

H-2

Pipe Strength Calculations



Pipe Strength Calculations

1. Purpose

Evaluate the stability of polyethylene pipe for use as contact water collection piping. Two conditions were evaluated:

1. Evaluate pipe stability under development rock overburden.
2. Evaluate the pipe stability under equipment loading.

2. Methodology

Ring deflection and wall buckling are the two primary parameters which need to be evaluated.

- A) Ring Deflection- The ring deflection is determined using a modified Spangler equation using a column load. The equations are as follows:

$$\text{column load: } W = \frac{\rho_{\text{soil}} * H * D}{144}$$

where; W = earthload (lb/in)

ρ_{soil} = soil density (pcf)

H = height of backfill above top of pipe (ft)

D = diameter of pipe (in)

$$\text{modified Spangler equation: } \Delta x = \frac{DI * K * W}{\frac{2 * E}{3 * SDR^3} + 0.061 * E_s}$$

where; Δx = vertical deflection of pipe (in)

DI = deflection lag factor (1.50)

K = bedding constant (0.10)

W = earthload on pipe from above (lb/in)

SDR = Standard dimension ratio

E_s = soil modulus (psi) = 3,000 psi (from Table 1)

E = modulus of pipe elasticity

- B) **Wall Buckling-** Wall buckling is evaluated by comparing the total vertical load to the critical buckling stress determined by the Von Mises formula. The equations are as follows:

vertical load: $P_b = \text{buckling pressure} = \frac{\rho_{\text{soil}} * H}{144}$

where; ρ_{soil} = backfill density, (pcf)
 H = height of backfill above top of pipe (ft)

Von Mises formula: $P_{cb} = \frac{1}{SF} \left(\frac{2.67 * R_w * B * E_s * E}{SDR^3} \right)^{0.5}$

where; P_{cb} = critical buckling stress (psi)

SF = safety factor = 2

R_w = water buoyancy factor

$$R_w = 1 - .33 * \frac{H_w}{H}$$

H = height of soil cover above pipe (ft)

H_w = height of water table above pipe (ft)

B = Empirical Coefficient of Elastic Support

$$B = \frac{1}{1 + 4 * e^{-0.065 * H}}$$

$$e = 2.718$$

SDR = Standard dimension ratio

E_s = soil modulus (psi) = 3,000 psi (from Table 1)

E = modulus of pipe elasticity

$$P_{cb} = \frac{1}{2} \left(\frac{2.67 * 1 * 0.89 * 3000 \text{ psi} * 30,000 \text{ psi}}{11^3} \right)^{0.5}$$

$$P_{cb} = 200.4 \text{ psi}$$



Table 1

AVERAGE VALUES OF MODULUS OF SOIL REACTION, E'
(For Initial Flexible Pipe Deflection)

Soil type-pipe bedding material (Unified Classification System ^a) (1)	E' for Degree of Compaction of Bedding, in pounds per square inch			
	Dumped (2)	Slight, <85% Proctor, <40% relative density (3)	Moderate, 85%-95% Proctor, 40%-70% relative density (4)	High, >95% Proctor, >70% relative density (5)
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 $E' = 0$			
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
Fine-grained Soils (LL < 50) Soils with medium to no plasticity CL, ML, ML-CL, with more than 25% coarse-grained particles	100	400	1,000	2,000
Coarse-grained Soils with Fines GM, GC, SM, SC ^c contains more than 12% fines				
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
Crushed Rock	1,000	3,000	3,000	3,000
Accuracy in Terms of Percentage Deflection ^d	±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).

