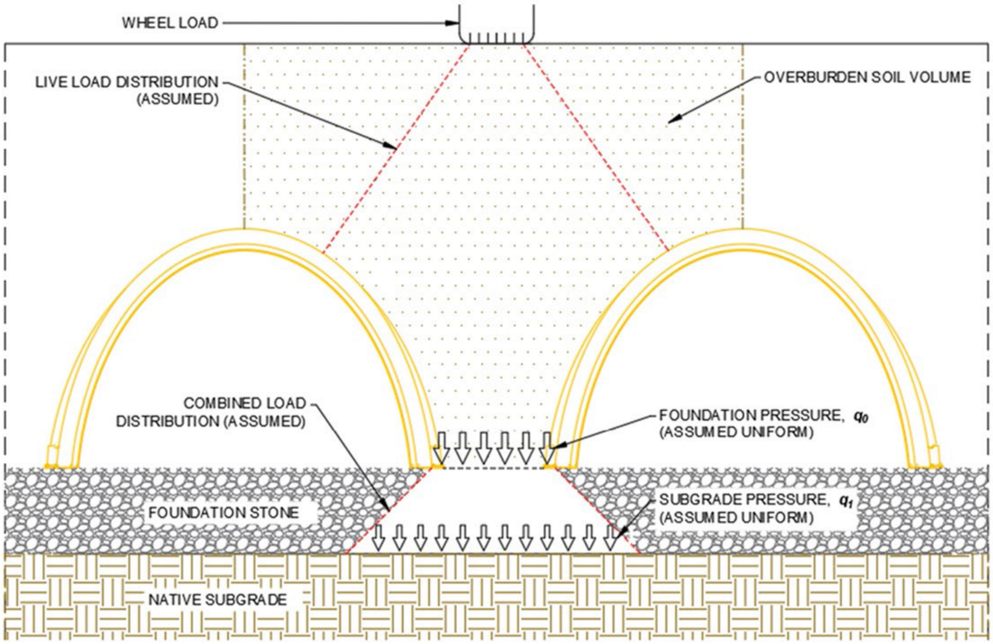
Technical Note

TN 6.25_C Stabilizing StormTech® Chamber Foundations with StormGrid™

StormTech Chambers are arch structures that concentrate overburden loads at the chamber bases and the stone columns between chamber rows. A layer of crushed foundation stone beneath the chambers helps to spread these concentrated loads, ensuring they are distributed to an appropriate bearing pressure on the subgrade. The foundation stone thickness for the specific chamber application is based on the overburden loads and allowable subgrade bearing capacity. Placing a StormGrid at the interface of the foundation stone and the subgrade is an innovative approach (patent-pending) to increase load transfer efficiency. This reduces the depth of foundation stone needed to achieve adequate pressure on the subgrade. Figure 1 presents the conceptual loading diagram.

Figure 1: Conceptual Loading Diagram[2]



Foundation Performance Considerations

It is common practice for geotechnical engineers to place a “Bridging Layer” consisting of high strength materials over weaker materials, such as the crushed stone foundation used by StormTech. For roadways this approach is used to achieve a working surface to support paving operations. Subgrade preparation for shallow foundations also uses this approach to increase bearing capacity and reduce potential settlement.

Use of StormGrid for stabilization increases the shear length and ductility of the aggregate layer. These stabilization effects are illustrated in Figure 2. This enhancement occurs as the aggregate particles are restrained against translation and rotation by interlocking with the StormGrid apertures.

StormGrid stabilized aggregate layers effectively increase bearing capacity by reducing shear-induced settlement mechanisms and consolidation of the subgrade. The stabilization effect distributes the footing load over a wider and deeper zone into the subgrade, reducing applied subgrade pressure concentrations as shown in Figure 3.

