Pipe Flotation

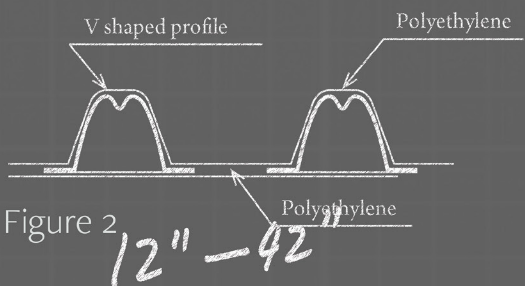


Figure 2

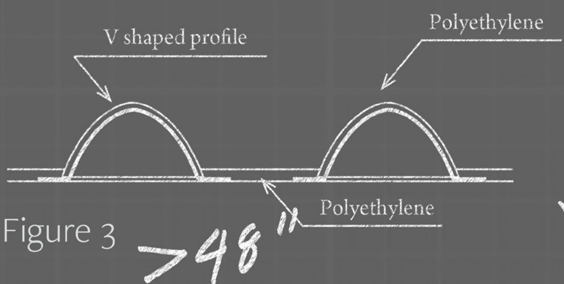


Figure 3

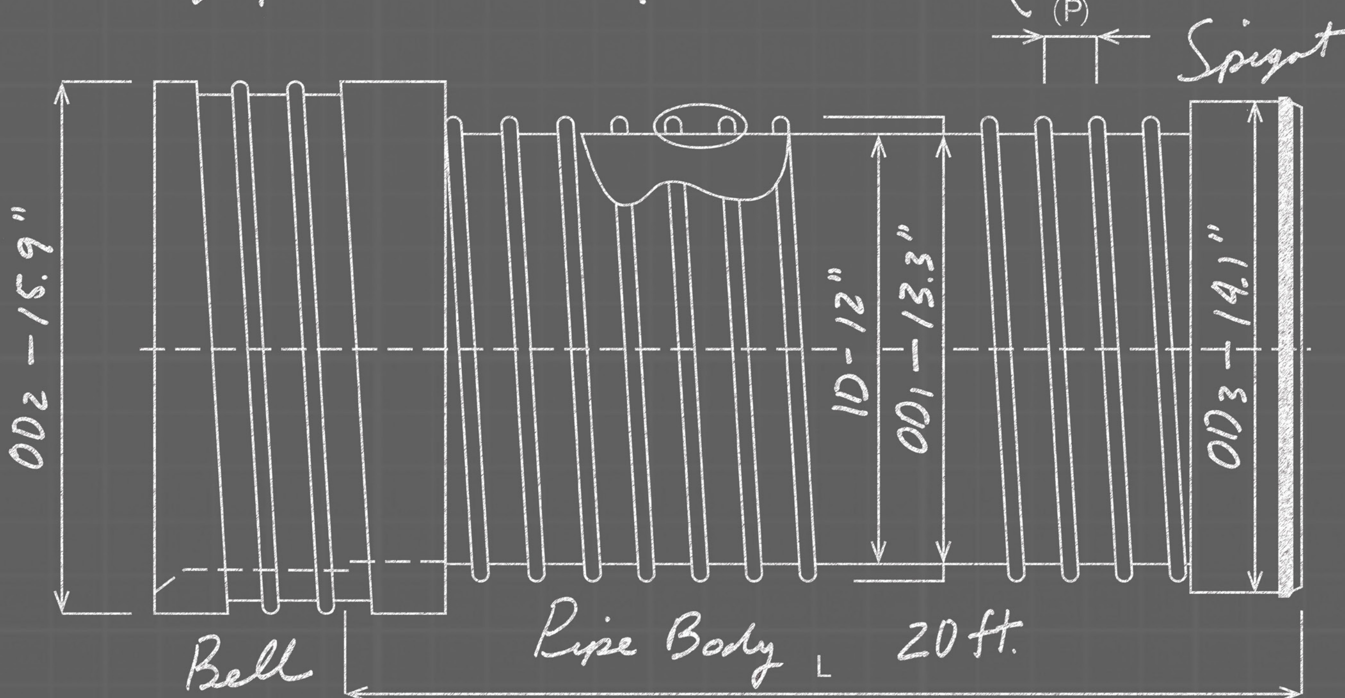


Figure 1

Introduction

Because of their light weight, Steel Reinforced Polyethylene (SRPE) pipes offer a distinctive advantage over concrete and metal pipes. Lighter weight facilitates handling and installation of the pipes, reduces the effort required by installers, and minimizes wear and tear of installation equipment. However, lighter SRPE pipes are susceptible to flotation. Under the right conditions in the field, concrete or metal pipes can also be subject to flotation. Whenever the uplift on the pipe or structure exceeds the downward forces generated by its weight and the load it carries, the pipe or structure will rise or "float". If flotation is a possibility with your application, proper installation design and anchoring of the pipe should be an essential part of your planing and execution. This technical bulletin offers an analysis of minimum cover heights required to prevent pipe flotation for Kanaflex SRPE pipes sizes 12"-72". It also covers buoyancy issues when using flowable fill.