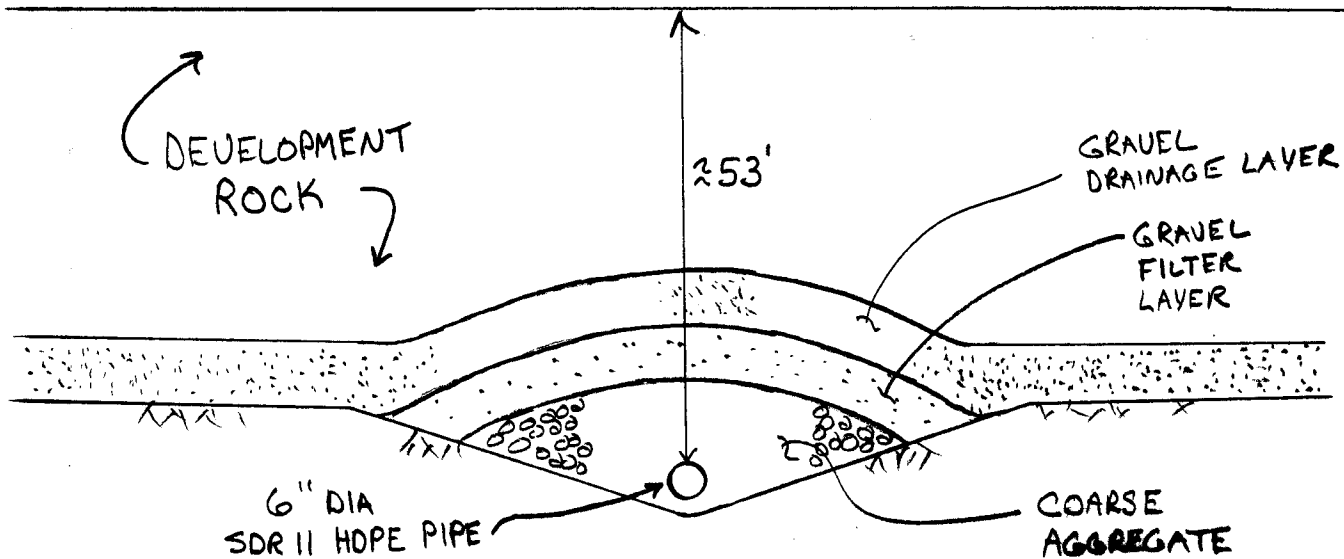
^dFor ±1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

Note: Values applicable only for fills less than 50 ft (15 m). 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). 1 psi = 6.9 kN/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

Source: Uni-Bell PVC Pipe Association (1991) Handbook of PVC Pipe – Design and Construction, Dallas, Texas, Page 474

Case 1: Evaluate Pipe Stability Under Development Rock Overburden:



Contact Water Collection Pipe

- b) Allowable deflection for SDR 11 PE (from Polypipe design guidelines) = 5%
- c) SDR = 11 for sideslope riser pipe
- d) E_s = soil modulus (psi) = 3,000 psi (from Table 1)
- e) E = modulus of SDR 11 PE pipe elasticity = 30,000 psi
- f) density of waste/cover soils = 125 lb/ft³ (see Stability Analyses)

3. Analysis

I. Evaluate piping under worst case waste and cover loading.

1. Ring Deflection:

$$W = \frac{125 \text{ lb/ft}^3 * 53 \text{ ft} * 6 \text{ in}}{144 \text{ in}^2/\text{ft}^2} = 276.0 \text{ lb/in}$$

$$\Delta x = \frac{1.5 * 0.10 * 276.0 \text{ lb/in}}{\frac{2 * 30,000 \text{ psi}}{3 * 11^3} + 0.061 * 3000 \text{ psi}} = 0.21 \text{ in}$$

$$\% \text{ deflection} = \Delta x / D * 100 = 0.21 / 6 * 100\% = 3.5\% < 5\%$$

Therefore, pipe is acceptable regarding deflection

2. Wall Buckling



Client: Kennecott Eagle Minerals Company
Project: Eagle Mine MPA
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$$P_b = \frac{125 \text{ lb/ft}^3 * 53 \text{ ft}}{144} = 46.0 \text{ psi}$$

Von Mises formula: $P_{cb} = \frac{1}{2} \left(\frac{2.67 * 1 * 0.89 * 3000 \text{ psi} * 30,000 \text{ psi}}{11^3} \right)^{0.5}$

$$P_{cb} = 200.4 \text{ psi}$$

$$P_b (46.0 \text{ psi}) < P_{cb} (200.4 \text{ psi})$$

Therefore, pipe is acceptable regarding wall buckling



Case 2: Evaluate Pipe Stability Under Equipment Loading:

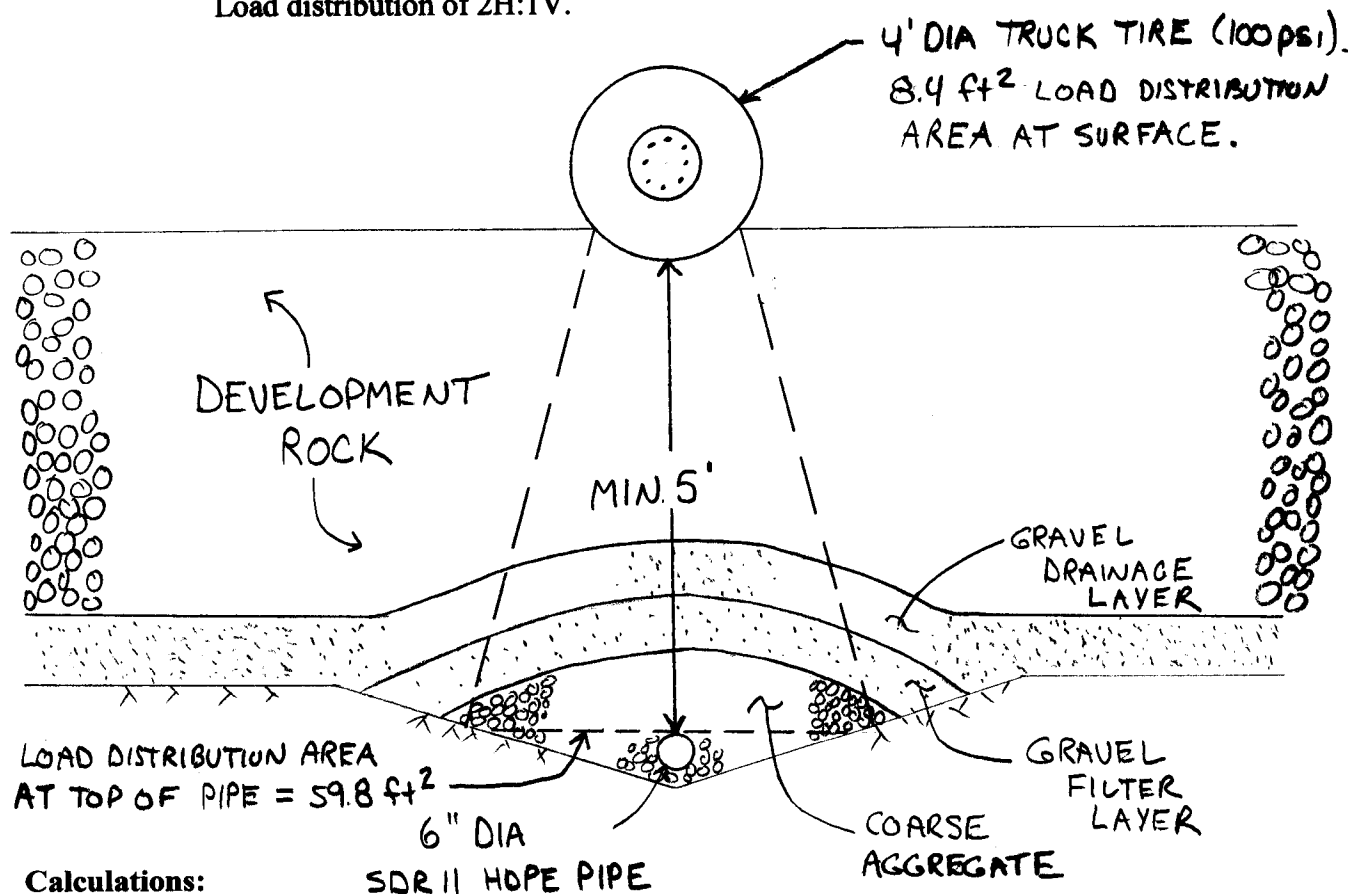
Potential equipment loading scenarios consist of 55 ton dump trucks (100 psi tire pressure) hauling development rock over the piping with a minimum 5' of cover. The live load from equipment can be expressed as the following:

Assumptions: 100 psi tire pressure.

4-foot diameter tire – contact area at the surface is 8.4 square feet.

Minimum of 5 feet of cover over the piping.

Load distribution of 2H:1V.



Load at Surface (lbs)

$$100 \text{ psi} * 8.4 \text{ ft}^2 * 144 \text{ psi/ft}^2 = 120,960 \text{ lbs}$$

Load at Top of Pipe (psi)

$$120,960 \text{ lbs} * 1/59.8 \text{ ft}^2 * 1 \text{ ft}^2/144 \text{ in}^2 = 14.0 \text{ psi}$$



14.0 psi < 200.4 psi (Pcb – Pipe wall buckling pressure)

Therefore, pipe is acceptable regarding equipment loading

The worst case loading scenario from equipment traveling directly over the pipe with 5-ft of cover soil was calculated to be 14.0 psi. This is less than the pipe wall buckling pressure (Pcb) as calculated above. Since the proposed piping met the acceptance criteria for the worst case rock and cover loading scenario it will also meet the acceptance criteria for the equipment load.

4. Conclusions

Based on the calculations listed above, SDR 11 polyethylene pipe is suitable for use as contact water collection piping.