Figure 2: Additional shear strength from geogrid stabilization measured in a very large triaxial compression test (after Lees 2018)

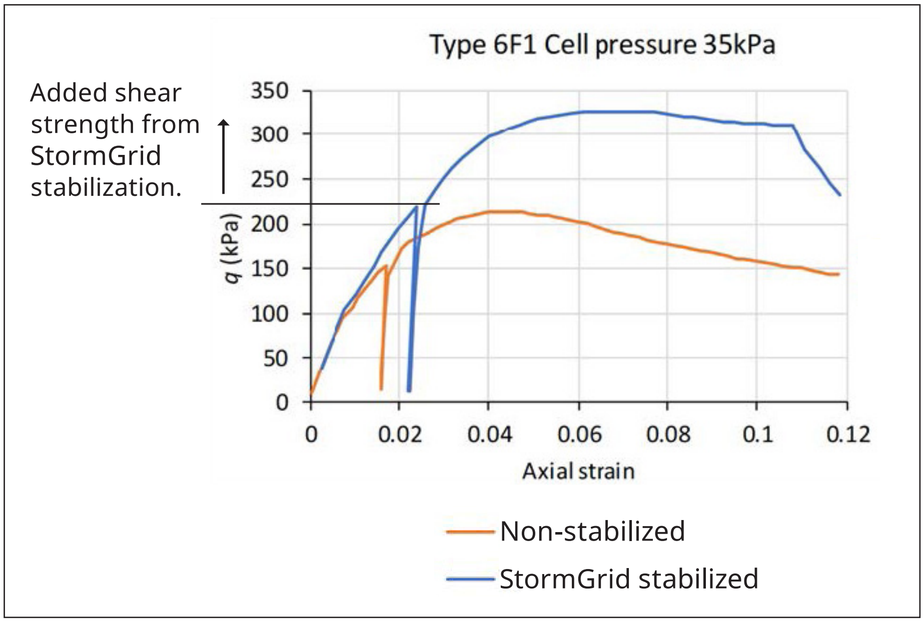
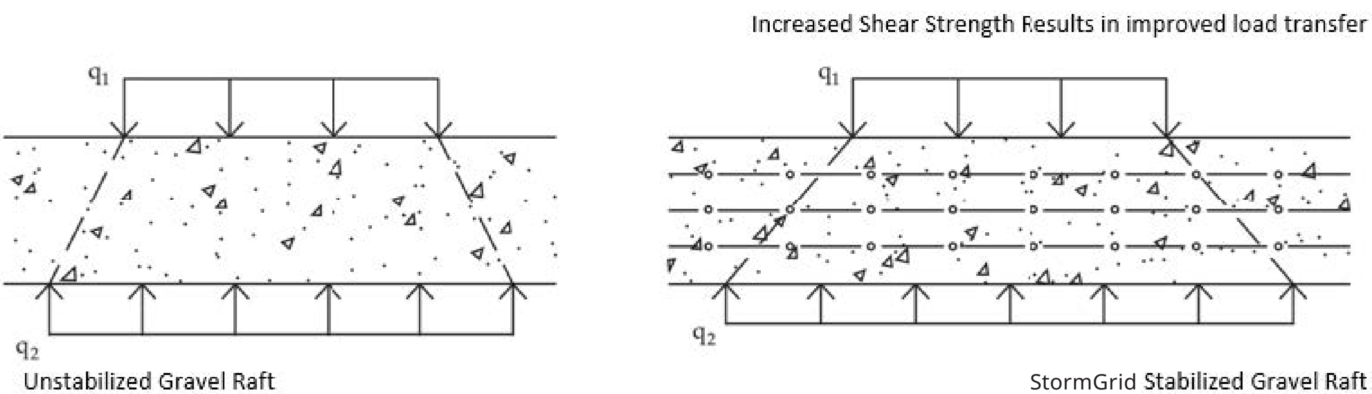


Figure 3: Improve load spread and transfer surcharge with StormGrid stabilized foundation stone



The benefit of StormGrid stabilized foundation stone on bearing capacity is characterized in the "T-Value" Method by Lees (2018) with the development of a linear relationship between bearing capacity ratio (q_u/q_s) and the normalized stabilized gravel raft thickness (H/B). Figure 4 depicts this generalized foundation design.

$$\frac{q_u}{q_s} = 1 + T\frac{H}{B} \quad \text{(strip footing)} \qquad \textbf{Equation 1}$$

$$\frac{q_u}{q_s} = \left(1 + T\frac{H}{B}\right)^2 \quad \text{(square footing)} \qquad \textbf{Equation 2}$$

