Pipe Flotation of BOSS HDPE Pipe

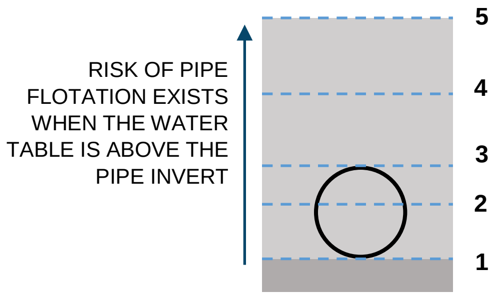
INTRODUCTION

All types of buried pipes are susceptible to flotation under specific conditions. The major factor influencing pipe flotation is the location of the groundwater table relative to the pipe zone. The risk of pipe flotation exists when the buoyant force on the pipe exceeds the downward forces of the pipe and the load it carries. The potential for uplift should always be checked if the pipe is buried in lighter soils, with shallow cover and/or installed in areas prone to high ground water.

Pipe flotation can be prevented by ensuring there is adequate soil cover above the pipe to counter the uplift force. In situations where the uplift force is too high for the soil load, the pipe can be secured to grade using earth anchors or concrete collars. Special attention should be paid to the potential for pipe flotation when backfilling with flowable fill **(see Technical Bulletin B2.41.1).**

Minimum Cover Calculation

Pipe flotation is a function of several factors including soil type, soil density, height of cover, water table location and pipe weight per linear metre. Pipe flotation is possible whenever the water table is above the pipe invert **(Figure 1)**. Pipe flotation is not considered an issue below the pipe invert.



1. Water table is at the pipe invert
2. Water table is between pipe invert and crown
3. Water table is at the pipe crown
4. Water table is higher than the pipe crown
5. Water table is at the ground surface level

FIGURE 1: Water table locations for pipe flotation of buried pipe

The amount of soil cover required to prevent pipe flotation can be determined by comparing the downward force of the soil load, pipe weight and pipe contents to the hydrostatic uplift force caused by the water table. For an empty pipe the minimum cover requirement can be established by ensuring the buoyancy uplift force F_B is less than the sum of the unit weight of dry and saturated soil above the pipe, W_D and W_S, respectively and the unit weight of the pipe W_P as shown in equation 1:

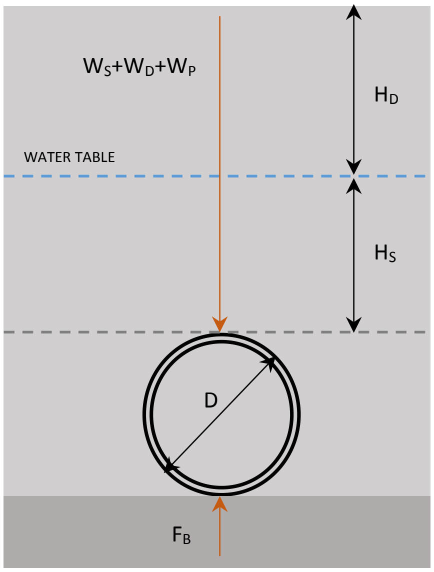
Equation 1

$$F_B \leq W_S + W_D + W_P$$

Where: W_S = weight of saturated soil (kg_f)
W_D = weight of dry soil (kg_f)
W_P = weight of pipe (kg_f)

Assuming the pipe is empty provides the worst case scenario for pipe flotation. Ground water flotation forces are illustrated in **Figure 2**.