High Water Table and Hydrostatic Uplift

Buoyancy becomes an issue for buried pipes when the groundwater reaches the pipe zone. Precautions should be taken to prevent the flotation of SRPE pipes on projects where high groundwater table, or water surrounding the pipe, is anticipated. To prevent pipe flotation, the vertical hydrostatic uplift force generated by the water table must be counterbalanced by the weight of the pipe and the soil overburden. Vertical hydrostatic uplift force (V) can be calculated using Equation 1 below:

Equation 1

$$V = \pi/_4 \, D^2 \delta w$$

Where V = lb/linear ft of pipe
D = O.D. of pipe, ft
δw = unit weight of water = 62.4 lb/ft^3

Soil loads supported by a pipe at various water table depths (W_{soil}) can be calculated using Equation 2. The illustrations in Figure 1 show the most common instances observed in the field where buoyancy can become problematic. These illustrations also provide a visual representation of the equation parameters used in Equation 2.

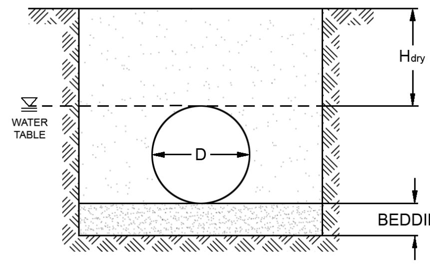
Equation 2

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

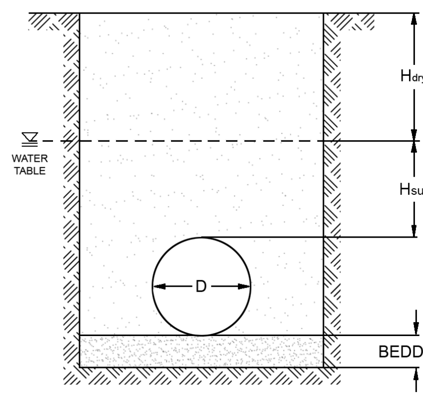
Where W_{soil} = weight of soil overburden, lb/linear ft of pipe
δ_{dry} = dry unit weight of soil, lb/ft^3
H_{dry} = depth of dry soil, ft.
H_{sub} = depth of submerged soil over top of pipe, ft.
δ_{sat} = saturated unit weight of the soil, lb/ft^3
$\delta_{sat} - \delta_w$ = submerged unit weight of the soil, lb/ft^3

Figure 1

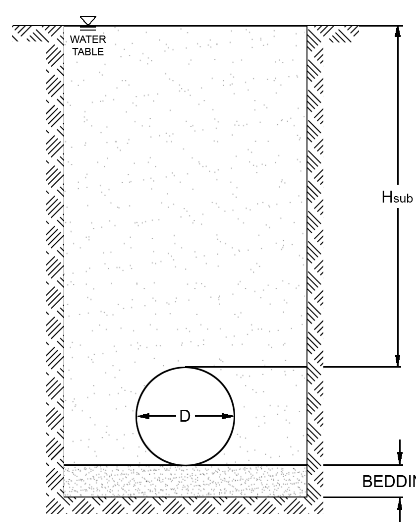
Installation conditions for potential flotation of SRPE pipe



(a) Water table at pipe crown



(b) Water table exceeds pipe crown elevation



(c) Water table is at ground surface

The average outside diameter and typical weights of Kanapipe SRPE pipes are shown below

Table 1
Approximated OD and weight of Kanapipe SRPE pipes

Nominal Diameter in. (mm)	Average OD in. (mm)	Weight lb/ft (kg/m)
12 (300)	13.3 (338)	3.3 (4.9)
15 (375)	16.3 (413)	4.1 (6.1)
18 (450)	19.3 (489)	4.8 (7.1)
24 (600)	25.7 (653)	8.8 (13.1)
30 (750)	32.2 (817)	11.9 (17.7)
36 (900)	38.2 (970)	20.2 (30.1)
42 (1050)	44.4 (1128)	28.0 (41.7)
48 (1200)	52.0 (1320)	39.5 (58.8)
60 (1500)	65.2 (1656)	51.1 (76.0)
72 (1800)	77.2 (1961)	64.1 (95.4)