Where:

q_u = bearing capacity at the top of the aggregate layer

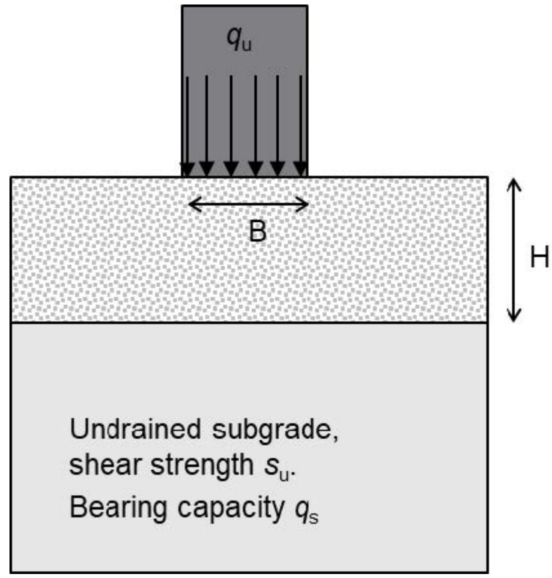
q_s = bearing capacity of the subgrade

T = load transfer efficiency determined from Figure 5

H = StormGrid stabilized foundation stone thickness

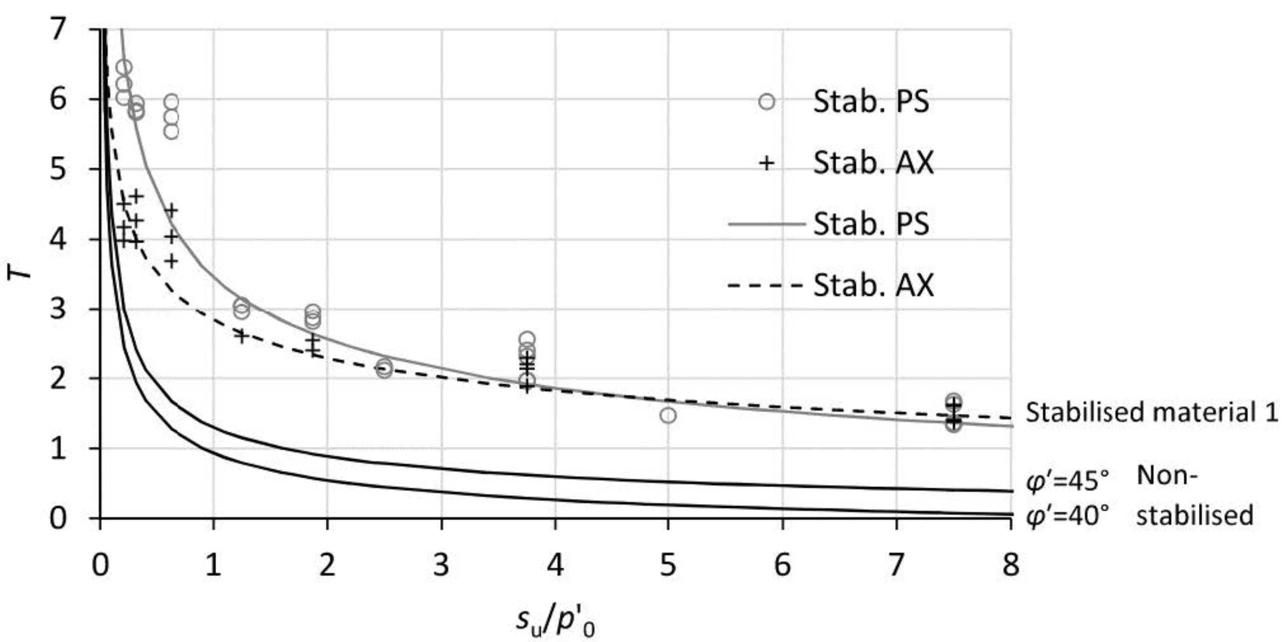
B = footing width

Figure 4: Geometry for StormGrid Stabilized Foundation Stone Design Method



The load transfer efficiency (T) of a foundation stone depends on the shear strengths of the aggregate layer and underlying subgrade as illustrated in Figure 5. The solution is normalized to p'_0, the effective vertical stress at the base of the aggregate layer.