FIGURE 2: Schematic of ground water flotation forces



The buoyancy uplift force F_B is calculated using equation 2:

Equation 2

$$F_B = \frac{\pi}{4} D^2 \rho_W$$

Where:

F_B = buoyant force (kg_f/m)
D = outside diameter of pipe (m)
ρ_W = density of water (kg/m^3)

The total soil load W_{SOIL} acting on the pipe at various water depths is the sum of the saturated soil load, W_S plus the dry soil load, W_D. It can be calculated using equation 3:

Equation 3

$$W_{SOIL} = W_D + W_S = \rho_D H_D D + (\rho_S - \rho_W)\left(H_S D + \frac{(4-\pi)}{8} D^2\right)$$

Where:

ρ_D = density of dry soil (kg/m^3)
H_D = depth of dry soil (m)
ρ_S = density of saturated soil (kg/m^3)
ρ_W = density of water (kg/m^3)
H_S = depth of saturated soil above pipe (m)

The weight of BOSS 2000 pipes, W_P, is shown in **Table 1** for various pipe diameters:

TABLE 1: Typical BOSS pipe weights

Nominal Inside Diameter (mm)	Nominal Outside Diameter (mm)	Pipe Weight		
		kg/m	kg/6m	lb/6m
100	122	0.9	5.4	11.9
150	177	1.7	9.9	21.8
200	236	2.9	17.6	38.8
250	295	4.3	26.0	57.3
300	363	5.5	33.2	73.1
375	448	9.0	53.9	118.7
450	541	12.0	71.9	158.3
525	630	16.7	100.4	221.0
600	728	20.3	121.6	267.4
750	895	32.0	192.0	422.4
900	1093	43.2	259.3	570.5

The minimum height of cover H to prevent flotation can be calculated using equation 4:

Equation 4

$$H = H_S + H_D$$

A conservative value for H is calculated by assuming the water table is at the ground surface and, therefore, the soil is completely saturated.

Example:

Calculate the minimum height of cover for a 900 mm diameter pipe with the water table at the ground surface. The dry and saturated soil densities are 1600 kg/m^3 and 1922 kg/m^{3,} respectively. The density of water is 1000 kg/m^3.

The buoyancy force F_B $= \pi / 4 \times (1.093)^2 \times 1000$
$= 937.55$ kg$_f$/m

The weight of the pipe W_P from Table 1 = 43.22 kg/m

To prevent pipe flotation $F_B = W_S + W_D + W_P = 937.55$ kg$_f$/m (soil is saturated so $W_D = 0$)
$937.55 = W_S + 43.22$
$W_S = 894.33$ kg/m

The weight of the soil $W_S = (1922 – 1000)\ (1.093\ H_S + 1.093^2\ (4 - \pi)/8) = 894.33$ kg/m
$H_S = 0.77$m

Therefore, the minimum height of cover required for a 900 mm pipe is 0.771 m (30 in)

Table 2 shows the minimum height of cover required to counteract flotation (uplift) forces for BOSS 2000 pipes. It has to be mentioned that these heights are only applicable for the conditions mentioned below. Different minimum heights of cover may be required for other structural or service reasons.

TABLE 2: Minimum height of cover to prevent pipe flotation*

Nominal Diameter	Minimum Height of Cover
mm	m (in)
100	0.083 (3.3)
150	0.122 (4.8)
200	0.162 (6.4)
250	0.204 (8.0)
300	0.254 (10.0)
375	0.312 (12.3)
450	0.379 (14.9)
525	0.440 (17.3)
600	0.511 (20.1)
750	0.628 (24.7)
900	0.771 (30.3)

Notes:

1. The pipe is assumed to be empty. Water in the pipe will reduce the minimum cover requirement.
2. Saturated soil density assumed to be 1922 kg/m^3 (130 lb/ft^3)
3. Water table is assumed to be at ground surface level. A lower water table will reduce minimum cover requirement.

