3. The soil is excavated by means of a shovel and dumped onto trucks having a capacity of 4.80 m^3 each. When loaded to capacity, these trucks are found to contain, on average, a net weight of soil and water equal to 72.7 kN.

In the construction process, the trucks dump their load on the fill, the material is spread and broken up, after which a sprinkler adds water until the moisture content is equal to 18%. The soil and water are thoroughly mixed by a disc (or similar equipment) and then compacted until the dry unit weight is equal to 17.3 kN/m^3.

a. Assuming that each load is a full-capacity load, how many truckloads are required to construct the fill?
b. What should be the volume of the pit that remains in the borrow area after all the material required for the fill has been removed?
c. How many liters of water will have to be added per truckload, assuming that the moisture lost by evaporation during excavation, haulage, and handling is negligible?
d. If the fill should become saturated at some time subsequent to the construction and does not change volume appreciably, what will be its saturation water content?

5.6 For a vibroflotation work, the backfill to be used has the following characteristics:
$D_{50} = 2$ mm
$D_{20} = 0.7$ mm
$D_{10} = 0.65$ mm

Determine the suitability number of the backfill. How would you rate the material?

5.7 For the soil A, B, and C in Problem 2.7, find the suitability numbers using Eq. (5.17) and the suitability of these soil for densification using vibroflotation method. What are these soil?

5.8 A 5 m thick doubly drained normally consolidated clay layer at a site has $e_o = 0.95$, $C_c = 0.54$, and $c_v = 4.0$ m^2/year. The effective overburden pressure at the middle of the clay layer is 70.0 kN/m^2. Some proposed construction work is expected to impose a 60.0 kN/m^2 load at the ground level.
a. Determine the primary consolidation settlement.
b. Noting that the expected primary consolidation settlement is high, it is proposed to apply a surcharge over a period of one year. What should the magnitude of this temporary surcharge be so there will be no postconstruction consolidation settlement?

5.9 In Problem 5.8, the client sees the one-year duration of the preload as too long and wants to limit this to 6 months. What should the total surcharge be during this period?

5.10 A 3.0 m thick singly drained normally consolidated clay layer has $e_o = 0.89$, $C_c = 0.46$, and $c_v = 3.5$ m^2/year. The effective overburden pressure at the middle of the layer is 105.0 kN/m^2. It is proposed to build a large warehouse that is expected to impose a pressure of 50.0 kN/m^2 at the ground level.
a. What would the primary consolidation settlement be?
b. If the engineer proposes to preload the site with a pressure of 90.0 kN/m^2, how long should this surcharge be left to ensure there is no postconstruction settlement when the warehouse is built?

5.11 The diagram of a sand drain is shown in Figures 5.21 and 5.22. Given: $r_w = 0.25$ m, $r_s = 0.35$ m, $d_e = 4.5$ m, $c_v = c_{vr} = 0.3$ m^2/month, $k_h/k_s = 2$, and $H_c = 9$ m. Determine:
a. The degree of consolidation for the clay layer caused only by the sand drains after six months of surcharge application
b. The degree of consolidation for the clay layer that is caused by the combination of vertical drainage (drained on top and bottom) and radial drainage after six months of the application of surcharge

Assume that the surcharge is applied instantaneously.

5.12 A 3.05-meter-thick clay layer is drained at the top and bottom. Its characteristics are $c_{vr} = c_v$ (for vertical drainage) = 39.02 cm^2/day, $r_w = 203$ mm, and $d_e = 1.83$ m. Estimate the degree of consolidation of the clay layer caused by the combination of vertical and radial drainage at $t = 0.2$, 0.4, 0.8, and 1 year. Assume that the surcharge is applied instantaneously, and there is no smear.

5.13 For a sand drain project (Figure 5.20), the following are given:

Clay: Normally consolidated
$H_c = 5.5$ m (one-way drainage)
$C_c = 0.3$
$e_o = 0.76$
$c_v = 0.015$ m^2/day
Effective overburden pressure at the middle of clay layer = 80 kN/m^2

Sand drain: $r_w = 0.07$ m
$r_w = r_s$
$d_e = 2.5$ m
$c_v = c_{vr}$

A surcharge is applied as shown in Figure P5.13. Calculate the degree of consolidation and the consolidation settlement 50 days after the beginning of the surcharge application.

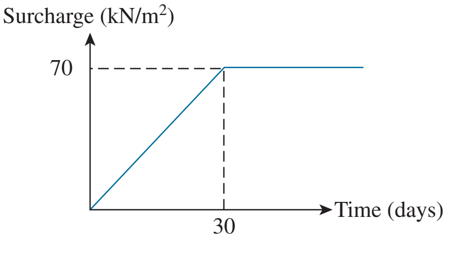

FIGURE P.5.13

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