Figure 5: Transfer Surcharge Efficiency Chart after Lees and Kawalec (2022)



Design Example: MC-7200 StormTech Chamber

Example 1: ADS StormTech Chamber MC-7200
Cover Height 2.1 meters (7’)
Chamber Rise 1.5 meters (5’)
Allowable (FOS = 2.5) Subgrade Bearing Capacity 124.5 kPa (2,600 lbs per square foot)
HS-20 Applied Loading
Assumed Unit Weight of Soil: 15.71 kN/m^3 (100 lb/ft^3)
Lees and Kawalec (2022), N_C= 5.19

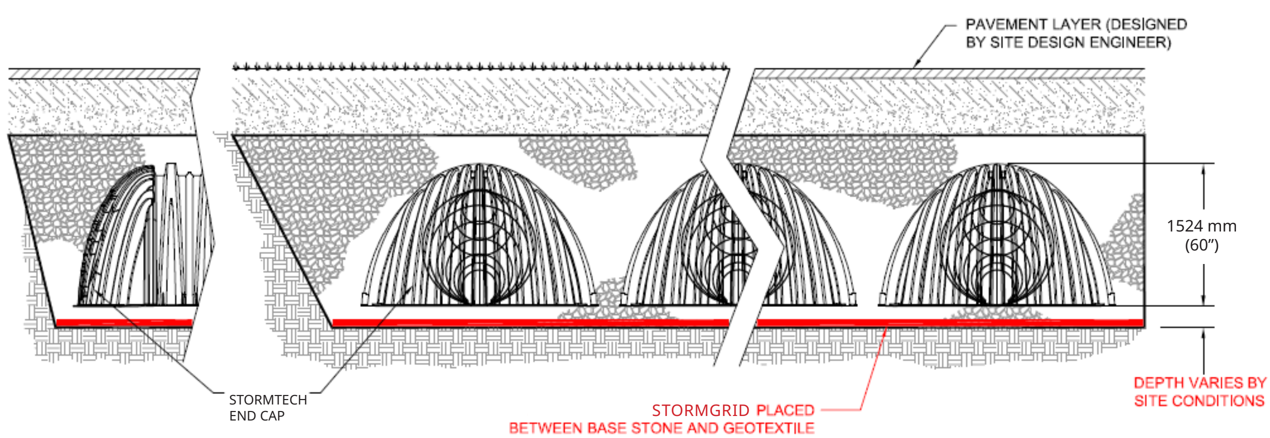
Determine the thickness of the foundation stone layer needed to support the StormTech chamber with:

- Allowable (FOS = 2.5) Subgrade Bearing Capacity (q_s): 124.5 kPa (2,600 lbs psf).
- $S_u = \frac{q_s}{N_c} = \frac{124.5\text{ kPa}}{5.14}$ = 24.2 kPa (505.8 psf). This is allowable S_u with the same factor of safety already determined for bearing capacity.
- Row Spacing is 229 mm (9”), chamber footing width 114 mm (4.5”): Applied load width is 114 mm (4.5”) + 114 mm (4.5”) + 229 mm (9”) = 457 mm (18”) = 0.46 m (1.5’) = B
- Applied Load (q_u) is 380.5 kPa (7,947 lbs psf) ASTM F2787
- $p'_0 = H * (y_s)$ = 457 mm * (15.71 kN/m^3) = 7.18 kPa
- $\frac{S_u}{p'_0} = \frac{24.2\text{ kPa}}{7.18\text{ kPa}} = 3.37$
- Equation 3 [Lees and Kawalec (2022)], $T = 4.06\left(\frac{S_u}{p'_0}\right)^{-0.36} - 0.6 = 2.02$
- Equation 1 [Lees and Kawalec (2022)], $\frac{q_u}{q_s} = 1 + T\left(\frac{H}{B}\right)$
- $\frac{q_u}{q_s} = \frac{380.5\text{ kPa}}{124.5\text{ kPa}} = 3.06$
- $3.06 = 1 + 2.02\left(\frac{H}{0.450}\right)$
- H = 0.459 m (1.52’) = 459 mm (18.3”)
- H is approximately 457 mm (18”) with the StormGrid.
  - This calculation is iterative as the H variable in the formula for p'_0 is the same as the H variable solved for in Equation 1. This is repeated to find the point where both H values converge.