Weights are for plain-end pipes, the lightest option

The minimum depth or height of cover (H) required to withstand uplift can be calculated by equating the sum of the downward forces to the sum of the upward, or buoyant, forces. A variety of methods can be used to determine soil load distribution on the pipe. On the conservative side, the minimum cover requirements of the soil load is assumed to be the soil column directly above the outside diameter of the pipe, as shown in Figure 2(a). As such, the minimum cover is calculated using Equation 3 and Equation 4:

Equation 3

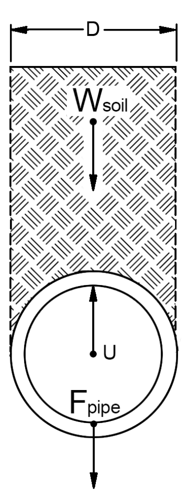
$$V \leq W_{soil} + W_{pipe}$$

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

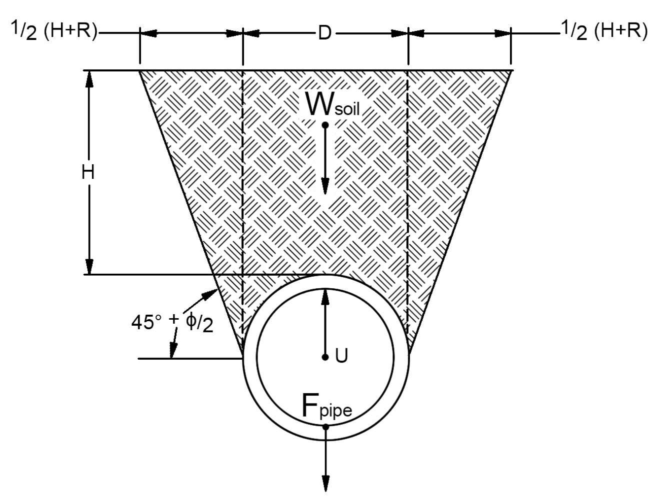
Equation 4

$$H = H_{dry} + H_{sub}$$

Figure 2
Forces affecting flotation



(a) Soil column loading conditions



(b) Prism loading conditions

Table 2
Minimum recommended cover to prevent flotation of Kanapipe SRPE pipe

Nominal Diameter in. (mm)	Minimum Cover to Prevent Flotation in. (mm)	Minimum Allowable Cover for Structural Capacity in. (mm)
12 (300)	8 (200) use 12 (300)	12 (300)
15 (375)	10 (250) use 12 (300)	12 (300)
18 (450)	12 (300)	12 (300)
24 (600)	15 (375)	12 (300)
30 (750)	20 (500)	12 (300)
36 (900)	23 (584)	12 (300)
42 (1050)	27 (685)	12 (300)
48 (1200)	31 (787)	12 (300)
60 (1500)	39 (990)	24 (600)
72 (1800)	43 (1092)	24 (600)

Calculation Notes:

1. An empty pipe is assumed. This simplifies calculations and creates a condition that would encourage flotation
2. The outside diameter of the corrugated HDPE pipe was used to calculate soil and water displacement
3. A saturated soil density of 130 pcf was used which is typical for many saturated soil mixtures. Soils with a greater density will diminish the chance of flotation.
4. The water table was assumed to be at ground level, as illustrated in Figure 1(c), simulating a fully saturated soil. This creates a "worst case scenario" condition to yield more conservative results.
5. The soil column loading condition shown in Figure 2(a) was used to determine the soil weight
6. For structural purposes, a minimum cover of 12" (300mm) is used for 12"-48" pipe sizes and 24" for 60"-72" pipe sizes. Minimum depths of cover are to be used when the water table is below the pipe zone.
7. For Kanapipe 12" and 15", use a minimum depth of cover of 12" to prevent flotation even, if the calculations yield a lower value. This guarantees the structural capacity of the buried pipe.

