TECHNICAL BULLETIN

BURIAL DEPTH GUIDANCE FOR PVC PIPE

PVC PIPE AS A FLEXIBLE CONDUIT

PVC pipe is considered a flexible pipe, which means that the pipe is designed to transfer external loads to the surrounding soil. The amount of deflection that PVC pipe will experience due to loading when buried depends largely on the soil stiffness of the bedding material.

For PVC pipe, pipe stiffness is the ability of a particular pipe to resist deflection under load. It is measured in lbf/in^2 and depends on the pipe dimension ratio (DR) and the PVC material properties (specifically the Modulus of Elasticity).

When considering resistance to deflection, the pipe stiffness (pipe property) and the soil support (compaction, soil material properties) must be considered. At shallow depths, live loads (i.e. traffic) will influence the external load on the pipe. As the depth of burial increases, live loads influence the load less and the weight of soil contributes more to the external load.

MODIFIED IOWA EQUATION

Pipe Deflection is estimated using the Modified Iowa Formula, which takes into account the support provided by the surrounding soil conditions and pipe properties. Further explanation for this equation can be found in the PVC Pipe Association's *Handbook of PVC Pipe Design and Construction*, Chapters 6 & 7.

$$Deflection\ \% = \left(\frac{\Delta Y}{D}\right) = \frac{(D_L KP + KW')100}{0.149PS + 0.061E'}$$

Where

- D_L = Deflection Lag Factor, Dimensionless Factor to for long-term deflection.
- K = Bedding Constant, Dimensionless Accommodates the response of the buried flexible pipe to the reaction of the load force derived from the bedding under the pipe.
- P = Vertical Soil Pressure due to Prism Load, psi This is the product of the unit weight of the soil over the pipe multiplied by the depth of cover.
- W' = Live Load, psi - This is the load on the buried pipe from sources such as highway or railway traffic.
- E' = Modulus of Soil Reaction, psi - This is an empirical value, assigned to a pipe bedding condition which takes into account the soil classification and the degree of compaction of the bedding.

DEFLECTION PERCENTAGE LIMITS

The performance limit for buried PVC pipe is considered to occur when the external loading on the pipe results in a reverse curvature of the pipe, which occurs at approximately 30% deflection. The PVC pipe industry suggests a maximum vertical ring deflection of 7.5% the original base inside diameter, which provides a 4:1 safety factor to account for manufacturing tolerances, Modified Iowa Equation accuracies, and uncertainties in choosing constants and factors. This maximum threshold value is reflected in ASTM D3034 and ASTM F679. Some utility owners and engineering firms choose to use an even more restrictive value of 5% deflection, yielding a 6:1 safety factor.

It is important to note that flow area of partially full gravity sewer pipe is slightly reduced as the pipe is forced from a circle into an ellipse. If this small change is a concern, we recommend a more detailed analysis be undertaken.

MINIMUM BURIAL DEPTH

ASTM D2321, Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications, Section 7.6 states:

"The minimum depth of cover should be established by the engineer based on an evaluation of specific project conditions."

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"In the absence of an engineering evaluation, the following minimum cover requirements should be used. For embedment materials installed in accordance with Table 3, provide cover (that is, depth of backfill above top of pipe) of at least 24 in. or one pipe diameter (whichever is larger) for Class I embedment, and a cover of at least 36 in. or one pipe diameter (whichever is larger) for Class II, III, and IV embedment, before allowing vehicles or construction equipment to traffic the trench surface, and at least 48 in. of cover before using a hydrohammer for compaction."

The Unibell PVC Pipe Association Handbook of PVC Pipe, Section 7.8.3 states:

"A minimum cover height of 12 in. is recommended for PVC (SDR35) pipe subjected to highway loads of up to 18 kip axle. To prevent cracking of the road surface, special attention should be given to the selection, placement, and compaction of backfill material around shallow buried flexible pipe (such as PVC pipe)..."

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CALCULATOR

- The Uni-Bell PVC Pipe Association has developed the "Buried Pipe Design" software which calculates the expected amount of deflection for a particular burial situation based on the Modified Iowa Formula. This is available free of charge from their website (https://www.uni-bell.org/resources/technical-library/software).

