

TECHNICAL NOTE

Pipe Flotation

TN 5.05
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Introduction

The light weight of HDPE pipe makes it desirable because of the ease of handling and installation but this same benefit also makes HDPE pipe prone to flotation. All pipe products, such as concrete and corrugated metal, are prone to flotation under the right circumstances. In fact, all pipe materials and other buried structures are subject to flotation. When the uplift on the pipe or structure exceeds the downward force of the weight and load it carries, the pipe (or structure) will rise or heave. Where flotation is a possibility, proper installation and/or anchoring of the pipe is critical. This document provides an analysis on minimum cover heights required to prevent pipe flotation for HDPE pipe sizes 12"-60". Buoyant forces due to Controlled low strength material (CLSM) will also be discussed.

Hydrostatic Uplift Due to a High Water Table

Buoyancy becomes an issue in buried pipe when the groundwater encroaches into the pipe zone. For projects where a high groundwater table or water surrounding the pipe is expected, precautions should be taken to prevent the flotation of HDPE pipe. Under the right conditions and when increased cover heights are possible, providing a minimum amount of cover will help prevent flotation.

The vertical hydrostatic uplift force, U , due to the water table can easily be calculated from Equation 1 below:

$$U = \frac{\pi}{4} D^2 \delta_w \quad (1)$$

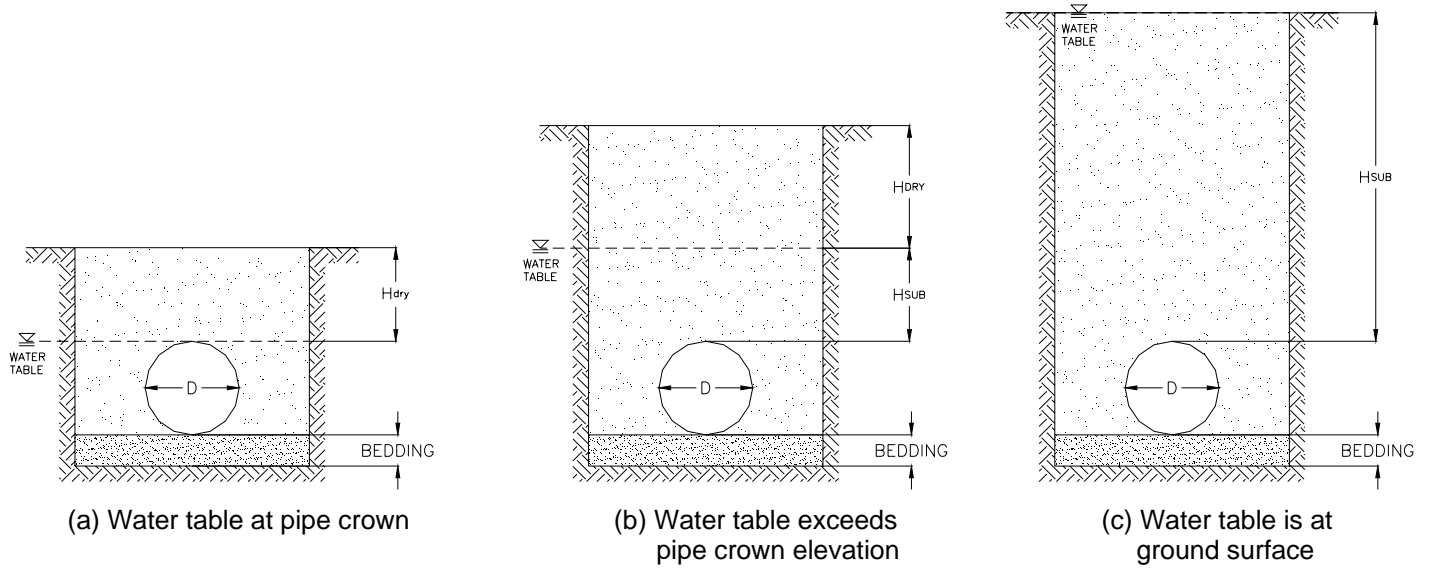
where U = lb/linear ft of pipe
 D = O.D. of the pipe in question, ft.
 δ_w = unit weight of water = 62.4 lb/ft³

This hydrostatic uplift force must be balanced by soil overburden and the weight of the pipe in order to ensure that the pipe will not float. Soil loads experienced by a pipe at varying water table depths (W_{soil}) can be calculated from Equation 2. Figure 1 illustrates each of the three cases seen in field installations where buoyancy becomes a concern, and also clarifies all of the parameters contained within Equation 2.

$$W_{soil} = \delta_{dry} H_{dry} D + (\delta_{sat} - \delta_w)(H_{sub} + 0.1073D) D \quad (2)$$

where W_{soil} = weight of soil overburden, lb/linear ft of pipe
 δ_{dry} = dry unit weight of the soil, lb/ft³
 H_{dry} = depth of dry soil, ft.
 H_{sub} = depth of submerged soil over top of pipe, ft.
 δ_{sat} = saturated unit weight of the soil, lb/ft³
 $\delta_{sat} - \delta_w$ = submerged unit weight of the soil, lb/ft³

Figure 1
Installation Conditions for Possible Flotation of HDPE Pipe



The typical weights (W_{pipe}) and average outside diameters are shown in Table 1.