StormGrid Stabilized Crushed Foundation Stone Installation

In most cases, StormGrid stabilized crushed foundation stone thicknesses range between 150 mm - 600 mm (6” - 24”). For StormTech system installation, the StormGrid is placed at the interface between the crushed foundation stone and the subgrade as shown in Figure 6.

Figure 6: Geogrid Location



Site Preparation

- Excavate the StormTech bed and prepare the subgrade per engineer's plans.
- Smooth the subgrade so that it is free from ruts or undulations greater than 100 mm (4") in depth.
- Install the ADS 601T nonwoven geotextile over the prepared subgrade and up the excavation walls.

Placing Geogrid

- Position the rolls of StormGrid at the edge of the excavation base, cut the roll bands and manually unroll the material over the prepared surface.
- Before fully unrolling the geogrid, anchor the beginning of the roll to the underlaying surface in the center and at the corners of the roll's edge. Anchoring can be done with small piles of aggregate, pins, or heavy gauge staples.
- Unroll the geogrid. Align it and pull it tight to remove wrinkles and lay down slack with hand tension, then secure in place. If necessary, geogrid can be repositioned after it has been unrolled. Lift adjacent unrolled sheets at their edges to avoid snagging.
- Geogrid should extend beyond the StormTech chambers by at least 300 mm (12") or depth of the aggregate base thickness, whichever is greater.
- Overlap geogrid at least 450 mm (18") in all directions.
- Adjacent geogrid rolls should be shingled in the intended direction of aggregate spread.

Dumping and Spreading Crushed Foundation Stone

- Place clean, crushed, angular stone foundation in controlled lifts over StormGrid.
- Only operate rubber-tired equipment directly on the geogrid if the underlying subsoil is not prone to rutting under construction traffic.
- Level grade the top of foundation stone and compact to achieve a flat surface.
- Refer to the StormTech Installation Guides for additional details about the construction of the StormTech system.

Making Repairs

If StormGrid becomes damaged during or after installation, repair it by patching the area with the following measures:

- Remove fill from the surface of the damaged geogrid and clear 900 mm (36") around the damage.
- The geogrid patch should cover the damaged area and extend 900 mm (36") beyond it in all directions.

Cold Weather

Store StormGrid above -29 °C (-20 °F) and avoid handling below 10 °C (-14 °F). At sub-freezing temperatures, StormGrid is less impact resistant and can be fractured with dynamic force (e.g. striking with a hammer). Other aspects of dynamic loading associated with very cold temperatures should be avoided.

Foundation Stone Specification

Foundation stone below the chambers from the subgrade up to the bottom of the foot (bottom) of the chamber shall consist of:

- Clean, crushed, angular stone or recycled concrete
- Have an internal friction angle of at least 45 degrees
- Meet the gradation for AASHTO M43 Size Numbers 3, 357, 4, 467, 5, 56 or 57

StormGrid Product Specification

General

- The Mechanically Stabilized Layer shall consist of two components:
    1. The stabilization geogrid component of the MSL shall be StormGrid Geogrid, which is manufactured from a coextruded, composite polymer sheet, which is then punched and oriented. The resulting structure consists of continuous and non-continuous ribs forming three aperture geometries (hexagon, trapezoid, and triangle) and an unimpeded suspended hexagon.
    2. An aggregate meeting the gradation for AASHTO M43 Size Numbers 3, 357, 4, 467, 5, 56 or 57 comprising and a peak angle of internal friction of at least 45 degrees.
- The mechanically stabilized layer thickness has been determined to meet or exceed the stated project specific performance targets and is based on the derivation of a project specific “load transfer efficiency” or “T-Value” of the mechanically stabilized layer incorporating stabilization geogrid(s).
- The load spread efficiency of the MSL has been determined using the following
    1. A suitable constitutive model to simulate mechanically stabilized aggregate material behavior. Design parameters are determined using a large 0.5 m diameter triaxial testing on the aggregate and geogrid combinations to determine stabilized strength of the resulting composite layer
    2. Simulation of the application in FEA validated by the full-scale testing
    3. An extensive parametric study to derive relationships between MSL-specific T-values and subgrade strength for the design method adopted
    4. Full scale testing of mechanically stabilized aggregate layers with the same geogrid products to bearing capacity failure to demonstrate and quantify the stabilization geogrid benefit
- Any alternative proposals or products shall be accompanied by a technical submission demonstrating the equivalence of the alternative composite construction along with the supporting test data, at least three weeks prior to the required product approval date.
- The properties for the geogrid component of the mechanically stabilized layer are included below for the purposes of product identification only and should not be associated with expected performance of the geogrid component of the mechanically stabilized layer. It should be noted that index properties or performance characteristics for any alternative geogrid in isolation, such as tensile properties measured in air, geometric dimensions, aperture stability modulus, or quality control data will not be accepted as an adequate demonstration of equivalent platform performance.