SOIL SUPPORT TABLE

The modulus of soil reaction, E', is the value assigned to the bedding conditions for a PVC pipe installation. The E' value includes the Bedding Material soil type and the degree of compaction specified for the bedding. The following table shows estimated values for E' for different soil/compaction conditions:

SOIL TYPE – PIPE BEDDING MATERIAL		E' FOR DEGREE OF COMPACTION OF BEDDING, PSI			
Description	Class	Dumped	Slight <85% Proctor <40% Relative Density	Moderate 85-95% Proctor 40%-70% Relative Density	High >95% Proctor >70% Relative Density
Fine-Grained Soils (LL>50): Soils with medium to high plasticity, CH, MH, CH-MH	V	No data available, consult a geotechnical engineer or use E'=0			
Fine-Grained Soils (LL<50): Soils with medium to no plasticity, CL, ML, ML-CL, with less than 25% coarse-grained particles	IV	50	200	400	1,000
Fine-Grained Soils (LL<50): Soils with medium to no plasticity, CL, ML, ML-CL, with more than 25% coarse-grained particles **Coarse-Grained soils with fines:** GM, GP, SW, SP, contain more than 12% fines	III	100	400	1,000	2,000
Coarse-Grained Soils with Little or No Fines: GW, GP, SW, SC, contain less than 12% fines	II	200	1,000	2,000	3,000
Crushed Rock	I	1,000	3,000	3,000	3,000

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PIPE CLASS SELECTION TABLE

The table below shows the thinnest class of gravity sewer pipe that can be used with a particular burial depth and E' and assuming a maximum deflection of 7.5% and H20 Highway Live Loading.

THINNEST CLASS OF GRAVITY SEWER PIPE WHEN SUBJECTED TO H2O HIGHWAY LIVE LOADING (MAXIMUM DEFLECTION PERMITTED OF 7.5%)					
Depth of Cover (ft)	Bedding Soil Modulus, E' (psi)				
	200	400	1,000	2,000	3,000
1	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46
2	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46
5	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46
10	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46
15	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46
20	SDR26 / PS115	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46
25	SDR26 / PS115	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46
30	DR21/PS224	SDR26 / PS115	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46
35	DR21/PS224	SDR26 / PS115	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46
40	DR21/PS224	DR21/PS224	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46
45	DR18/PS364	DR21/PS224	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46
50	DR18/PS364	DR21/PS224	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46
55	DR18/PS364	DR18/PS364	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46
60	DR18/PS364	DR18/PS364	SDR35 / PS46	SDR35 / PS46	SDR35 / PS46
65	DR14/PS815	DR18/PS364	SDR26/ PS115	SDR35 / PS46	SDR35 / PS46
70	DR14/PS815	DR18/PS364	DR21/PS224	SDR35 / PS46	SDR35 / PS46
75	DR14/PS815	DR14/PS815	DR21/PS224	SDR35 / PS46	SDR35 / PS46

Assumptions: D_L=1.0, K=0.1, Backfill Weight=120 lb/ft^3, Live Load=H20 Highway

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DEFLECTION PERCENTAGE TABLES

The following 3 tables show the expected amount of pipe deflection for a specific burial depth, E', pipe class, and H20 Highway Live Loading based on values calculated using the Modified Iowa Equation. For values that exceed 7.5%, a stiffer class of PVC pipe must be used or the bedding soil conditions must be improved.

PIPE DEFLECTION (%) FOR GRAVITY SEWER PIPE AT VARIOUS DEPTHS AND BEDDING CONDITIONS SUBJECTED TO H20 HIGHWAY LIVE LOADING

Depth of Cover (ft)	Bedding Soil Modulus, E' (psi)									
	200		400		1,000		2,000		3,000	
	SDR35 PS46	SDR26 PS115	SDR35 PS46	SDR26 PS115	SDR35 PS46	SDR26 PS115	SDR35 PS46	SDR26 PS115	SDR35 PS46	SDR26 PS115
1	7.0	4.5	4.3	3.2	2.0	1.7	1.0	1.0	0.7	0.7
2	3.8	2.5	2.3	1.7	1.1	0.9	0.6	0.5	0.4	0.4
5	3.1	2.0	1.9	1.4	0.9	0.8	0.5	0.4	0.3	0.3
10	4.4	2.8	2.7	2.0	1.2	1.1	0.6	0.6	0.4	0.4
15	6.6	4.3	4.0	3.0	1.8	1.6	1.0	0.9	0.7	0.6
20	8.7	5.7	5.3	4.0	2.5	2.1	1.3	1.2	0.9	0.8
25	10.9	7.1	6.7	5.0	3.1	2.7	1.6	1.5	1.1	1.0
30	13.1	8.5	8.0	6.0	3.7	3.2	1.9	1.8	1.3	1.2
35	15.3	9.9	9.3	7.0	4.3	3.7	2.3	2.1	1.5	1.5
40	17.5	11.4	10.7	8.0	4.9	4.3	2.6	2.4	1.8	1.7
45	19.7	12.8	12.0	9.0	5.5	4.8	2.9	2.7	2.0	1.9
50	21.9	14.2	13.3	10.0	6.1	5.3	3.2	3.0	2.2	2.1
55	24.1	15.6	14.7	11.0	6.8	5.9	3.6	3.3	2.4	2.3
60	26.2	17.0	16.0	12.0	7.4	6.4	3.9	3.6	2.6	2.5
65	28.4	18.5	17.3	13.0	8.0	6.9	4.2	3.9	2.9	2.7
70	30.6	19.9	18.7	14.0	8.6	7.5	4.5	4.2	3.1	2.9
75	32.8	21.3	20.0	15.0	9.2	8.0	4.9	4.5	3.3	3.1