Table 1
Approximate Weights of Dual Wall HDPE Pipe

Nominal Diameter in. (mm)	Nominal OD in. (mm)	Weight lb/ft (kg/m)
4 (100)	4.6 (117)	0.44 (0.6)
6 (150)	7.0 (178)	0.85 (1.3)
8 (200)	9.5 (241)	1.5 (2.2)
10 (250)	12 (305)	2.1 (3.1)
12 (300)	14.5 (368)	3.2 (4.7)
15 (375)	18 (457)	4.6 (6.8)
18 (450)	22 (559)	6.4 (9.5)
24 (600)	28 (711)	11.0 (16.4)
30 (750)	36 (914)	15.4 (22.9)
36 (900)	42 (1067)	19.8 (29.4)
42 (1050)	48 (1219)	26.4 (39.3)
48 (1200)	54 (1372)	31.3 (46.6)
60 (1500)	67 (1702)	45.2 (67.3)

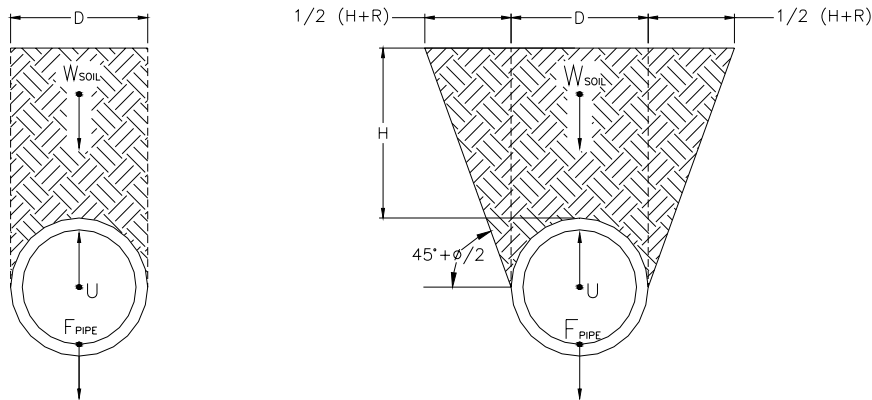
The minimum depth of cover (H) required to resist uplift can be calculated by equating the sum of the downward forces to the sum of the upward or buoyant forces. While there are varying methods to account for soil load distribution on the pipe, for conservative minimum cover requirements, the soil load is assumed to be the soil column directly above the outside diameter of the pipe as illustrated in Figure 2(a). Therefore, minimum cover is calculated using Equations 3 and 4 below:

$$U \leq W_{\text{Soil}} + W_{\text{Pipe}} \quad (3)$$

where W_{pipe} = weight of the pipe, lb/linear ft of pipe

$$H = H_{\text{dry}} + H_{\text{sub}} \quad (4)$$

**Figure 2
Forces Affecting Flotation**



(a) Soil Column Loading Conditions

(b) Prism Loading Conditions

Table 2, below, provides the calculated minimum cover requirements to prevent flotation of HDPE pipe.

**Table 2
Minimum Cover* To Prevent Flotation
of Dual Wall HDPE Pipe**

Nominal Diameter in. (mm)	Minimum Cover in. (mm)	Nominal Diameter in. (mm)	Minimum Cover in. (mm)
4 (100)	3 (77)	24	17 (711)
6 (150)	4 (102)	30	22 (914)
8 (200)	5 (127)	36	25 (1067)
10 (250)	7 (178)	42	29 (1219)
12 (300)	9 (368)	48	33 (1372)
15 (375)	11 (457)	60	40 (1702)
18 (450)	13 (559)		

*For structural purposes, a minimum cover of 12" shall apply for 4"-42" pipe, and 24" for 48"-60" pipe.

The following assumptions were used to determine minimum cover requirements listed in table 2. For applications where different installation conditions are present, the possibility of flotation should be reviewed based on the specific project conditions.

1. The pipe is assumed to be empty. This not only simplifies the calculations but creates a condition that would encourage flotation. Unless the system is constructed to be watertight, this condition would not likely be found in an actual installation.
2. The outside diameter of the corrugated pipe was used to determine soil and water displacement.
3. Saturated soil density used was 130 pcf which is typical for many saturated soil mixtures. Soils of greater densities will reduce the chance of flotation.
4. The water table was assumed to be at the ground surface, as illustrated in Figure 1(c), simulating a fully saturated soil. This assumption creates a “worst case” condition to yield more conservative results.

