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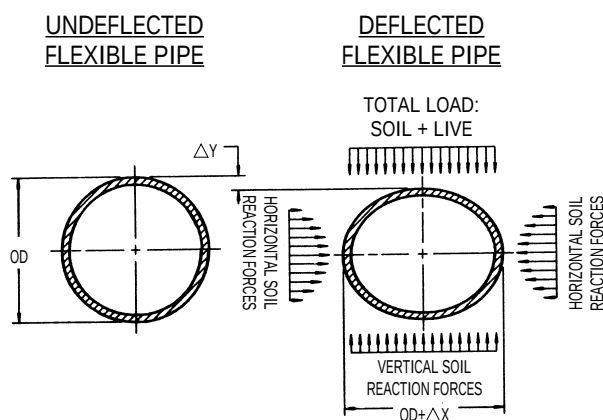
Depth of Burial For PVC Pipe

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 PWPipe 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 2
Live Loads on PVC Pipe**

Height of Cover (ft)	Live Load Transferred to Pipe, (lbs/in ²)		
	Highway H20 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	*	*	*

¹Simulates 20 ton truck traffic + impact.

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

³180,000 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 3
Prism Load Soil Pressure (lbs/in²)**

Height of Cover (ft)	Soil Unit Weight (lb/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	30.83	32.12	33.40
38	26.39	29.03	31.67	32.99	34.31
39	27.08	29.79	32.50	33.85	35.21
40	27.78	30.56	33.33	34.72	36.11
41	28.47	31.32	34.17	35.59	37.01
42	29.17	32.08	35.00	36.46	37.92
43	29.86	32.85	35.83	37.33	38.82
44	30.56	33.61	36.67	38.19	39.72
45	31.25	34.38	37.50	39.06	40.63
46	31.94	35.14	38.33	39.93	41.53
47	32.64	35.90	39.17	40.80	42.43
48	33.33	36.67	40.00	41.67	43.33
49	34.03	37.43	40.83	42.53	44.24
50	34.72	38.19	41.67	43.40	45.14

Table 4
PVC Pipe Stiffness' (PS)

PIP, Well Casing, and IPS SDR Water Pipes			PVC Electrical Utility Ducts	
Pressure Rating (psi)	SDR	Pipe Stiffness (psi)	Type	Pipe Stiffness (psi)
63	64	7	EB-20	20
80	51	14	EB-35	35
100	41	28	DB-60	60
125	32.5	57	DB-100	100
160	26	115	DB-120	120
200	21	224		
315	13.5	916		
PVC Sewer / Drain Pipes			Water Pipe, Well Casing, and Electrical Conduits	
SDR 35, PWRib			<u>Schedule 40</u>	
All have a minimum pipe stiffness of 46 psi. SDR 26 has a minimum pipe stiffness of 115 psi.			Size (inches)	Pipe Stiffness (psi)
			½	5,928
			¾	3,136
			1	2,547
			1¼	1,397
			1½	1,008
			2	596
			2½	784
			3	509
			4	307
			6	154
			8	104
			10	78
			12	64
ASTM D 2729 - Drain Line			<u>Schedule 80</u>	
Size (inches)	Pipe Stiffness (psi)		Size (inches)	Pipe Stiffness (psi)
3	19		½	17,066
4	11		¾	9,078
6	3		1	6,995
AWWA C900 Water Pipes			1¼	3,930
Pressure Class (psi)	DR	Pipe Stiffness (psi)	1½	2,911
100	25	129	2	1,846
150	18	364	2½	2,141
200	14	815	3	1,473
AWWA C905 Water Pipes			4	949
Pressure Rating (psi)	DR	Pipe Stiffness (psi)	6	607
165	25	129	8	417
235	18	364	10	356
Schedule 40 CoExcel DWV Pipe			12	330
	Size (inches)	Pipe Stiffness (psi)		
	1½	600		
	2	300		
	3	300		
	4	200		
	6	120		

Table 5
AVERAGE VALUES OF MODULUS OF SOIL REACTION, E' (for Initial Flexible Pipe Deflection)

Pipe Bedding Materials		E' for Degree of Compaction of Pipe Zone Backfill, psi			
SOIL CLASS	SOIL TYPE (Unified Classification System ^a)	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 Coarse-grained Soils with Fines GM, GC, SM, SC ^c contains more than 12% fines	100	400	1,000	2,000
Class II	Coarse-grained Soils with Little or No Fines GW, GP, SW, SP ^c 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

^aASTM Designation D 2487, USBR Designation E-3.

^bLL = Liquid limit.

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

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

Note: Values applicable only for fills less than 50 ft (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 embedment soil, and compaction density of embedment soil. The designer then compares the predicted deflection to the recommended 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 D 3034 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

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

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

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

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 specifica-

tion of embedment materials and compaction, and proper installation.

Example 2: Deep Burial

A pipe system designer is interested in using ASTM D 3034 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

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

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

$$\% \text{ DEFLECTION} = 2.9 \pm 1\%$$

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 PWPipe 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