

JANUARY 2009

DEPTH OF BURIAL FOR PVC PIPE

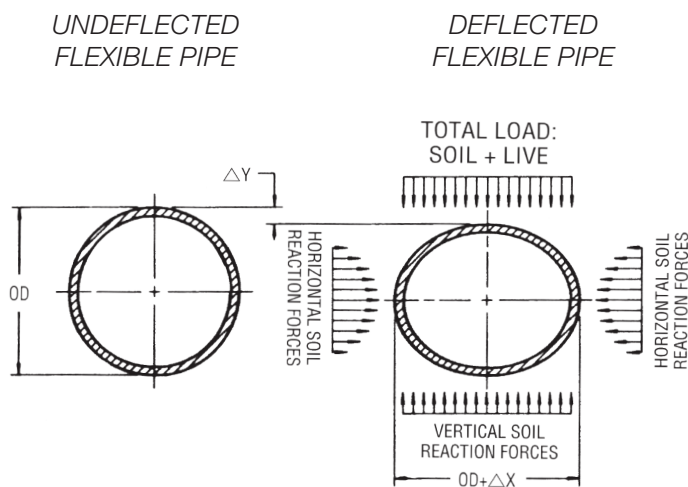
FLEXIBLE PIPE THEORY

PVC pipes are classified as flexible pipes. They flex without breaking when loaded externally from soil weight and vehicular traffic. Rigid pipes, such as those made of concrete or clay, do not perceptibly flex when loaded and experience wall crushing when their load limit is reached. This mode of failure for rigid pipes has given rise to the terms “crush strength” and “D-Load”, but these terms do not apply to PVC pipes.

When a PVC pipe encounters external loading, its diameter will begin to deflect, meaning its sides will move outward and slightly downward. If the pipe is buried in supportive soil, the stiffness of the soil will resist the deflection (see Figure 1). This action and reaction is the key to how a PVC pipe carries external loads.

Figure 1

FLEXIBLE PIPE DEFLECTION



The combination of the embedment soil stiffness and the pipe stiffness form a system that acts to support

external loads. By itself, the pipe may not support much weight, but the soil/pipe system can have tremendous load capacity.

A PVC pipe’s resistance to deflection in an unburied state is measured by its “pipe stiffness”. Pipe stiffness is usually less significant than soil stiffness in PVC pipe installations, but in general, a higher pipe stiffness results in a higher load capacity.

Soil stiffness is most affected by the level of compaction achieved, and to a lesser extent by the soil type. Soil stiffness values for various conditions and soil types have been derived through extensive testing.

CALCULATING ALLOWABLE BURIAL DEPTH

Because a PVC pipe flexes rather than breaks when loaded, the failure criterion is not fracture strength. Instead, a limit is placed on pipe diametric deflection. This limit is expressed in terms of percentage reduction in diameter due to external loading. Industry recommendations for maximum deflection are shown in Table 1.

Table 1

MAXIMUM RECOMMENDED DIAMETRIC DEFLECTION

PVC Pressure Pipes	5%
PVC Sewer / Drain Pipes	7½%
PVC Electrical Conduits	5%

A “failure” of a flexible pipe system from external loading is defined by the point at which the top of the pipe begins to experience inverse curvature. Research has shown this point occurs at a minimum of 30% deflection; recommendations for maximum deflection therefore incorporate safety factors of 4:1 or 6:1.

In order to determine the suitability of a particular burial depth, a system designer estimates the pipe deflection through the use of an empirical equation called the “Modified Iowa Equation”. A simplified, conservative version of the equation is presented below:

MODIFIED IOWA EQUATION

$$\% \text{ DEFLECTION} = \frac{0.1 (W' + P) 100}{0.149 (PS) + 0.061E'}$$

Where:

% DEFLECTION = predicted percentage of diametric deflection.

W' = Live Load (lbs/in²): pressure transmitted to the pipe from traffic on the ground surface. Live Load values are found in Table 2.