Example 1: Calculate the minimum depth of cover required to prevent 48” N-12 from floating when the water table is at the top of grade. The dry and saturated unit weights of the soil are 110 lb/ft³ and 130 lb/ft³, respectively.

Solution: $U \leq W_{\text{Soil}} + W_{\text{Pipe}}$

$$W_{\text{pipe}} = 32.0 \text{ lb/ft (from Table 1)}$$

$$U = \frac{\pi}{4} (4.5)^2 (62.4) = 992.4 \text{ lb/ft}$$

The water table is at top of grade, so Figure 1(c) applies. Since $H_{\text{dry}}=0$, the first term in Equation 2 is eliminated:

$$\text{Therefore, } W_{\text{soil}} = (130 - 62.4)[H_{\text{sub}} + (0.1073)(4.5)](4.5) + 32 = 304.2 H_{\text{sub}} + 146.9 + 32$$

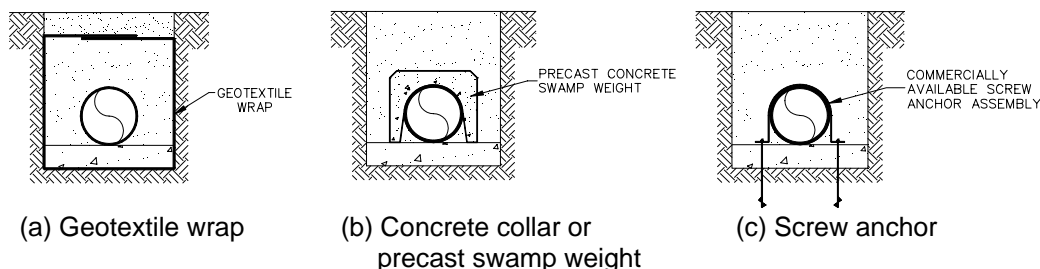
$$\begin{aligned} \text{Equation 3 then yields:} \quad & 992.4 = 304.2 H_{\text{sub}} + 178.9 \\ \therefore H_{\text{sub}} = 2.67' = 32.1'' \text{ (use 33'')} \end{aligned}$$

Finally, calculate minimum cover from Equation 4: **$H = H_{\text{sub}} = 33''$**

The above calculations are conservative. The angle of internal friction of the soil, ϕ , and the coefficient of lateral earth stress, K_0 , are not accounted for in the above equations. These parameters are best left to the geotechnical engineer. If these parameters are added to the above calculations, the depth of cover required would be reduced.

If adequate soil cover cannot be obtained to prevent pipe flotation, an alternate method of stabilizing the pipe can be chosen. Some examples are shown in Figure 3.

Figure 3
Pipe Stabilizing Alternatives



Uplift Due to CLSM Backfill

Controlled low strength material (CLSM) is flowable fill which usually consists of Portland Cement, sand, water, and fly ash. Uplift due to CLSM backfill can be calculated from Equation 5.

$$U = \frac{A_{\text{disp}} \delta_{\text{CLSM}}}{144} \quad (5)$$

Where, A_{disp} = Area of pipe displaced by CLSM, in²
 δ_{CLSM} = Unit weight of CLSM, lb/ft³
 U = Uplift due to CLSM backfill, lb/in

Due to the vast differences in the unit weights between water and CLSM, CLSM uplift can be greater than two times that of hydrostatic uplift. When backfilling with CLSM, the absence of soil overburden will cause the pipe to float. Therefore, the pipe must be anchored to remain on its intended alignment and grade. This is commonly done by anchoring rebar in an X-pattern over the top of the pipe and into the side walls of the trench, by utilizing dry CLSM material as anchors, or by other types of commercially available anchors.

Spacing of support anchors can vary depending on pipe diameter, height of CLSM lift, and anchor type. The Engineer's design should take these factors into account so to maintain the intended pipe grade. The maximum spacing between anchor supports should not exceed 10 feet. In this manner, pipe is supported at each joint and at the midpoint of each length of pipe to ensure adequate stabilization. After determining the spacing between pipe anchors, an anchor type must be chosen based on the required restraining forces to prevent flotation. Due to the variations in CLSM mixtures, in-situ soil densities, and the restraining force of the anchors, a geotechnical engineer should evaluate the project-specific conditions to determine the required anchor type and spacing to prevent flotation.

Conclusion

Many instances pipe flotation may simply be addressed with adequate cover, in those situations where adequate cover cannot be achieved, alternate methods for restraining the pipe are available. Even under the significant uplift conditions of placing CLSM, the pipe's embedment grade and alignment can be maintained using anchors.