Technical Note

TN 5.22_C Design of Thermoplastic Drainage Structures

Overview

Vertical drainage structures made from thermoplastic pipe are an effective alternative to pre-cast concrete units for manholes, catch basins, and access structures on stormwater systems. As part of a critical infrastructure, vertical structures in stormwater systems should be designed to meet strict performance criteria under installed conditions for the duration of the service life. While such designs are standard to horizontal pipe installations, the practice is less common for vertical structures. This Technical Note explains the design standard used by ADS® to evaluate its vertical structure products. The purpose of the document is to assist stormwater system planners in understanding the performance considerations and installation guidelines associated with the successful use of thermoplastic vertical structures.

Table 1 summarizes the standard installation limits of each class of ADS thermoplastic drainage structure. The minimum and maximum height limits refer to the structure height from rim to base, including the sump and reducing top cone (if used). Structures below the minimum height are generally impractical to fabricate, while structures above the maximum height maybe be subject to excessive structural loading with out additional reinforcement. The groundwater height limit refers to the design high groundwater elevation relative to the base of the structure—groundwater levels above these limits increase the risk of a buoyant condition. Finally, minimum separation angle between stubs is critical to the structural performance and fabrication of the riser—limiting angles depend on the riser and stub diameters. Refer to the Minimum Angle Table (Ref. 2 & 3) for specific values. Please consult the other sections of this technical note for additional information about design considerations that generated these limits.

Table 1: Standard Installation Limits for ADS Thermoplastic Drainage Structures

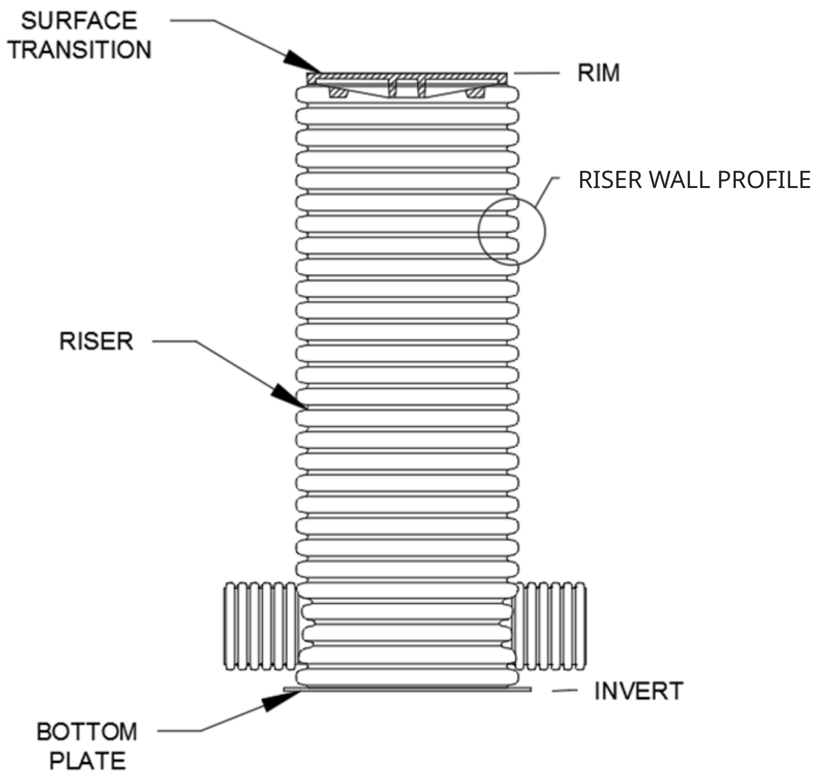
Structure		Installation Limits			
Riser Class	**Material**	**Min Height m (ft)**	**Max Height m (ft)**	**GW Height[2]**	**Stub Angle**
N-12® (Dual Wall)[1] Riser: 300 – 1200 mm (12” - 48”)	HDPE	0.9 (3)	3 (10)	(1/2)*H	See Ref. 2 & 3 (Minimum Angle Table)
SaniTite® HP (Triple wall) Riser: 750 - 1200 mm (30” - 48”)	PP	0.9 (3)	4.5 (15)		

1. N-12 pipe is a corrugated dual wall manufactured product.
2. Groundwater limit is relative to the buried height of the structure. The site designer is responsible for establishing the design groundwater level.