InterAxSWT Properties	Test/Measurement Method	General
Aperture shapes		Hexagonal, Trapezoidal, Triangular
Structure		Coextruded and Integrally Formed
Rib shape		Rectangular
Continuous parallel rib pitch	Nominal	80 mm (3.2”)
Rib aspect ratio[1]		>1.2
Color identification		White / Black / White

Notes

- Unless indicated otherwise, values shown are minimum average roll values determined in accordance with ASTM D4759-02
- 1.) Ratio of the mid-rib depth to the mid-rib width

Subgrade Performance Considerations

Determination of allowable bearing pressure is routine geotechnical practice which involves consideration of ultimate bearing capacity (resistance to shear failure), settlement conditions, local expertise, and other site- or project-specific factors. The discussion below is meant to assist geotechnical designers in evaluating some of the unique characteristics of StormTech. However, it is not a complete list of considerations and in general the native subgrade below a StormTech system must be stable and unyielding for proper function of the system and for protection of surface improvements.

Bearing Capacity

Bearing capacity failure is not tolerable. Local shear (punch shear) is an important design consideration, given the narrow row spacing and relatively thin over-loaded zone of the subgrade.

Settlement

The chamber system is tolerant to minor settlement. However, for design, total settlement at any point should be limited to 75 mm (3”). Differential settlement should not exceed 25 mm (1”) across one chamber structural span. Settlement tolerances are intended to provide the basis for foundation design and ensure structural performance of the chamber-soil system. Chamber designs do not consider settlement or ground movement tolerance of surface improvements above the chambers.

Subgrade Saturation

If the system design allows for infiltration (i.e. no impermeable liner is specified) then water content of the subgrade soil is expected to increase above natural levels immediately after a storm event. The degree of saturation will depend on the hydraulic conductivity of the subgrade and the storm intensity among other factors. If an impermeable liner is to be used, then it can be assumed the StormTech system will not increase the saturation of the subgrade.

General Comments

1. Chamber designs do not consider settlement or ground movement tolerance of surface improvements above the chambers.
2. A bearing capacity factor of safety of 2.5 was used in determining the allowable bearing pressure.
3. Geogrid stabilized raft only aids in the increase of the bearing capacity at the base of the chamber. It is assumed that the effect of any net unloading during construction and any wetting of the subgrade soil from water contained in the chambers on the shear strength of the subgrade soil is taken into account in design.
4. Maximum cover heights do not exceed 3.6 m (12’) and applied loads are less than 12,000 per square foot.
5. Scour / erosion and its effect on the performance of stabilized foundation stone is not considered.

References

1. A. Lees and J. Kawalec, “The Design of Mechanically Stabilized Working Platforms”. EuroGeo 7 Conference Proceedings pages 380 390
2. ADS Technical Note TN 6.22 StormTech® Subgrade Performance Considerations
3. ASTM F2787 – 13, “Standard Practice for Structural Design of Thermoplastic Corrugated wall Stormwater Collection Chambers
4. AASHTO M43-88 Sizes of Aggregate for Road and Bridge Construction.
5. Lees A. Performance of gravel rafts stabilized with Tensar geogrids in Canterbury Earthquake Sequence (CES). International White Paper, 2017, Blackburn, UK.
6. Lees A. Bearing capacity of a geogrid-stabilized granular layer on clay, International White Paper, July 2018, Blackburn, UK.
7. Lees, A.S. (2020) The bearing capacity of a granular layer on clay. Proceedings of the Institution of Civil Engineers – Geotechnical Engineering, 173, No. 1,13-20