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STORMCAPTURE®

Technical Note SC-01

Designing Unreinforced Gravel Foundations for Open Bottom StormCapture Systems

Water

Purpose

This Technical Note is intended to provide guidance to engineers designing underground stormwater detention using the StormCapture system as developed by Oldcastle, in the open bottom configuration. This Technical Note also provides guidance to geotechnical engineers conducting investigations and providing recommendations related to such systems. Designers and geotechnical engineers should understand that allowable soil bearing pressure is an important design consideration for open bottom applications of the StormCapture system.

Figure 1 and Figure 2 illustrate the open and closed bottom configurations of the StormCapture system, respectively. Procedures outlined in this Technical Note are intended for open bottom applications only. Oldcastle does not promote the use of LinkSlab elements in conjunction with StormCapture open bottom vaults with unreinforced gravel foundations.

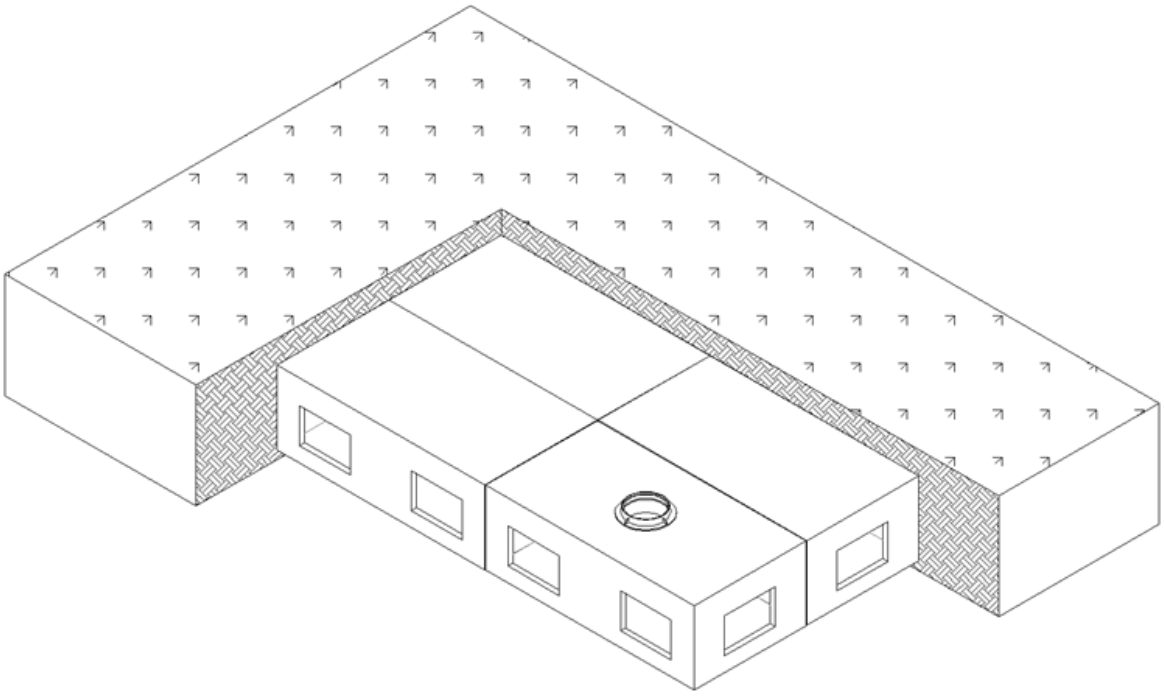

Figure 1: Open Bottom StormCapture System

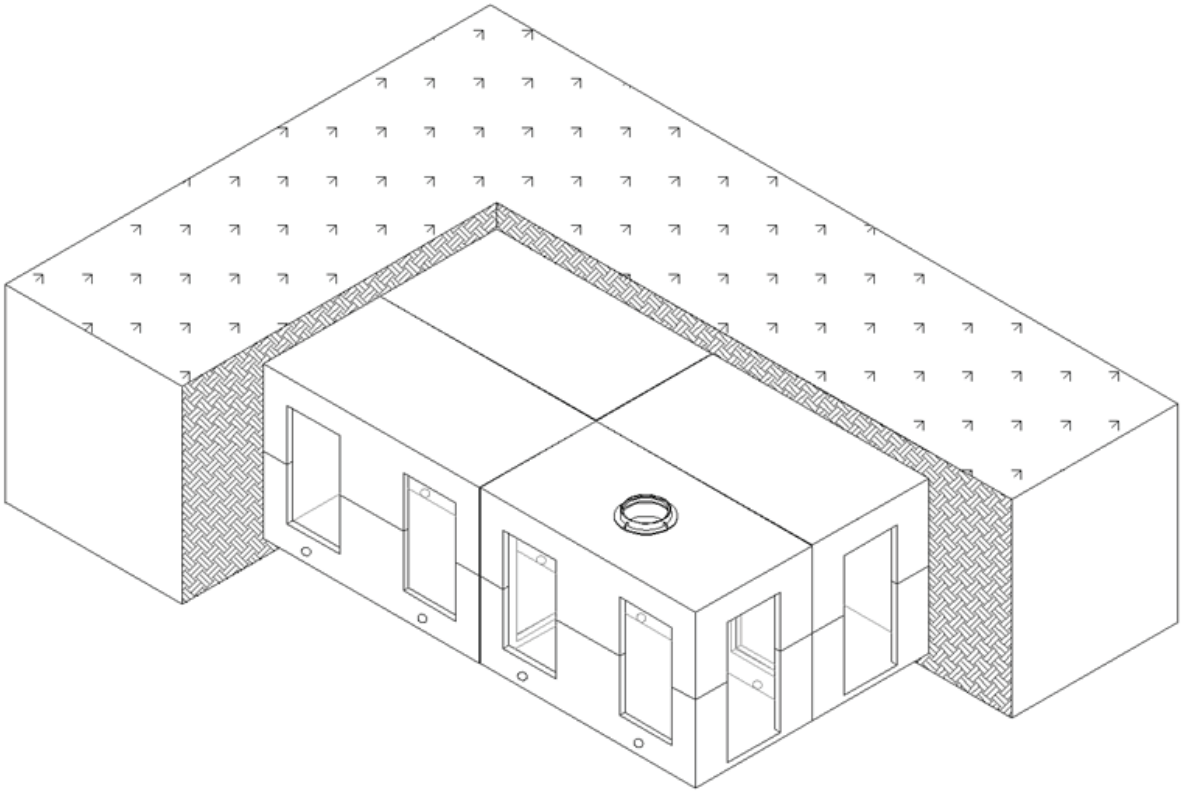

Figure 2: Closed Bottom StormCapture System

The Aggregate Bearing Layer

Open bottom applications of the StormCapture system must be provided with a highly competent compacted crushed Aggregate Bearing Layer (ABL), as shown on **Figure 3**. Oldcastle also recommends providing a geotextile filter fabric layer on top of the native subgrade and under the ABL to prevent the migration of fines from the subgrade and to help minimize settlement of the rock layer into the native soil layer. Oldcastle recommends a No. 57 or No. 56 stone gradation per ASTM C33 for the ABL. Specifications for the geotextile filter fabric should be developed by the designer. Contact Oldcastle for assistance if needed. Adherence to specifications is important to assure that appropriate stress distribution occurs in the ABL, so that the allowable soil bearing pressure of the subgrade is not exceeded. Adherence to the specification will also help to minimize the potential for settlement. Following the procedures outlined below, the designer can determine the thickness of the ABL required to meet the geotechnical recommendations for allowable soil bearing pressures. Extra care and analysis is recommended for open bottom applications of the StormCapture system for sites with allowable soil bearing pressure below 2000 psf. For sites with allowable soil bearing pressure below 1500 psf several alternatives exist, including the use of a StormCapture precast bottom slab.

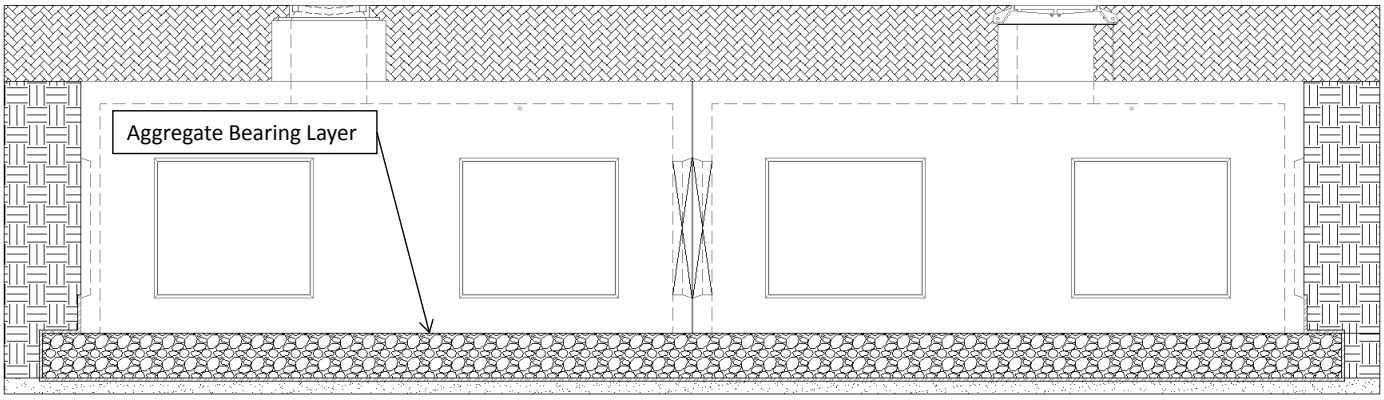

Figure 3: StormCapture System Elevation View

Checklist for Design