Background

ADS fabricates HP Manholes and N-12 catch basins in a range of diameters using our HP (polypropylene) and N-12 (high-density polyethylene) pipe products, respectively. The post-installation performance of the structures are evaluated per the guidance of ASTM F1759 (Ref. 1). Analysis per ATSM 1759 was used in developing the standard performance limits detailed in References 2 & 5, which govern HP Manholes and N-12 catch basins.

Figure 1: ADS Thermoplastic Manholes and Standard Terminology



References

1. ASTM F1759 – "Design of High-Density Polyethylene Manholes for Subsurface Applications"
2. ADS Standard Detail 4.03 – HP Manhole Installation
3. ADS Standard Detail 4.01Q – HDPE Manhole Installation Out of Roadway
4. ADS Standard Detail 4.03 – HP Manhole Installation

Loading Scenario

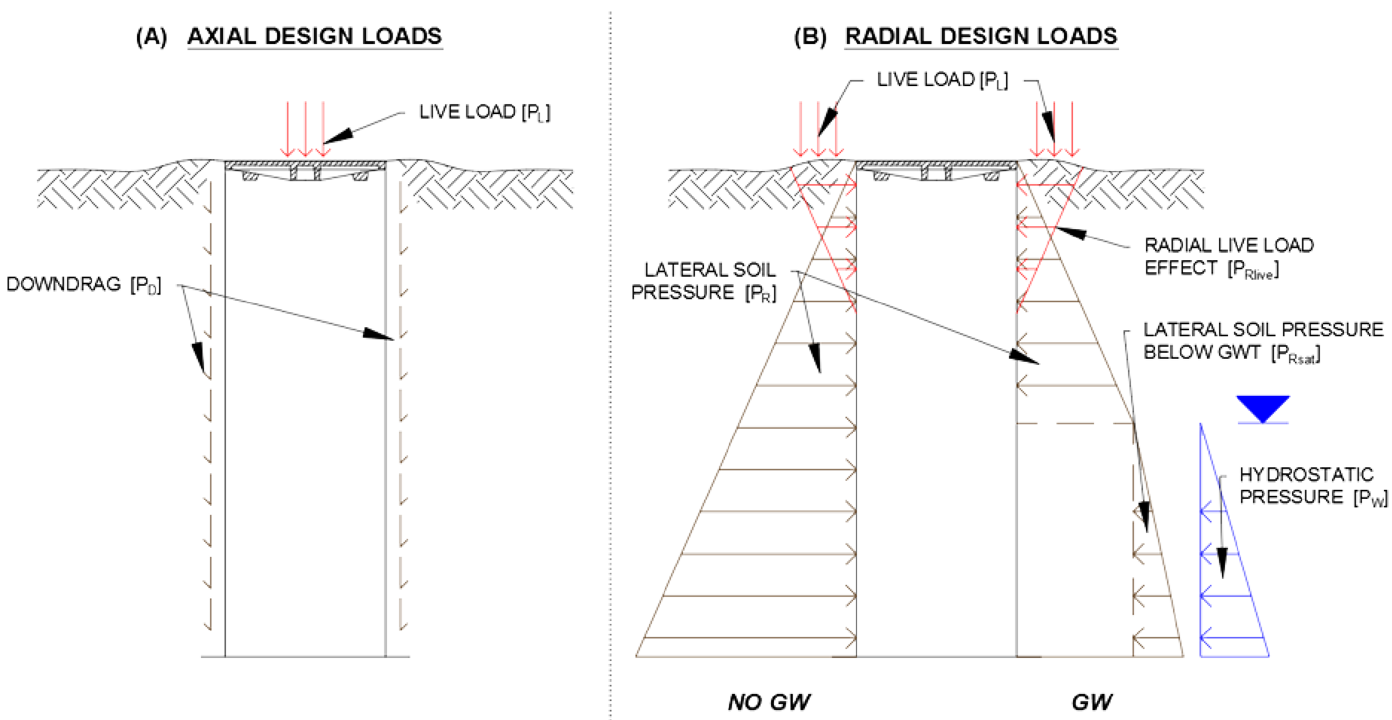
Figure 2 shows a conceptual diagram of the forces acting on a vertical structure. The follow paragraphs describe each load assessed in design, however, please refer ASTM F1759 (Ref. 1) for specific guidance on computing these loads.