P = Prism Load (lbs/in²): pressure acting on the pipe from the weight of the soil column above the pipe (also called “Dead Load”). Prism Load values are found in Table 3.

PS = Pipe Stiffness (lbs/in²): a flexible pipe’s resistance to deflection in an unburied state. Pipe Stiffness values for JM Eagle products are found in Table 4.

E' = Modulus of Soil Reaction (lbs/in²): stiffness of the embedment soil. Values for Modulus of Soil Reaction are found in Table 5.

Table 3

PRISM LOAD SOIL PRESSURE (LBS/IN ²)					
HEIGHT OF COVER (FT)	SOIL UNIT WEIGHT (LBS/FT ³)				
	100	110	120	125	130
1	0.69	0.76	0.83	0.87	0.90
2	1.39	1.53	1.67	1.74	1.81
3	2.08	2.29	2.50	2.60	2.71
4	2.78	3.06	3.33	3.47	3.61
5	3.47	3.82	4.17	4.34	4.51
6	4.17	4.58	5.00	5.21	5.42
7	4.86	5.35	5.83	6.08	6.32
8	5.56	6.11	6.67	6.94	7.22
9	6.25	6.88	7.50	7.81	8.13
10	6.94	7.64	8.33	8.68	9.03
11	7.64	8.40	9.17	9.55	9.93
12	8.33	9.17	10.00	10.42	10.83
13	9.03	9.93	10.83	11.28	11.74
14	9.72	10.69	11.67	12.15	12.64
15	10.42	11.46	12.50	13.02	13.54
16	11.11	12.22	13.33	13.89	14.44
17	11.81	12.99	14.17	14.76	15.35
18	12.50	13.75	15.00	15.63	16.25
19	13.19	14.51	15.83	16.49	17.15
20	13.89	15.28	16.67	17.36	18.06
21	14.58	16.04	17.50	18.23	18.96
22	15.28	16.81	18.33	19.10	19.86
23	15.97	17.57	19.17	19.97	20.76
24	16.67	18.33	20.00	20.83	21.67
25	17.36	19.10	20.83	21.70	22.57
26	18.06	19.86	21.67	22.57	23.47
27	18.75	20.63	22.50	23.44	24.38
28	19.44	21.39	23.33	24.31	25.28
29	20.14	22.15	24.17	25.17	26.18
30	20.83	22.92	25.00	26.04	27.08
31	21.53	23.68	25.83	26.91	27.99
32	22.22	24.44	26.67	27.78	28.89
33	22.92	25.21	27.50	28.65	29.79
34	23.61	25.97	28.33	29.51	30.69
35	24.31	26.74	29.17	30.38	31.60
36	25.00	27.50	30.00	31.25	32.50
37	25.69	28.26	31.67	32.12	33.40
38	26.39	29.03	32.50	32.99	34.31
39	27.08	29.79	33.33	33.85	35.21
40	27.78	30.56	34.17	34.72	36.11
41	28.47	31.32	35.00	35.59	37.01
42	29.17	32.08	35.83	36.46	37.92
43	29.86	32.85	36.67	37.33	38.82
44	30.56	33.61	37.50	38.19	39.72
45	31.25	34.38	38.33	39.06	40.63
46	31.94	35.14	39.17	39.93	41.53
47	32.64	35.90	40.00	40.80	42.43
48	33.33	36.67	41.67	41.67	43.33
49	34.03	37.43	42.53	42.53	44.24
50	34.72	38.19	43.40	43.40	45.14

Table 2

LIVE LOADS ON PVC PIPE			
HEIGHT OF COVER (FT)	LIVE LOAD TRANSFERRED TO PIPE, (LBS/IN ²)		
	HIGHWAY H2O ¹	RAILWAY E80 ²	AIRPORT ³
1	12.50		
2	5.56	26.39	13.14
3	4.17	23.61	12.28
4	2.78	18.40	11.27
5	1.74	16.67	10.09
6	1.39	15.63	8.79
7	1.22	12.15	7.85
8	0.69	11.11	6.93
10	*	7.64	6.09
12	*	5.56	4.76
14	*	4.17	3.06
16	*	3.47	2.29
18	*	2.78	1.91
20	*	2.08	1.53
22	*	1.91	1.14
24	*	1.74	1.05
26	*	1.39	*
28	*	1.04	*
30	*	0.69	*
35	*	*	*
40	*	*	*

¹ Simulates 20 ton truck traffic + impact.