In order to proceed with design of the ABL thickness in accordance with this Technical Note, the designer should have already completed the hydraulic and geometric design of the StormCapture system for the site. This process will determine both the system height and depth of cover, which are needed to compute the foundation loading of the StormCapture vaults. The designer must also determine the appropriate traffic loading the system will be subject to, if applicable. For applications that will be subjected to normal highway truck loading, HS-20 loading generally may be assumed. Applications subject to heavy construction equipment may involve higher design traffic loading. Contact Oldcastle for guidance on the impact of construction loading on StormCapture units and foundations. Finally, the designer must know the allowable soil bearing pressure, which will normally be provided by a geotechnical engineer. The following checklist is provided to assist the designer in collecting the necessary information:

1. StormCapture system height.
2. Depth of cover.
3. Traffic loading.
4. Allowable soil bearing pressure at bottom of system.

Geotechnical Criteria

The geotechnical engineer should provide an allowable soil bearing pressure for native soils at the location and depth of the StormCapture system as determined or planned by the system designer. These systems will typically bear 5 to 10 feet below finished grade in the open bottom configuration, and thus an allowable bearing pressure somewhat higher or lower than might be recommended for structures bearing at shallow depths may be appropriate, depending on ground conditions. The geotechnical engineer should consider both bearing capacity and allowable post-construction settlement in determining the allowable soil bearing pressure for open bottom StormCapture system applications. The geotechnical engineer should take into consideration groundwater conditions and seismic criteria (if applicable) in preparing recommendations. If actual foundation loading is not available to the geotechnical engineer from the system designer at the time of preparation of the geotechnical report, the geotechnical engineer can conservatively assume the "typical maximum" load indicated on Figure 4, though recommendations based on actual design configuration should enhance economy and thus are encouraged. Special care is recommended for open bottom applications of StormCapture systems bearing within 2 feet of the groundwater table, or where the allowable bearing pressure is less than 2000 psf.

Determine Design Foundation Loading

Foundation loading for design may typically be determined using Figure 4, which is for HS-20 traffic loading. Enter the chart with the vault inside height and depth of cover, and determine the foundation load, which is a line load given in kips per linear foot. A maximum StormCapture system height of 7 feet (inside dimension), and a maximum depth of cover of 5 feet (from top outside of vault to finish grade), produces the typical maximum load of about 3750 pounds per lineal foot per wall on top of the ABL. When two walls are adjacent to each other the maximum load is doubled to 7500 plf as indicated on Figure 4.

The depth of cover should include the fill thickness over the top of the vault, plus any pavement or road base thickness. Figure 4 is based on HS-20 traffic loading. For applications involving different traffic loading, the designer may contact Oldcastle for assistance.