Axial (vertical) load is applied to the riser by vehicle traffic [P_L] and by down drag from settlement of the backfill soil [P_D]. See **Figure 2(A)** below. The vehicle load to be used in analysis depends on the application and on the design of surface transition. For out-of-roadway installations no live load is assumed for evaluation (although capacity may exist in the product). For installations subject to traffic loading, the single-wheel load is assumed (e.g. HL-93 or BCL-625). The type and design of the surface transition governs how much of the load is carried by the riser—however, in most cases most of the load should be distributed to the backfill. The down drag load is take as the maximum frictional force at the interface of the backfill and the riser. This concept is simplistically represented as the product of the average radial soil pressure [P_R] and shear capacity at the interface zone. Shear capacity (represented as a friction coefficient) depends on whether the backfill soil interacts with the riser through material friction with the exterior wall (closed profile pipe-HP) or through interlock with the corrugation and internal shearing of the soil (open profile pipe-N-12).

Radial load on the riser consists primarily of lateral pressure from the backfill soil [P_R]. Horizontal arching is assumed to be mobilized in the backfill by stress relaxation in the thermoplastic riser, so that active earth pressure conditions can be used in design. If the groundwater table is higher than the invert of the structure, then hydrostatic pressure [P_W] is also exerted on the riser, and the lateral soil pressure is modified for buoyant effects [P_R / P_{Rsat}]. If the surface transition is designed to transfer a substantial amount of vehicular load to the backfill, then the lateral soil pressure should be augmented by a uniform surface load [P_{Rlive}]. See **Figure 2(B)** below.

All loads are assumed to be radially symmetric about the center of the riser. And all loads are assumed to vary longitudinally along the axis of the riser. Note, these assumptions are nearly the converse of horizontal pipe analysis, where axial variation is assumption negligible and radial variation is a key part of design.

Figure 2: Design Loads on Subsurface Vertical Structures



Performance Limits

The purpose of analyzing a subsurface vertical structure is to determine whether performance criteria will be met under the loading scenario through the design life of the system. **Table 2** details the structural performance limits considered by ASTM F1759. For each limit, the driving force and critical resisting properties of the riser are also listed. The intent is to demonstrate conceptually the relationships between limit states, installation conditions (i.e. the loading scenario), and designable characteristics of the riser. For specific guidance on evaluating each limit, refer to ASTM F1759. Please note that in addition to the structural limits in **Table 2**, ADS also considers fabrication issues such as the stub configuration and internal weir design when assessing the feasibility of a vertical structure.

Table 2: Structural Performance Limits for Subsurface Vertical Structures

Limit	Load[1]	Critical Riser Properties[2, 3]
Ring Thrust Strain	Peak Radical Pressure	Profile Area
Ring Binding Strain	Radical Pressure + Asymmetric Deflection	Profile Area / Profile Stiffness
Ring Combined Strain	[sum of thrust & bending strains]	Profile Area / Profile Stiffness
Ring Buckling	Peak Radical Pressure	Profile Area / Profile Stiffness / Backfill Stiffness
Axial Strain	Downdrag Pressure + Live Load	Profile Net Thickness
Axial Buckling	Downdrag Pressure + Live Load	Profile Area / Profile Stiffness
Bottom Plate Deflection[4]	Hydrostatic Pressure	Bottom Plate Thickness / Riser Diameter
Buoyant Uplift[4]	Hydrostatic Pressure	Riser Diameter

