TERRANOTES
A Ground Improvement Update from TerraSystems

WICK DRAIN DESIGN

Wick drains, sometimes called prefabricated vertical drains, have gained very rapid acceptance since the late 70's within the geotechnical design and construction industry. Many hundreds of million feet of wick have been installed in the U.S. alone and several billion feet of wick worldwide. The design of wick drains is complex in that a detailed knowledge of the subsurface conditions is necessary, as well as an understanding of the design equations for wick drain spacing and their limitations.

This article is intended to provide designers with a brief overview of the equations and discussions of the limitations of the design assumptions.

The principal objective of installing wick drains is to accelerate the time for settlement or consolidation of a compressible layer to occur. Wick drains do not cause soil to settle more than without wicks. Rather, wick drains make the soil settle faster by shortening the drainage path that the pore water has to travel in order to escape.

The general equation for calculating the time for soil consolidation to occur with wick drains is:

$$t = (D^2 / 8\, c_h)(F(n) + F_s + F_r) \ln (1/1-\overline{U}_h))$$

where

t = time required to achieve the desired consolidation
$\overline{U}_h$ = average degree of consolidation desired
D = diameter of zone of influence of the wick drain
c_h = coefficient of consolidation for horizontal drainage
$F(n)$ = drain spacing factor = $\ln(D/d_w)$ -3/4
d_w = equivalent diameter = $2(a+b)/\pi$, where a = width of drain and b = thickness of drain
F_s = soil distance factor = $((k_h/k_s) - 1) \ln(d_s/d_w)$
k_h = coefficient of horizontal permeability in the undisturbed soil
k_s = coefficient of permeability in the disturbed soil zone
d_s = diameter of the idealized disturbed zone around the drain
F_r = factor for drain resistance = $\pi z (L-z) (k_h/q_w)$
z = distance below the top surface of the compressible layer
L = effective drain length, i.e., total drain length when drainage occurs at one end only, half length when drainage occurs at both ends
q_w = discharge capacity of the wick drain at a gradient of 1

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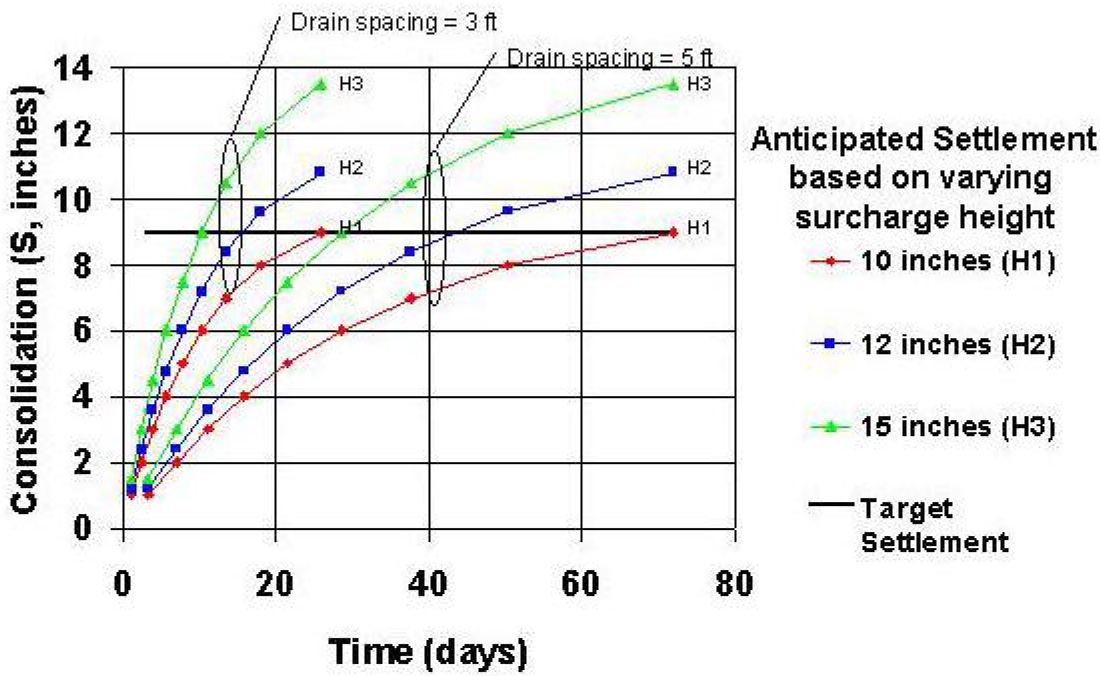
Quite often the general equation is simplified by ignoring the effects of soil disturbance and drain resistance, i.e., F_s and F_r are assumed to be zero. The assumption of negligible soil disturbance is reasonable in most situations, provided that small mandrel cross-sections are used. The theoretical effect of drain resistance is much less than the effect of drain spacing or soil disturbance, and typically F_r is less than 0.05.

Using the simplified equation, the primary design parameter is the spacing of the wick drains. The time required for a specific percent consolidation is approximately proportional to the *square* of the spacing. Cutting the spacing in half will accelerate the time required by a factor of 4. Probably the second most important variable is the height of surcharge. Typically, the "target" settlement for a surcharge program is 90 to 100% of the total estimated settlement under the design load. For instance, if 10 inches of total settlement are anticipated, the goal of a surcharge program might be to induce at least 9 inches of settlement. Based on geotechnical parameters, the equation described previously can be used to calculate a drain spacing that can cause the desired amount of settlement to occur within the desired time frame.

A second design parameter, the height of the surcharge, can also be used to influence the rate of consolidation. For example, consider that the amount of target consolidation is 9 inches, 90% of the total estimated consolidation of 10 inches under the design load. Likewise it would be 75% consolidation for a surcharge that would cause 12 inches of total settlement, or 67% if the surcharge is raised to the level where 15 inches of consolidation would be expected. To develop this graphically, time-consolidation curves are plotted for assumed surcharge heights of H1, H2 and H3, as shown on the accompanying figure. This has been done for wick spacings of 3 and 5 feet. By creating these families of graphs, the designer can obtain information to assist him in evaluating the most economical combination of wick spacing, consolidation time and surcharge height to accomplish the ground consolidation within the project time and budget constraints.



If you would like to know more about wick drains or another ground improvement technique, or would like to discuss an upcoming project, please give us a call at 540-882-4130 or e-mail us at jjones@terrasystems-inc.com. We would welcome the opportunity to hear from you.

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