Office of Design

200F-7

Prefabricated Vertical Wick Drains (PVDs)

Design Manual
Chapter 200
Geotechnical Design
Originally Issued: 01-15-14

Prefabricated vertical drains (PVDs), also referred to as wick drains, are installed into compressible (and typically low-strength) soils to accelerate consolidation and strength gain of compressible cohesive soils. Contrary to what many people may think, wick drains do not reduce settlement, they simply accelerate it. The use of the term “wick drains” is a misnomer since water is not wicked from the compressible soil, but flows due the differential pressure gradient induced by excess pore pressure developed during fill placement. However, the term “wick drains” is still frequently and commonly used at the Iowa DOT and many other places. PVDs provide a vertical drainage path through the compressible materials in which the excess pore pressures can dissipate.

Quick Tips:

- Standard Penetration Tests (SPT) or other techniques should be performed during the geotechnical investigation to determine if pre-drilling is necessary for wick drain installation.
- Prior to selecting the use of PVDs, predictions of the amount and rate of settlement both during and after construction are required.

Methods

The Soils Design Section estimates the amount and rate of settlement both during and after construction using the information obtained in the S2 through S4 events. If the predicted rates of settlement and construction delay are in excess of a certain amount (such as 90 days), consideration is often given to installing PVDs to accelerate the settlement. The PVD system should be designed to meet the post construction settlement performance criteria provided in Sections 200F-2 and 200F-3 within the anticipated construction schedule.

The main components of PVD design are the selection of the type, spacing, and length of the drains to reduce construction delay and accomplish the required settlement in order to meet the performance criteria. The three-dimension limits of the PVD, the pattern layout, and the depth of penetration (PVDs typically need to fully penetrate the compressible layers) as estimated by the Iowa DOT is included in the S3/S4 submittals and shown/included in the letting plans.

PVD Materials

PVDs have a flexible rectangular plastic drainage core (about 1/8 inch thick by 4 inches wide) covered by a non-woven geotextile jacket. The geotextile jackets are typically made of nonwoven polyester or polypropylene filter fabric material. The plastic drainage core has two main purposes: to give semi-rigid support to the filter fabric; and to provide a longitudinal flow path along the drainage length. The function of the jacket is to act as a filter, allowing water to permeate into the drain while preventing fine soil particles from entering.

Installation

The drains are typically installed using a mandrel to drive or push them to the required depth. Thus, if obstructions or a very dense or stiff soil layer is located above the compressible layer(s), predrilling may be necessary for wick drain installation. Field testing during the soil investigation, including Standard Penetration Test (SPT), is required to determine if pre-drilling is necessary. Typical PVD equipment can install drains to depths of about 60 feet.

In addition, a minimum 2 to 3 foot thick sand drainage blanket with internal drainage lines and appropriate outlets that allow gravity drainage is typically placed across the ground surface prior to installing PVDs. After the PVDs are installed, the fill embankment, and possibly a surcharge fill, are placed above the drainage blanket. During consolidation, this blanket and its drainage system then allows water to drain horizontally away from the base of the new embankment. In some instances, prefabricated drainage strips that are horizontally positioned over the tops of the PVDs can be used instead of a sand blanket.

Design

Although vertical sand drains are still used (and are actually preferred in some instances), PVDs have generally replaced vertical sand drains. PVD design theories were adapted from sand drain design. The primary purpose of PVDs is to reduce the drainage path distance and subsequently decrease the time for settlement, which allows strength gain to occur. To accomplish this purpose, PVDs are typically installed on a rectangular or triangular grid pattern to reduce the flow distance for dissipation of excess pore water pressures that occur in compressible clay (or other) layers as a result of fill placement. Design of the drains requires proper evaluation of the soil and its vertical and horizontal drainage properties, and the effects of installation on the soil. Design parameters are also dependent on the scale of the project, construction schedule, and uniformity of the soil conditions. Simple projects can be analyzed with hand calculations (outlined in NAVFAC, 1982) or with the use of a spreadsheet program. Commercially available computer programs can be used for analyses where the rate of loading becomes more complex and hand solutions become impractical.

The following section outlines the main input parameters that influence the design of a PVD system.

Horizontal Consolidation Coefficient (c_h)

The horizontal consolidation coefficient (c_h) can be estimated using the vertical consolidation coefficient (c_v) resulting from one dimensional laboratory testing (Office of Materials Iowa Test Method 105). The horizontal consolidation coefficient (c_h) is evaluated using the following relationship:

$$c_h = \frac{k_h}{k_v} \times c_v$$

where:

k_h =horizontal soil permeability

k_v =vertical soil permeability

The ratio k_h/k_v is referred to as the “ratio of permeability”. It typically ranges from 1 to 5 at strain levels within disturbed soil. This ratio can also be expected to vary with soil sensitivity and the presence or absence of preferential flow pathways. In uniform clays, k_h/k_v ranges from 1.2 to 1.5. A conservative approach in uniform clays is to assume a k_h/k_v of 1, which makes c_h equal to c_v. If the clays contain silt and sand seams and lenses, the k_h/k_v typically ranges between 2 to 4 and is a function of the sand seam/lens density.

Equivalent Circular Drain Diameter

The equivalent circular drain diameter of a PVD has been determined using various methods and is a function of the PVD material dimensions. Equivalent circular diameters general range from 1.6 to 5.5 inches with the most common being 2.4 inches.

Drain Influence Zone/Spacing

The diameter of the influence cylinder, D, is a function of the drain spacing only. When using an equilateral triangular pattern, the diameter of the cylinder of influence, D, is 1.05 times the spacing between each drain. In a square pattern, D is 1.13 times the spacing between drains. Typically, to achieve approximately 90 percent consolidation in 3 to 4 months, designers often choose drain spacing between 3 to 5 feet in homogeneous clays, 4 to 6 feet in silty clays, and 5 to 6.5 feet in coarser soils.

Time

The time duration required to achieve the desired average degree of consolidation to meet the post-construction settlement criteria is a function of PVD spacing, and the embankment height and surcharge loading (if a surcharge above the normal embankment height is used). Typically, time is used as a constant (normally set to meet a specific construction schedule) The height of the embankment and possible surcharge (if used) and the PVD spacing are used as variables. In order to increase the PVD spacing and reduce the number of PVDs installed, a surcharge embankment can be included in the design to achieve the same amount of consolidation over the same time period. The addition of surcharge using a constant PVD spacing will also reduce the time for consolidation to occur.

References

1. Federal Highway Administration, 1986. Prefabricated Vertical Drains Volume 1, Report No. FHWA/RD-86/168.
2. Elias, V., Welsh, J., Warren, J., Lukas, R., Collin, J.G., and Berg, R.R., 2006. Ground Improvement Methods, Volumes I and II, FHWA NHI-06-019 and FHWA NHI-06-020, US Dept. of Transportation, Federal Highway Administration.
3. NAVFAC, 1982. Design Manual: Soil Mechanics, Foundations, and Earth Structures, DM-7.

Chronology of Changes to Design Manual Section:

200F-007 Prefabricated Vertical Drains

1/15/2014	NEW New