² Simulates 80,000 lb/ft railway load + impact.

³ 180,000 lbs. dual tandem gear assembly; 26-inch spacing between tires and 66-inch center-to-center spacing between fore and aft tires under a rigid pavement 12 inches thick + impact.

* Negligible live load influence.

Table 5

AVERAGE VALUES OF MODULUS OF SOIL REACTION, E' (FOR INITIAL FLEXIBLE PIPE DEFLECTION)					
SOIL CLASS	PIPE BEDDING MATERIALS SOIL TYPE (Unified Classification System ^a)	E' FOR DEGREE OF COMPACTION OF PIPE ZONE BACKFILL (PSI)			
		Loose	Slight < 85% Proctor, < 40% relative density	Moderate 85% - 95% Proctor, 40% - 70% relative density	High > 95% Proctor, > 70% relative density
Class V	Fine-grained Soils (LL>50) ^b Soils with medium to high plasticity CH, MH, CH-MH	No data available; consult a competent soils engineer; Otherwise use E' = 0			
Class IV	Fine-grained Soils (LL < 50) Soils with medium to no plasticity CL, ML, ML-CL, with less than 25% coarse-grained particles	50	200	400	1,000
Class III	Fine-grained Soils (LL < 50) Soils with medium to no plasticity CL, ML, ML-CL, with more than 25% coarse-grained particles 1004001,0002,000 Coarse-grained Soils with Fines GM, GC, SM, SCC contains more than 12% fines	100	400	1,000	2,000
Class II	Coarse-grained Soils with Little or No Fines GW, GP, SW, SPC contains less than 12% fines	200	1,000	2,000	3,000
Class I	Crushed Rock	1,000	3,000	3,000	3,000
	Accuracy in Terms of Percentage Deflection	±2	±2	±1	±0.5

^a ASTM Designation D 2487, USBR Designation E-3

^b LL = Liquid limit

^c Or any borderline soil beginning with one of these symbols (i.e. GM-GC, GC-SC)

^d For ± 1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

Note: Values applicable only for fills less than 50ft (15m). Table does not include any safety factor. For use in predicting initial deflections only; appropriate Deflection Lag Factor must be applied for long-term deflections. If bedding falls on the borderline between two compaction categories, select lower E' value or average the two values. Percentage Proctor based on laboratory maximum dry density from test standards using about 12,500 ft-lb/cu ft (598,000 J/m³) (ASTM D 698, AASHTO T-99, USBR Designation E-11). 1psi = 6.9kN/m².

Source: "Soil Reaction for Buried Flexible Pipe" by Amster K. Howard, U.S. Bureau of Reclamation, Denver Colorado. Reprinted with permission from American Society of Civil Engineers Journal of Geotechnical Engineering Division, January 1977, pp. 33-43.

A pipe system designer uses this equation to predict PVC pipe deflection given type of PVC pipe, burial depth, soil density, type of traffic, type of embedments oil, and compaction density of embedment soil. The designer then compares the predicted deflection to there commended maximum deflection in Table 1 to check if the burial depth is appropriate.