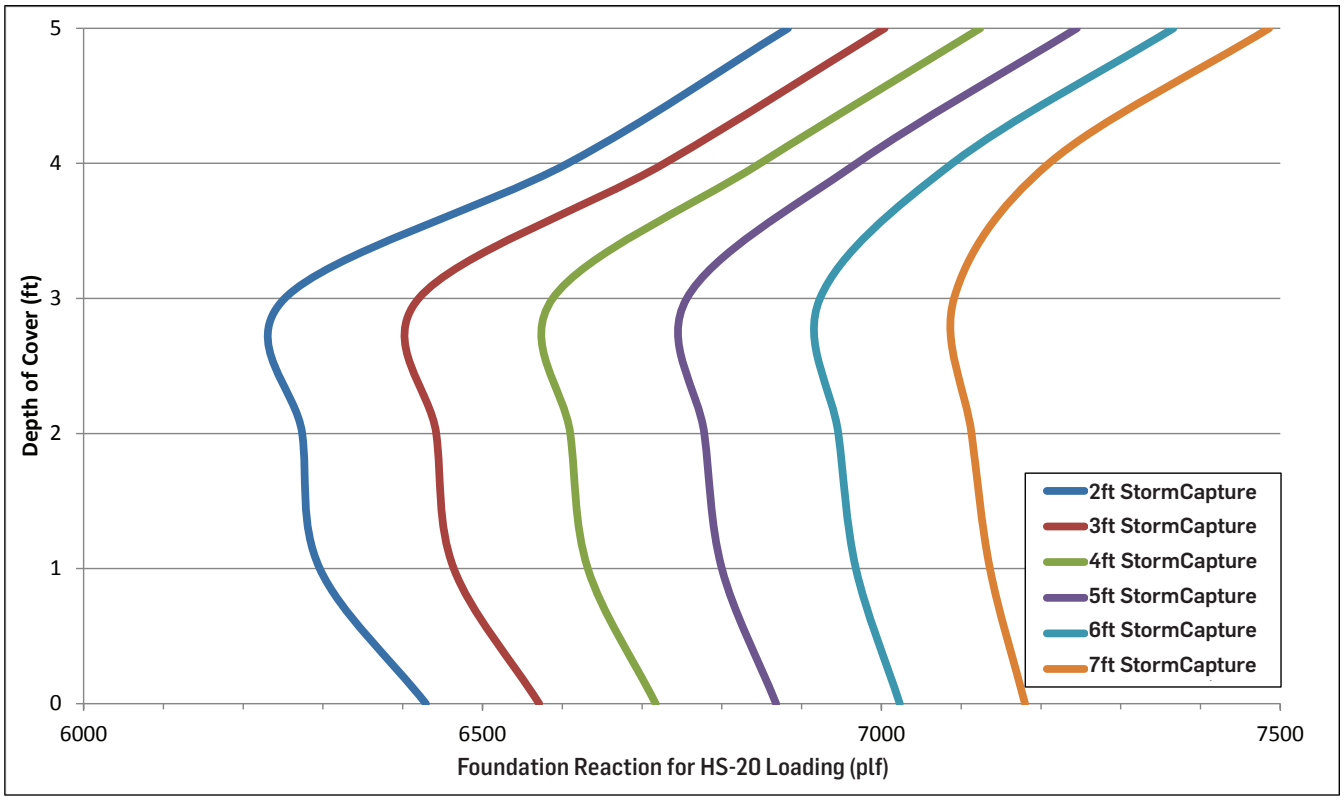

Figure 4: Foundation Reaction for HS-20 Loading with Two Adjacent Walls

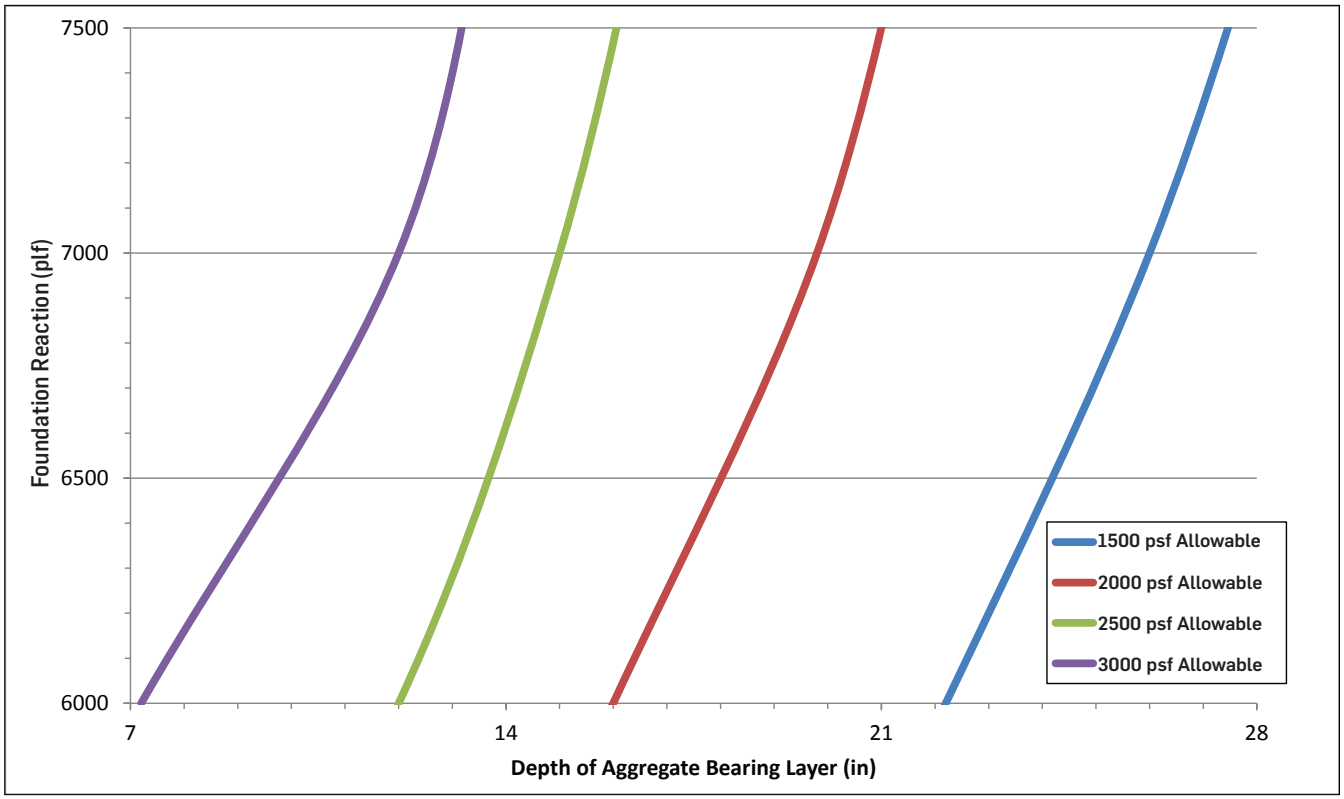

Figure 5: Aggregate Bearing Layer Thickness

Determine ABL Thickness

ABL thickness may be determined using **Figure 5**. This chart is based on a Westergard stress distribution in the ABL as is explained in numerous references (Sowers, 1979).