1. Maximum radial loads typically occur at the invert of the riser (i.e. the deepest point). Maximum axial loads are also assumed at the invert, although the actual distribution depends on the application and installation conditions.
2. Stiffening effects of the bottom plate are ignored for the radical and axial limit states.
3. Effects of stub connections are ignored for all analyses. The impact of stubs on the structural performance of the riser is complex. Smaller connections likely stiffen the riser against ring compression and bending, while larger stub likely reduce the riser's capacity in both radical and axial modes. The additional limits set in the minimum angle tables for the standard installation details (Ref. 2 & 3) should be followed to mitigate these concerns.
4. Groundwater related performance limits are treated briefly in ASTM F1759, and therefore similarly in this Technical Note. ADS publishes standard product limits with the assumption that the groundwater table is generally less the 1/3 of the riser height above the base of the structure. If higher groundwater levels are anticipated, please contact Applications Engineering for assistance.

Additional Considerations

Successful performance of subsurface vertical structures depends on proper installation conditions. Such conditions are assumed to exist by the design standards but are not guaranteed in the field. This section provides additional discussion on backfill and groundwater conditions, both of which are under the review and (partial) control of a stormwater system designer. Specially considerations for very deep installations are provided here as well.

Backfill Conditions

Vertical structures should be placed on a bedding layer of compacted granular fill no less than 150 mm (6”) thick. The excavated area extending at least 600mm (24 in) from the outer surface of the structure riser should be backfilled with granular fill. This backfill should be placed and compacted around all sides of the structure in even lifts of up to 300 mm (12 in). The size of compaction equipment used near the structure should be limited to avoid damage to the riser or stub connections.

These backfill conditions support optimal performance of the structure. Use of granular backfill, as opposed to cohesive, eliminates the potential for long-term settlement of the soils abutting the riser. This limits the magnitude of downdrag pressure and confines the effects to the period immediately following installation, allowing stress relaxation in the thermoplastic to partially distribute load back to soil in the long-term. Even placement and compaction of the fill prevents racking or tilting of the full structure as well local asymmetric deflections, which could contribute to premature buckling or bending failures. Finally, achieving a high degree of compaction of the backfill results in a higher internal angle of friction, which corresponds to increased horizontal soil arching and decreased in radial soil pressure (relative to lower levels of compaction).

Groundwater Conditions

Given the inherent uncertainty in predicting groundwater levels and the relatively limited height of ADS structures (typically less than 3 m or 10 ft), ADS assumes no hydrostatic effects for standard analysis. Comprehensive analysis of the ADS structures has shown that when the groundwater level is less than one-third of the riser height above the invert of the structure the deformation of the bottom plate is minimal and buoyant uplift is more than sufficiently counter-balanced by friction between the backfill and riser. However, as the depth to groundwater decreases so too does the safety factor against both bottom plate and buoyant uplift failures. There is some latent, but incalculable capacity to resist buoyant uplift via the stub connection and surface transition which provide an additional degree of safety. That said, at depth to groundwater (the specific limit varies for product type, riser ID, and backfill type) buoyant uplift becomes a concern that should be addressed by a designed solution. If high groundwater levels are anticipated on a project, please contact Applications Engineering for assistance.

Deep Structures

As the burial depth increases so do the soil loads acting on the structure. ADS has carefully analyzed its products and past project experience to set the maximum burial limits in Table 1. Installations at greater depths, while possible, typically requires special measures such as the use of flowable backfill to prevent damage to the stub connections and/or riser. Additionally, the risk of substantial hydrostatic forces and buoyant uplift increases as the structure depth increases. In particular, designers and installers of deep thermoplastic structures should consider uplift forces during the construction phase, when the resisting soil loads may be greatly reduced due a partial backfill condition.

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