Example 1

When the water table is at the top of the grade (surface), calculate the minimum height of cover required to prevent 48" Kanapipe SRPE pipe from floating. The dry and saturated unit weights of the soil are 110 lb/ft^3 and 130 lb/ft^3, respectively.

$$W_{pipe} = 39.5 \text{ lb/ft (from Table 1)}$$

$$V = \frac{\pi}{4}\ (4.3)^2\ (62.4) = 906.2 \text{ lb/ft}$$

W_{soil} must be equal to V

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

$$W_{soil} = (130-62.4)[H_{sub}+(0.1073)(4.3)](4.3) + 39.5 = 290.7H_{sub} + 134.1 + 39.5$$

Equation 3 then yields:

$$906.2 = 290.7H_{sub} + 173.6$$

$$H_{sub} = 732.6/290.7 = 2.52' = 30.2" \text{ (use 31")}$$

Finally, calculate the minimum cover using Equation 4:

$$H = H_{sub} = 31"$$

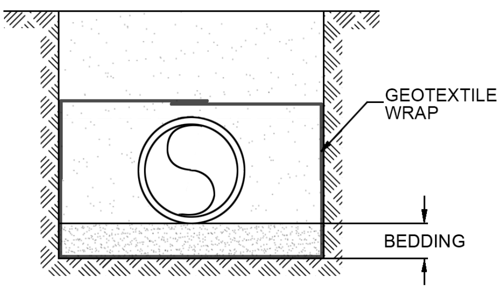
The calculations above are conservative. The angle of internal friction of the soil, ϕ, and the coefficient of lateral earth stress, K_o, are not accounted for in the above equations. These parameters are best left to the geotechnical engineer. If these parameters are added to the above calculations,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

Anchoring Systems

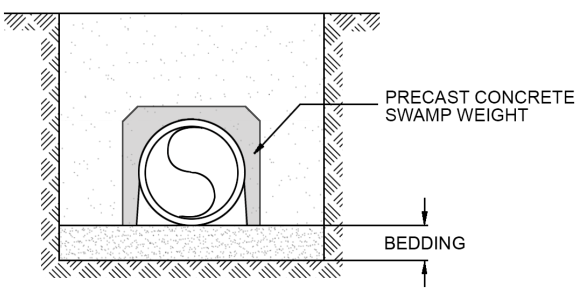
Pipe flotation can usually be addressed by providing adequate depth of cover. In the rare instances where adequate cover cannot be achieved, there are several options available for restraining the pipe. Some examples are shown in Figure 3.

Because of variations in in-situ soil densities, water table heights, and the restraining capacity of the anchors, it is the responsibility of the engineer to evaluate the project-specific conditions and determine the required anchor type and spacing to prevent flotation. The maximum spacing between anchor supports should not exceed 10 feet. This helps ensure that the pipe is supported at each joint and near its midpoint, which helps with adequate stabilization.

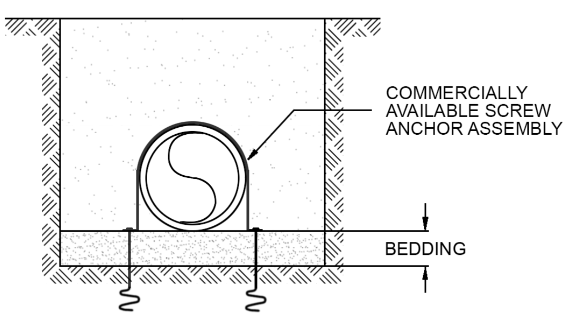
Pipe Stabilizing Options



(a) Geotextile wrap



(b) Concrete collar



(c) Screw anchor

Uplift as a Result of Using Flowable Fill Backfill

Flowable fill backfill, also sometimes referred to as controlled density fill (CDF), controlled low-strength material (CLSM) or slurry fill, is used as an alternative to compacted granular fill. Flowable fill usually consists of Portland Cement, sand, water, and fly ash. Vertical uplift forces due, to flowable fill, can be calculated using Equation 5.

$$V = (A_{disp}\ \delta_{FF})/144 \qquad (5)$$

Where

A_{disp} = Area of pipe displaced by flowable fill, in^2

δ_{FF} = Unit weight of flowable fill. lb/ft^3

V = Vertical uplift force due to flowable fill backfill, lb/ft

Due to vast differences in unit weights between water and flowable fill, uplift generated by flowable fill can be greater than two times that of hydrostatic uplift. When backfilling with flowable fill, and in the absence of soil overburden, the pipe will float, since the weight of the pipe will not offset the vertical uplift forces. Precautions have to be taken to ensure that the pipe remains on its intended alignment and grade. This is commonly done by anchoring the pipe in place or placing the flowable fill in incremental lifts. Refer to project-specific design documents for additional information.

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