To determine the ABL thickness enter the chart with the foundation line load determined as outlined above, and the allowable soil bearing value from the geotechnical report. The chart provides the thickness of the ABL in inches. As with **Figure 4**, this chart is for open bottom StormCapture vaults placed adjacent to each other, which will normally control the ABL thickness.

Recommendations

The following recommendations are provided to engineers and contractors considering use of StormCapture units in open bottom configuration:

1. As indicated in the design examples that follow, the allowable bearing pressure should be developed for the depth and loading of the StormCapture system. Depending on a number of factors, use of a generic allowable bearing pressure for building foundations may or may not be appropriate.
2. Consider grade changes in developing the allowable bearing pressure. A significant grade change at the system location could affect the allowable pressure.
3. Bearing at or below the groundwater table is not recommended for an open bottom configuration. Oldcastle recommends bearing a minimum of 2 feet from the groundwater elevation.
4. Open bottom systems require special care for allowable bearing pressure less than 2000 psf.
5. Open bottom applications bearing on significant thicknesses of site fill (other than ABL) are generally not recommended, unless that fill is specifically engineered to tolerate subsequent moisture infiltration, or a liner is provided.
6. Similarly, open bottom applications are generally not recommended over moisture sensitive soils such as highly expansive soils or collapse-prone soils, unless specifically evaluated and addressed by the geotechnical engineer, or an appropriate liner is provided.

Sowers, G. F. (1979). *Introductory Soil Mechanics and Foundations: Geotechnical Engineering.* New York: Macmillan.

Appendix: Design Examples

Design Example 1

Description:

The project involves construction of a shopping center in the coastal plain on the eastern seaboard. Underground detention is desired in a portion of the paved parking area. The geotechnical engineer was informed of this desire and was provided with the location, basic geometry, and loading estimates for the StormCapture system prior to his investigation. Borings located for the proposed system detected a thin (3 to 5 foot thick) surface layer of stiff sandy clay over 20 or more feet of medium dense to dense sands and silty sands, with groundwater at 15 feet. Grading plans call for finished grade to be 2 to 3 feet above existing grade in the area of the proposed detention system. Hydraulic and geometric design has been performed for the system to determine vault height and depth of cover.

Available information:

1. Inside height of StormCapture vault = 5 feet.
2. Depth of cover = 5 feet.
3. Standard highway truck loading.
4. Geotechnical report recommends "3000 psf allowable native soil bearing pressure for StormCapture open bottom system bearing approximately 10 feet below finished grade (or 7 to 8 feet below existing grade), supported on a compacted crushed aggregate bearing layer (ABL) designed and constructed in accordance with Oldcastle recommendations for StormCapture vaults."

Solution:

1. Since standard highway truck loading applies, Figure 4 is applicable for determination of foundation load.
2. See Figure 6, design loading is taken to be 7.3 kips per foot (for two adjacent walls).
3. The geotechnical report provides an allowable soil bearing pressure for the appropriate location and depth, with a general stated understanding of the proposed system.
4. The allowable bearing value is sufficiently high and the reported groundwater sufficiently deep that open bottom StormCapture system is appropriate.
5. From Figure 5, an ABL of 13 inches is appropriate for an allowable bearing pressure of 3000 psf (see Figure 7).

The aggregate bearing layer should be prepared with a minimum of 13" highly compacted crushed aggregate.