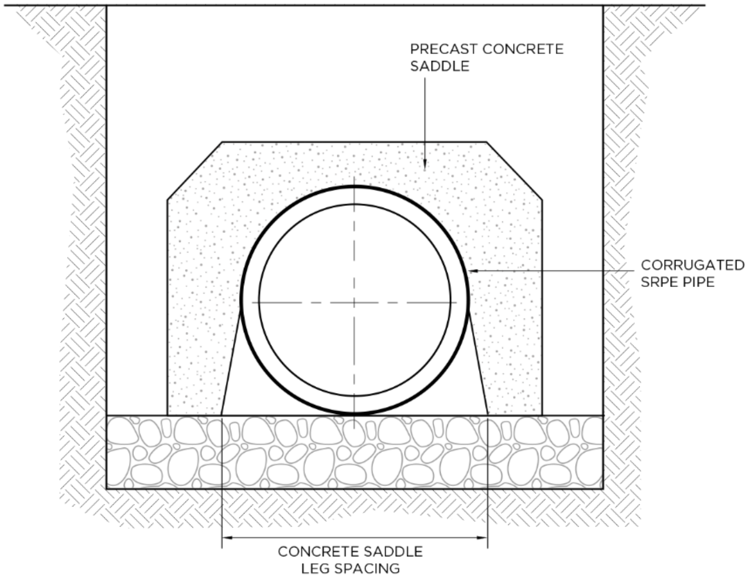
PIPE ANCHORING OPTIONS

If sufficient cover is unavailable to prevent pipe flotation, other options are available to restrain the pipe. These include:

1. Concrete Weight / Saddles

A precast concrete weight or saddle is positioned over the pipe, encasing it and anchoring it to the bedding below (Figure 3). The sizing of the anchoring system and its placement should be specified by the design engineer and is a function of the pipe diameter and height of the water table. The concrete saddle leg spacing should accommodate potential pipe deflection. Pipe deflection should not exceed 7.5% of the base inside diameter or the deflection requirements of the project design (whichever is less).

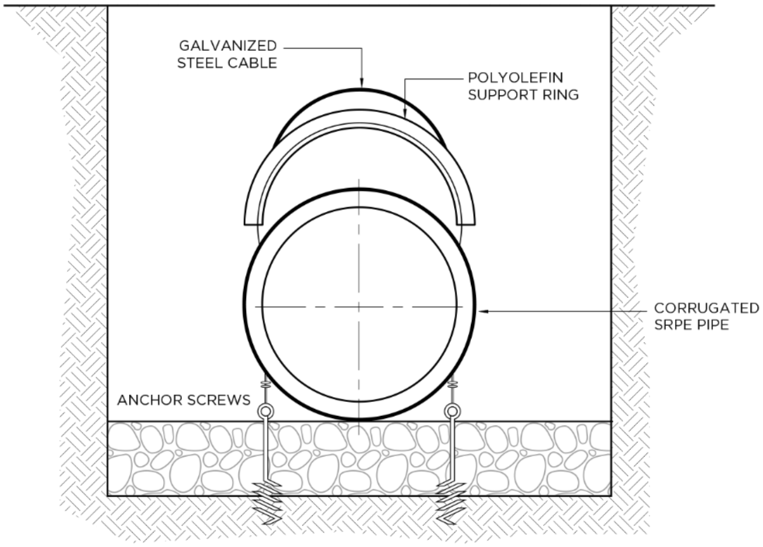
FIGURE 3: Typical precast concrete saddle configuration



2. Stacking

Pipe can also be secured to the bedding using screw anchors. Straps or anchors are screwed into the ground as shown in Figure 4. The guy screw and harness ring should be located adjacent to the pipe joints and midway along the pipe length. The foundation bedding should be stable and provide a secure base for the anchoring system. No voids should be left in the haunch area near the anchors during backfill. The guy wire manufacturer should be consulted to ensure sufficient restraint forces for the buoyant conditions.

FIGURE 4: Typical anchor guy screw configuration



Complete installation guidelines and procedures for BOSS HDPE pipe can be found in CSA Standard B182.11 *“Recommended Practices for Installation of Thermoplastic Drain, Storm and Sewer Pipe and Fittings”* or *BNQ 1809-300 “Construction - General Technical Clauses - Water and Sewer Pipes”*.