Example 1: Shallow Burial

A pipe system designer is interested in using ASTM D3034 SDR 35 PVC sewer pipe in a shallow-burial installation with the following characteristics: -1 foot burial depth:

- 120 pounds per cubic foot soil density
- H20 highway traffic
- sand embedment material
- 90% Proctor density embedment soil compaction

$$\% \text{ DEFLECTION} = \frac{0.1 (P+W^1) 100}{0.149 (PS) + 0.061E^1}$$

$$\% \text{ DEFLECTION} = \frac{0.1 (0.83 + 12.5) 100}{0.149 (46) + 0.061(2,000)}$$

$$\% \text{ DEFLECTION} = 1.0 \pm 1\%$$

The maximum predicted deflection is 2.0%, well below the maximum recommended for PVC sewer pipe in Table 1 of 7½%.

Minimum Burial Depth: The minimum recommended burial depth for PVC pipes beneath a highway is

one foot. This recommendation assumes proper specification of embedment materials and compaction, and proper installation.

Example 2: Deep Burial

A pipe system designer is interested in using ASTM D3034 SDR 35 PVC sewer pipe in a deep-burial installation with the following characteristics:

- 45 foot burial depth
- 120 pounds per cubic foot soil density
- H20 highway traffic (Note: Live loads are negligible for deep burials)
- sand embedment material
- 90% Proctor density embedment soil compaction

$$\% \text{ DEFLECTION} = \frac{0.1 (P+W^1) 100}{0.149 (PS) + 0.061E^1}$$

$$\% \text{ DEFLECTION} = \frac{0.1 (37.5 + 0) 100}{0.149 (46) + 0.061(2,000)}$$

$$\% \text{ DEFLECTION} = 1.0 \pm 1\%$$

The maximum predicted deflection is 3.9%, well below the maximum recommended for PVC sewer pipe in Table 1 of 7½%.

For more information, see the following JM Eagle Technical Bulletins:

- PVC Pipe Trench Construction
- Deflection Testing of PVC Sewer Pipe
- PVC Sewer and Drain Pipe Burial Depth Charts
- PVC Water Pipe Burial Depth Charts

Table 4

PVC PIPE STIFFNESS' (PS)		
PIP, WELL CASING, AND IPSSDR WATER PIPES		
PRESSURE RATING (PSI)	SDR	PIPE STIFFNESS (PSI)
63	64	7
80	51	14
100	41	28
125	32.5	57
160	26	115
200	21	224
315	13.5	916
PVC SEWER / DRAIN PIPES		
SDR 35, PWRIB		
All have a minimum pipe stiffness of 46 psi.SDR 26 has a minimum pipe stiffness of 115 psi.		
ASTM D2729 - DRAIN LINE		
SIZE (INCHES)	PIPE STIFFNESS (PSI)	
3	19	
4	11	
6	3	
AWWA C900 WATER PIPES		
PRESSURE CLASS (PSI)	DR	PIPE STIFFNESS (PSI)
100	25	129
150	18	364
200	14	815
AWWA C905 WATER PIPES		
PRESSURE RATING (PSI)	DR	PIPE STIFFNESS (PSI)
165	25	129
235	18	364
SCHEDULE 40 COEXCEL DWV PIPE		
SIZE (INCHES)	PIPE STIFFNESS (PSI)	
1½	600	
2	300	
3	300	
4	200	
6	120	

PVC PIPE STIFFNESS' (PS)	
PVC ELECTRICAL UTILITY DUCTS	
TYPE	PIPE STIFFNESS (PSI)
EB-20	20
EB-35	35
DB-60	60
DB-100	100
DB-120	120
WATER PIPE, WELL CASING, AND ELECTRICAL CONDUITS	
SCHEDULE 40	
SIZE (INCHES)	PIPE STIFFNESS (PSI)
½	5,928
¾	3,136
1	2,547
1 ¼	1,397
1 ½	1,008
2	596
2 ½	784
3	509
4	307
6	154
8	104
10	78
12	64
SCHEDULE 80	
SIZE (INCHES)	PIPE STIFFNESS (PSI)
½	17,066
¾	9,078
1	6,995
1 ¼	3,930
1 ½	2,911
2	1,846
2 ½	2,141
3	1,473
4	949
6	607
8	417
10	356
12	330