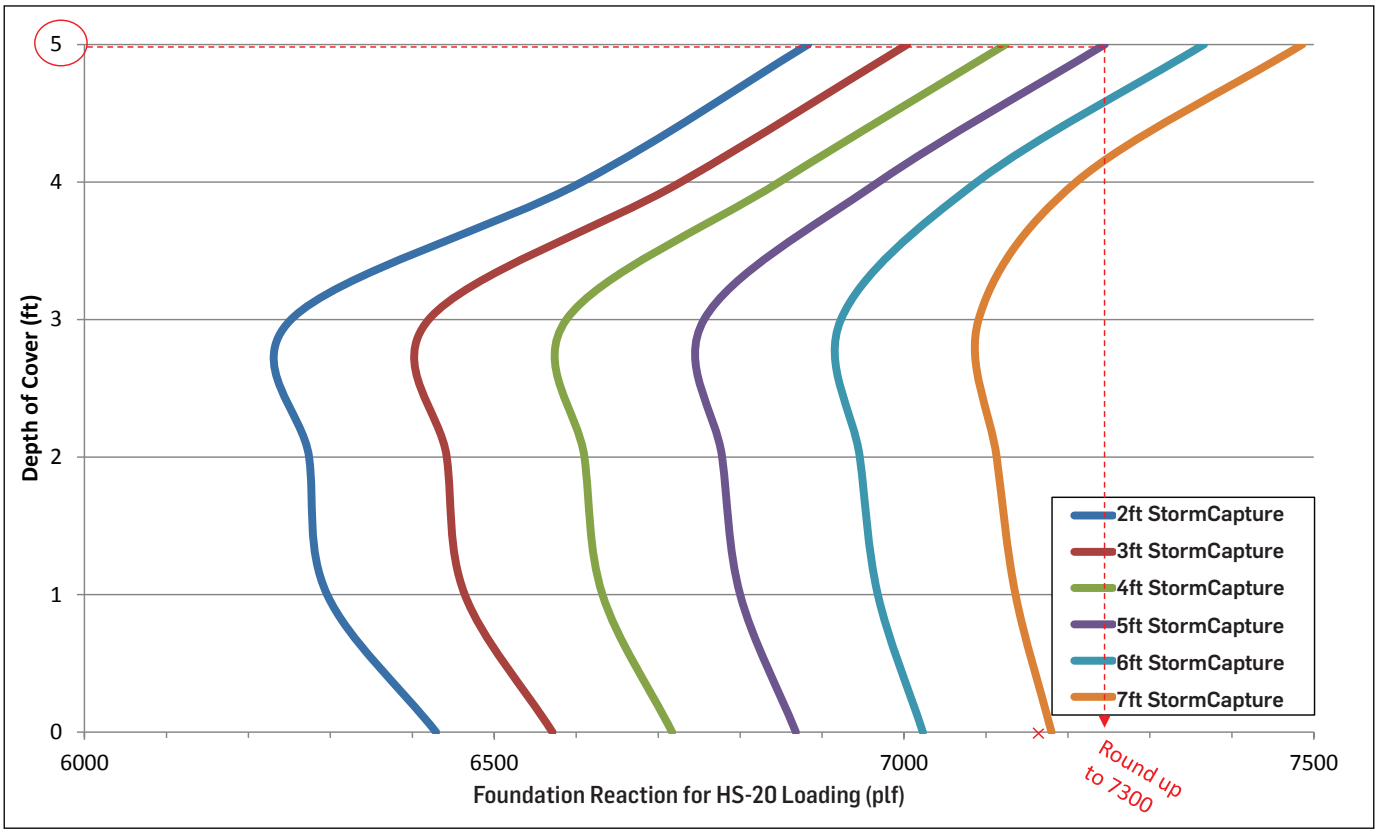

Figure 6: Replication of Figure 4 for Design Example 1

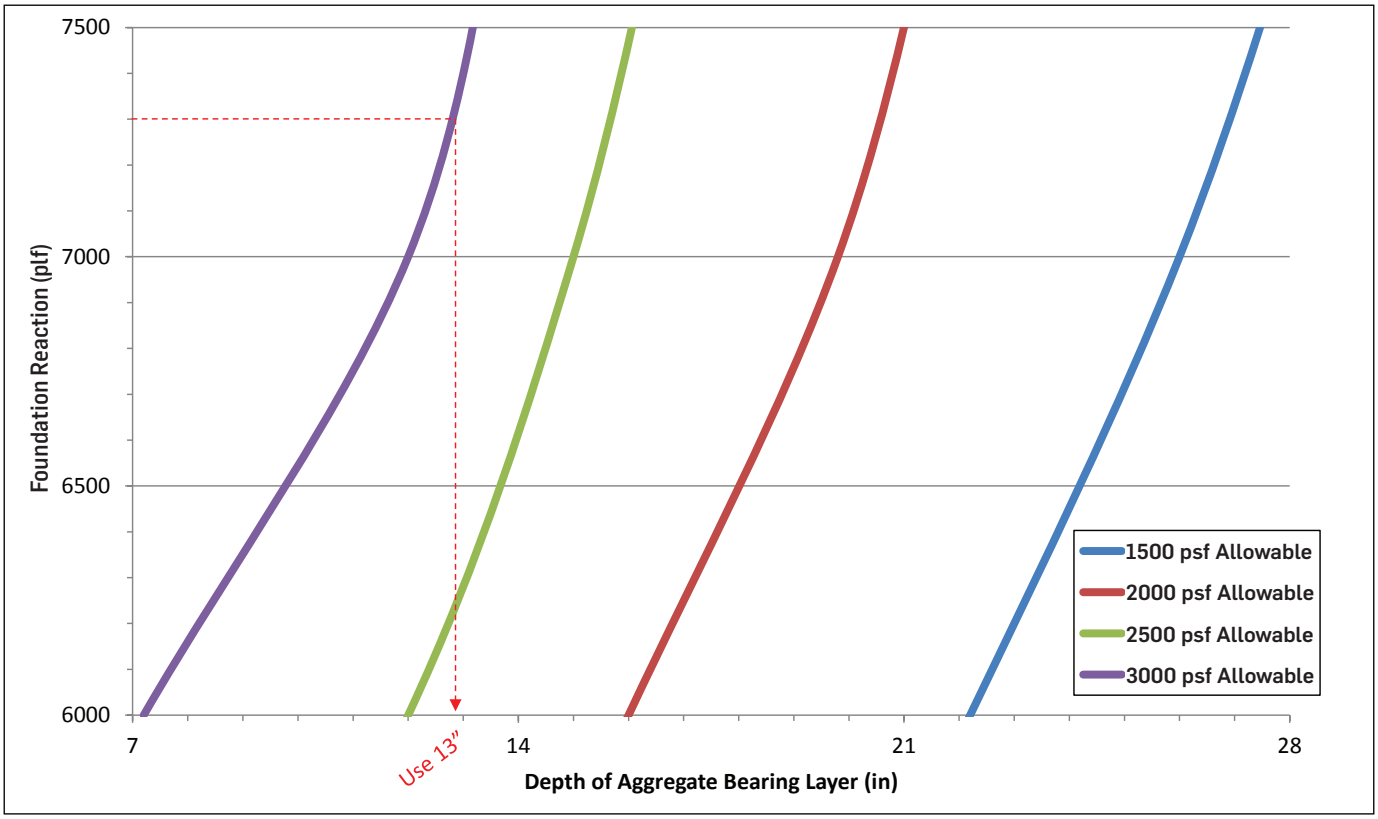

Figure 7: Replication of Figure 5 for Design Example 1

Design Example 2

Description:

The project involves construction of a mixed use office and retail complex in a southern state. Space is at a premium, so underground detention is desired. However, this need has only recently become apparent. The geotechnical report is over 2 years old, and predates plans for underground detention. Borings scattered throughout the building and parking areas appear to cover the area that has been selected for the proposed StormCapture system, but the geotechnical report does not address underground detention, nor does it provide allowable bearing values for the appropriate depths. Borings detected pockets of existing loose sand fill in the upper 5 feet, and the report provides recommendations for removing and replacing this material with imported engineered fill. Deeper soils were loose to medium dense sands, with blow counts increasing with depth. The report recommends an allowable bearing pressure of 2000 psf for footings placed in engineered fill, or in native material subject to inspection, with the expectation that these footings will bear 18 to 24 inches below finished grade. Groundwater was encountered about 13 to 16 feet below grade in the general area proposed for the underground system. Proposed grade change in this area is minimal. Hydraulic and geometric design has been performed for the system to determine vault height and depth of cover.