Assumptions: D_L=1.0, K=0.1, Backfill Weight=120 lb/ft^3, Live Load=H20 Highway

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PIPE DEFLECTION (%) FOR CIOD PRESSURE PIPE AT VARIOUS DEPTHS AND BEDDING CONDITIONS SUBJECTED TO H20 HIGHWAY LIVE LOADING										
Burial Depth (ft)	200		400		1,000		2,000		3,000	
	DR14 PS815	DR18 PS364	DR14 PS815	DR18 PS364	DR14 PS815	DR18 PS364	DR14 PS815	DR18 PS364	DR14 PS815	DR18 PS364
20	1.2	2.5	1.1	2.1	0.9	1.4	0.7	0.9	0.5	0.7
25	1.6	3.1	1.4	2.6	1.1	1.8	0.9	1.2	0.7	0.9
30	1.9	3.8	1.7	3.2	1.4	2.2	1.0	1.4	0.8	1.1
35	2.2	4.4	2.0	3.7	1.6	2.5	1.2	1.7	1.0	1.2
40	2.5	5.0	2.3	4.2	1.8	2.9	1.4	1.9	1.1	1.4
45	2.8	5.6	2.6	4.8	2.1	3.3	1.5	2.1	1.2	1.6
50	3.1	6.3	2.9	5.3	2.3	3.6	1.7	2.4	1.4	1.8
55	3.4	6.9	3.1	5.8	2.5	4.0	1.9	2.6	1.5	1.9
60	3.7	7.5	3.4	6.4	2.7	4.3	2.1	2.8	1.6	2.1
65	4.1	8.2	3.7	6.9	3.0	4.7	2.2	3.1	1.8	2.3
70	4.4	8.8	4.0	7.4	3.2	5.1	2.4	3.3	1.9	2.5
75	4.7	9.4	4.3	7.9	3.4	5.4	2.6	3.5	2.1	2.6

Assumptions: D_L=1.0, K=0.1, Backfill Weight=120 lb/ft^3, Live Load=H20 Highway

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PIPE DEFLECTION (%) FOR IPS PRESSURE PIPE AT VARIOUS DEPTHS AND BEDDING CONDITIONS SUBJECTED TO H20 HIGHWAY LIVE LOADING					
Burial Depth (ft)	200	400	1,000	2,000	3,000
	DR21 PS224	DR21 PS224	DR21 PS224	DR21 PS224	DR21 PS224
20	3.7	2.9	1.8	1.1	0.8
25	4.6	3.6	2.2	1.3	1.0
30	5.5	4.3	2.6	1.6	1.2
35	6.4	5.0	3.1	1.9	1.3
40	7.3	5.8	3.5	2.1	1.5
45	8.2	6.5	4.0	2.4	1.7
50	9.1	7.2	4.4	2.7	1.9
55	10.1	7.9	4.9	2.9	2.1
60	11.0	8.7	5.3	3.2	2.3
65	11.9	9.4	5.7	3.5	2.5
70	12.8	10.1	6.2	3.8	2.7
75	13.7	10.8	6.6	4.0	2.9

Assumptions: D_L=1.0, K=0.1, Backfill Weight=120 lb/ft^3, Live Load=H20 Highway

REFERENCES:

ASTM D3034. Standard Specification for PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings. May 2016.
ASTM F679. Standard Specification for Poly(Vinyl Chloride) (PVC) Large-Diameter Sewer Pipe and Fittings. March 2015.
AWWA C900. AWWA C900-16: Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 4"(100mm) through 60"(1,500mm)
ASTM D2241. Standard Specification for Poly(Vinyl Chloride)(PVC) Pressure-Rated Pipe (SDR Series),
Uni-Bell PVC Pipe Association. Handbook of PVC Pipe Design and Construction. 5th Ed. Chapters 6 & 7.

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