Available information:

1. Height of vault 5 feet.
2. Depth of cover 4 feet.
3. Standard highway truck loading.
4. Geotechnical report does not address underground detention, and does not provide bearing pressures relevant to the StormCapture system.

Solution:

1. Contact owner and geotechnical engineer and explain need for allowable bearing value at depth approximately 9 feet below existing and proposed grade in area of proposed detention system. Provide loading estimate and background information on StormCapture system.
2. Geotechnical engineer reviews file, including boring logs, lab data, and previous calculations. He conducts some additional calculations and informs the system designer and owner that at the location and depth in question, a somewhat higher allowable pressure is appropriate, since the system will bear below any questionable near surface soils, and the density generally improves with depth at this location. After some discussion, he recommends an allowable native soil bearing pressure of 2500 psf for the specific location and depth in question. Now you have what you need.
3. Using **Figure 4**, the foundation line load is approximately 7000 kips per linear foot (see **Figure 8**).
4. Enter **Figure 5** with 7000 kips per linear foot and an allowable native soil bearing pressure of 2500 psf. From **Figure 5**, an ABL with a thickness of 15 inches is sufficient (see **Figure 9**).

The aggregate bearing layer should be prepared with a minimum of 15” highly compacted crushed aggregate.

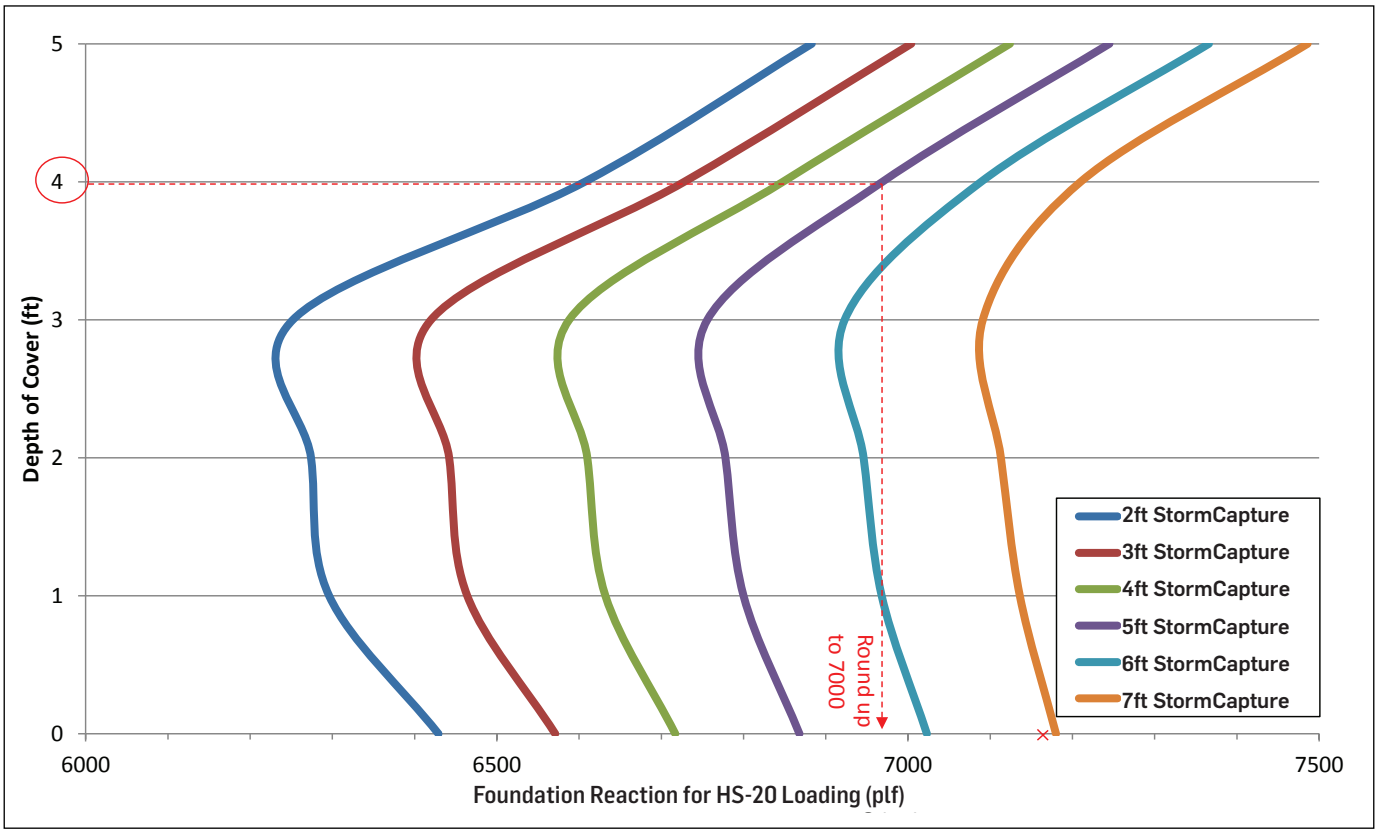

Figure 8: Replication of Figure 4 for Design Example 2

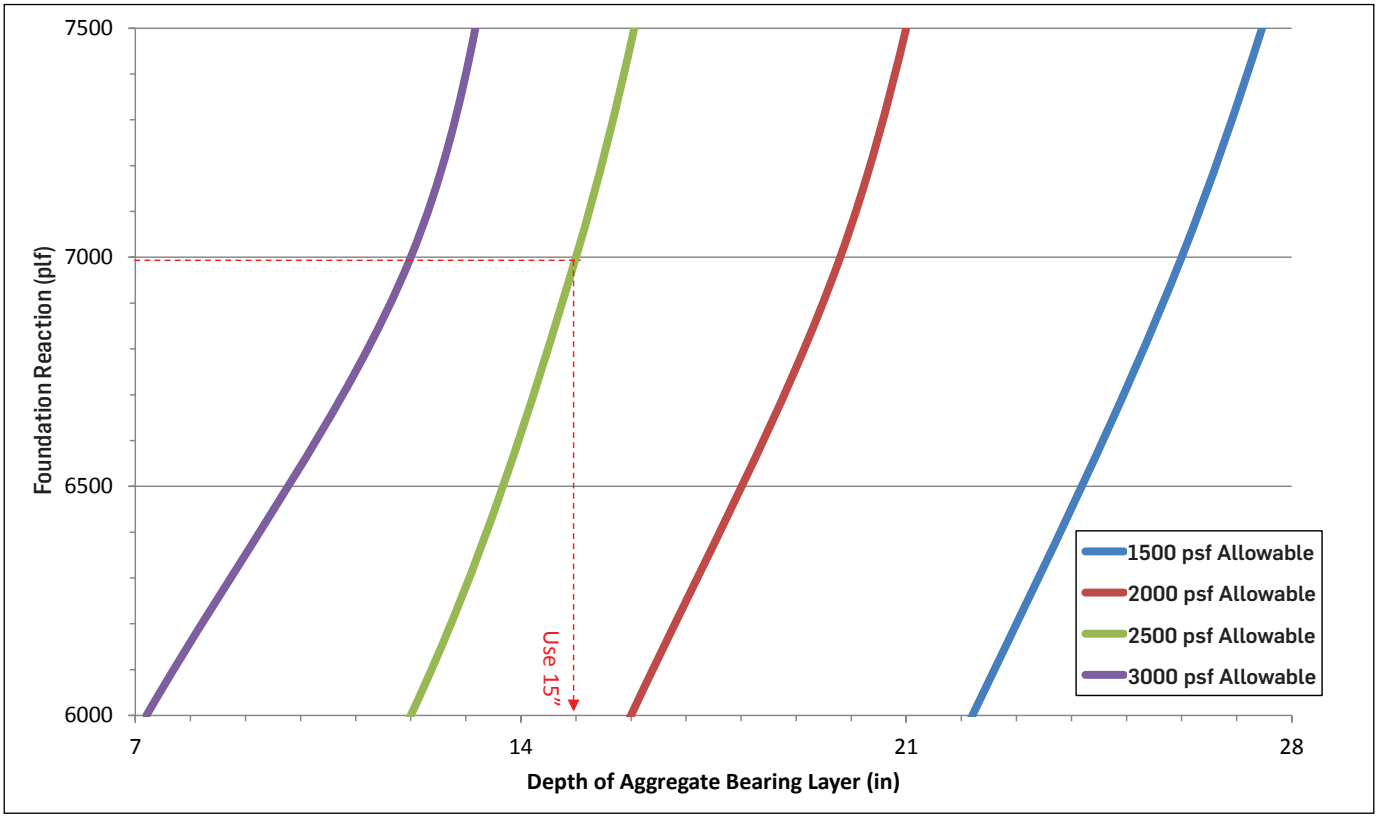

Figure 9: Replication of Figure 5 for Design Example 2

Design Example 3

Description:

The project involves construction of a large apartment complex with surface parking lots along the gulf coast. Adequate space for a conventional surface detention pond is not available, and an underground detention system is desired. The geotechnical engineer understood this when the report was prepared, but he did not understand the details and concepts of the StormCapture open bottom system, and prepared his report with recommendations related to closed bottom systems. Borings in the area of the proposed system found 8 to 12 feet of relatively firm sand over a layer of soft, organic clay, becoming softer with depth. Groundwater was encountered near the top of this soft clay layer. Grading plans call for a grade raise of about 2 feet in the area of the proposed system. The geotechnical report identifies settlement concerns where grade is raised, and thus recommends settlement monitoring following grading. Foundation recommendations include shallow (18 inch depth) footings designed for 3000 psf allowable bearing pressure after settlement monitoring is complete. It also provides an alternative for deep foundations. Preliminary hydraulic and geometric design has been completed for an open bottom StormCapture system.

Available information:

1. Height of vault 5 feet.
2. Depth of cover 3 feet.
3. Standard highway truck loading.
4. Geotechnical report does not provide bearing pressures relevant to the StormCapture system in open bottom configuration.

Solution:

1. Contact owner and geotechnical engineer and explain need for allowable bearing value at depth approximately 8 feet below proposed grade (6 feet below existing grade) in area of proposed detention system. Provide loading estimate and background information on StormCapture system in open bottom configuration.
2. Geotechnical engineer reviews file, including boring logs, lab data, and previous calculations. He expresses concern over use of open bottom in this application due to the soft clay layer near the bearing level of the system. He conducts some additional analysis, and meets with the civil engineer. They review grading plans and the depth of the soft layer and conclude that it should be 3 or more feet below the excavation bottom at the location of the proposed system due to the grade rise in the area. After some discussion and additional analysis, he recommends an allowable native soil bearing pressure of 2000 psf for the specific location and depth in question, subject to special inspection of ground conditions. In addition, he cautions that the grade raise and settlement monitoring must be complete prior to excavation and construction of the system.
3. Figure 4 applies. The foundation line load is approximately 6800 kips per linear foot (see Figure 10).
4. Enter Figure 5 with 6800 kips per linear foot and an allowable native soil bearing pressure of 2000 psf. An ABL with a thickness of 20” inches is sufficient (see Figure 11).

Prepare plans for an ABL with minimum thickness of 20 inches. Include notes cautioning contractor regarding special inspection and settlement monitoring.

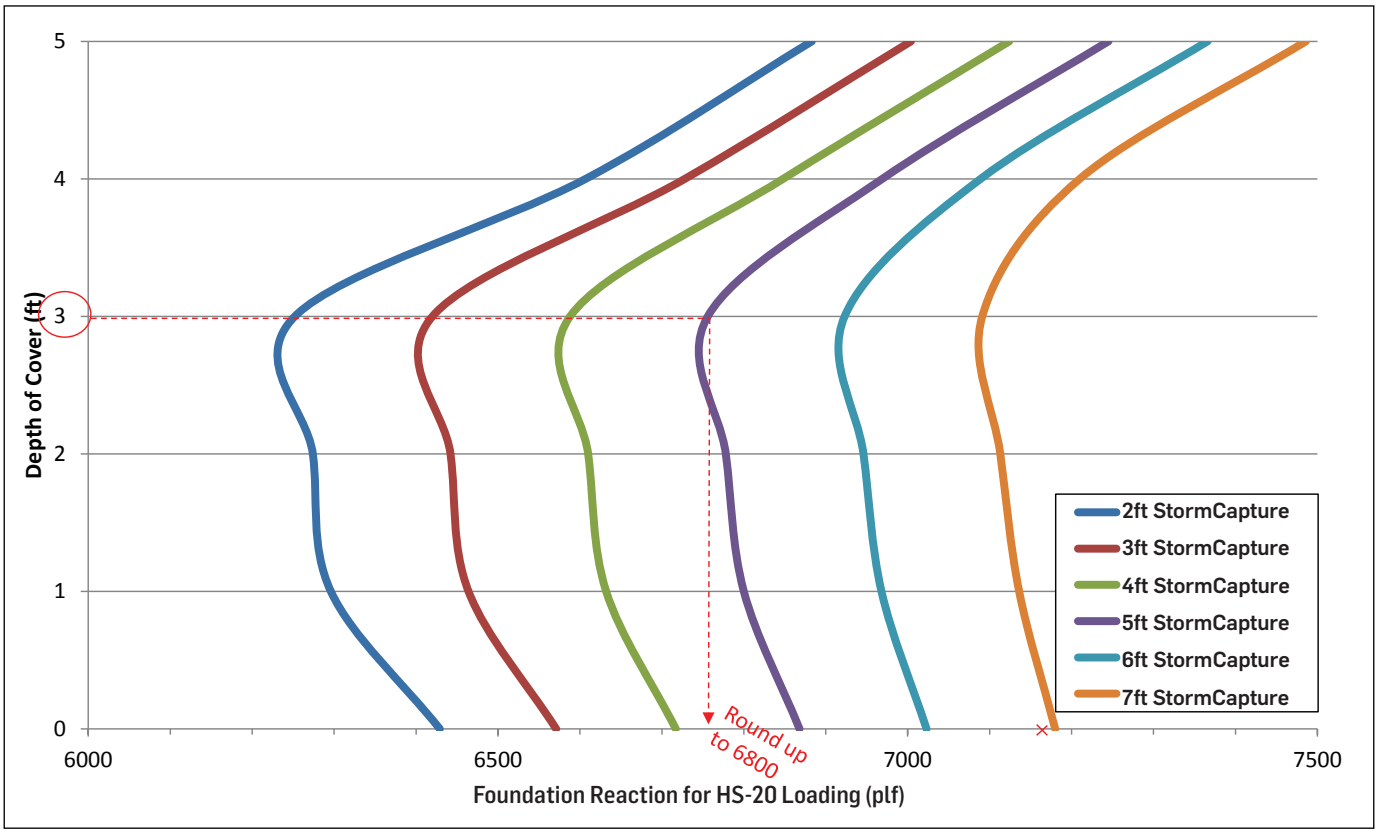

Figure 10: Replication of Figure 4 for Design Example 3

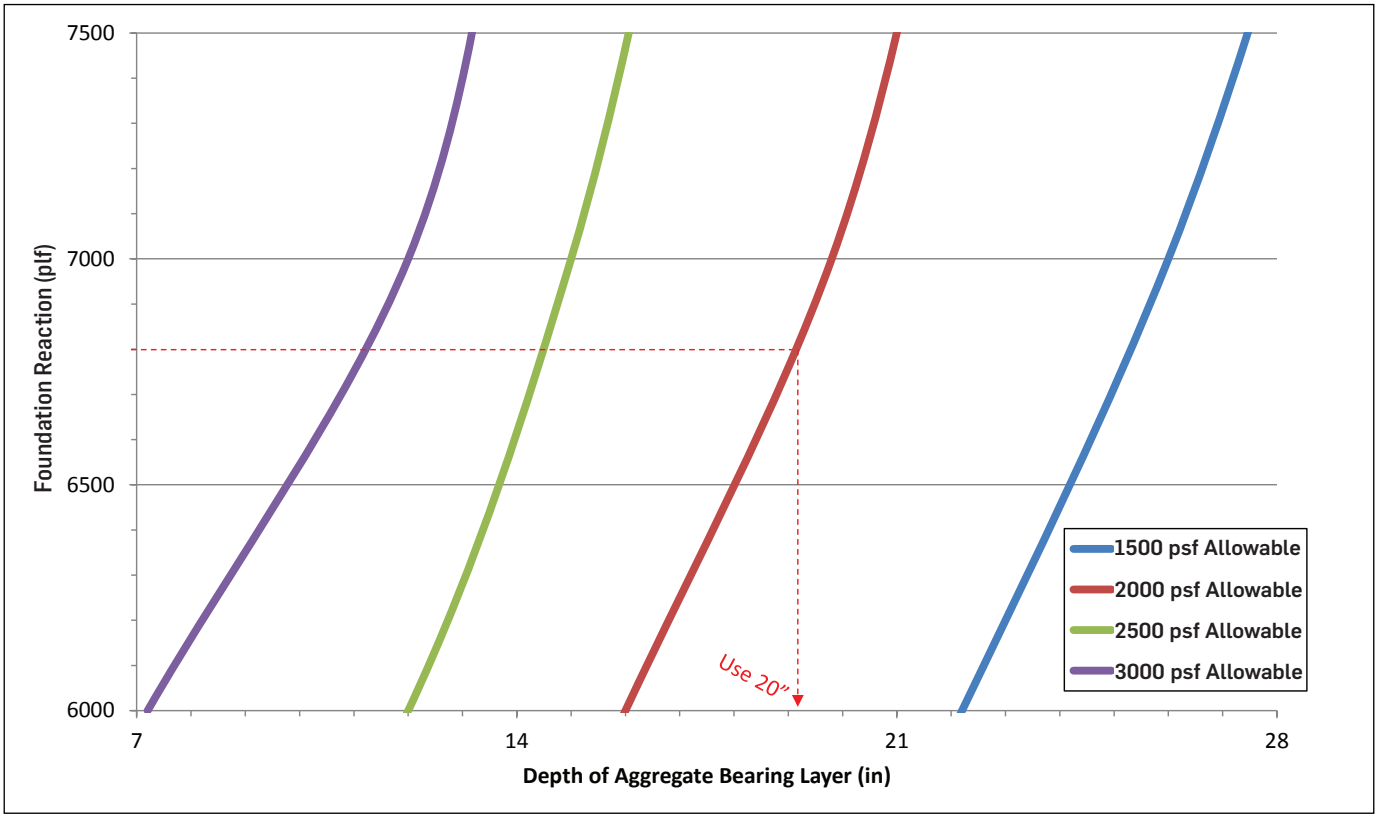

Figure 11: Replication of Figure 5 for Design Example 3

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