PETROFLEX

# TECHNICAL DATA

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## INTRODUCTION:

When designing buried pipelines, there are two distinct types of pipe to consider - rigid and flexible. Rigid pipe, such as metal or concrete, is designed to be used in stand alone systems. That is, they must bear all of the internal and external loads. When using flexible pipe, such as polyethylene, the pipe is only one half of the soil pipe system. The strength of the soil and the wall thickness of the polyethylene pipe both contribute to the life of the pipe. In order to have a properly designed flexible pipe system, it is necessary to limit ring deflection, wall buckling, and wall crushing. When using buried PE pipe, the SDR (Standard Dimension Ratio) of the pipe and the strength of the soil envelope must be specified to keep the three burial design parameters within acceptable limits.

## DESIGN CONSIDERATIONS:

Petroflex PE pipe performs effectively when buried because of its ability to deflect in the interacting pipe-soil system. Contrary to rigid pipe design, deflection of a flexible (PE) pipe actually reduces the load acting upon it, i.e., the pipe actually gains strength from the surrounding soil. This occurs when the soil forms an arch over the pipe as it becomes compacted by mechanical or hydraulic means. This arching effect transfers the external loads acting upon the pipe, such as earth loads, surface live loads (road traffic), or ground water pressure to the sides of the trench. As the soil is compressed, it develops increased resistance until it reaches static equilibrium, without further compression. Deformation of the pipe becomes critical only when the ring deflection exceeds a maximum allowable limit. A study by Hoechst on deformation measurements of PE pipe were made over a period of twelve years and proves that PE pipe does not continuously deflect to the point of collapse, as suggested by some rigid pipe industry people. Petroflex pipe is ductile enough to ensure that it will not crack even when it has totally collapsed. Therefore, limitations of maximum deflection are established to ensure proper geometry.

## SUMMARY:

Actual tests by Hoechst prove that HDPE pipe does not continuously deflect to the point of collapse. Collapse due to deflection or wall crushing is not a problem for HDPE pipe. By checking the three basic design parameters, the long term performance of buried, non-pressurized pipe can be insured.

# TECHNICAL DATA
# DESIGN PARAMETERS

## WALL CRUSHING:

When Petroflex HDPE Pipe is buried, the total external vertical pressure, $P_t$, is supported by the thickness of the wall of the pipe at the horizontal spring line. Theoretically, very high soil pressures, applied to a given wall thickness, could exceed the long term compressive hoop strength of the pipe causing localized wall crushing. Very seldom do the proper conditions for wall crushing occur, however, it is usually considered in the cases of large diameter, thin wall pipes and/or in cases of very high soil pressure. The following check will determine if wall crushing is possible at a given $P_t$.

$$S_a = \frac{(SDR-1)P_t}{2}$$

where:
- $S_a$ = Actual ring compressive hoop stress (PSI).
- SDR = Standard Dimension Ratio
- $P_t$ = Total external pressure at top of pipe (PSI).

Safety Factor = (cys) where: cys = Compressive yield strength of Petroflex HDPE = 1600 PSI

The following chart shows the maximum capability of each Petroflex SDR.

Wall Crushing Design Limit - SDR vs. Maximum Total External Soil Pressure, $P_t$ (At 73.4°F and 2:1 safety Factor).

| Pipe SDR | Maximum Soil Pressure PSF | psi | Equivalent Depth* Of Dry Soil @ 100#/Cu. Ft. |
|---|---|---|---|
| 7 | 38,448 | 267 | 384 |
| 9.5 | 27,106 | 188 | 271 |
| 11 | 23,040 | 160 | 230 |
| 11.5 | 21,943 | 152 | 219 |
| 13.3 | 18,720 | 130 | 187 |
| 13.5 | 18,432 | 128 | 184 |
| 15.5 | 15,889 | 110 | 159 |
| 17 | 14,400 | 100 | 144 |
| 19 | 12,800 | 89 | 128 |
| 21 | 11,520 | 80 | 115 |
| 26 | 9,216 | 64 | 92 |
| 32.5 | 7,314 | 51 | 73 |

*No Surface Loads Included

## WALL BUCKLING:

Wall buckling of HDPE pipe is a longitudinal wrinkling of the pipe wall. Tests by Hoechst and others on non-pressurized HDPE pipe show that buckling and collapse do not occur when the soil envelope is in full contact with the pipe and is compacted to a dense state. Theoretically, if the $P_t$ at the top of a non-pressurized pipe exceeds the pipe-soil system's critical buckling pressure, $P_{cb}$, a gradual collapse may occur over the ling term, i.e., ten to fifty years. Note: All pipe diameters with the same SDR in the same burial conditions have the same critical collapse and critical buckling endurance. Experimental data is used to determine collapse pressure causing wall buckling since many variables exist in the pipe-soil system. A calculated value for the critical buckling pressure can be obtained by the following:

$$P_{cb} = 0.8 \sqrt{E' \times P_c}$$

Where: $P_{cb}$ = Critical buckling soil pressure at top of pipe (PSI)

$P_t$ = Total vertical soil pressure at top of pipe

$E'$ = Soil modulus in psi calculated as the ratio of the vertical soil pressure to vertical soil strain at a specified density (please see chart)

$P_c$ = Hydrostatic, critical-collapse differential pressure

$$P_c = \frac{2E(t/D)^3 \ (Dmin/Dmax)^3}{(1 - u^2)}$$

$$P_c = \frac{2.32E}{(SDR)3}$$

Where: (Dmin/Dmax) = .95
u = Poission's Ratio
u = .45 for HDPE
E = Stress and time dependant tensile modulus of elasticity (PSI)

## RING DEFLECTION:

Ring deflection is defined as the ratio of the vertical change in diameter to the original diameter(%). Ring deflection for buried HDPE is approximately the same as the vertical compression of the soil envelope around the pipe. Therefore, pipe ring deflection is a calculation of vertical soil strain. Please refer to plot of vertical stress-strain data.

$$\% \text{ Soil Strain} = \epsilon_s = \frac{P_t}{E' \min} \times 100$$

The recommended allowable deflection for the various SDR's are:

| SDR | Allowable Ring Deflection % |
|---|---|
| 7 | 1.7 |
| 9.5 | 2.3 |
| 11 | 2.7 |
| 11.5 | 2.9 |
| 13.3 | 3.3 |
| 13.5 | 3.4 |
| 15.5 | 3.9 |
| 17 | 4.2 |
| 19 | 4.7 |
| 21 | 5.2 |
| 26 | 6.5 |
| 32.5 | 8.1 |

In regard to ring deflection, the density of the bedding and soil envelope determines the performance capability of the pipe-soil system. Tests conducted at Utah State University show that HDPE pipe will not buckle under ordinary conditions if the soil envelope is compacted and is in full contact with the pipe. The following is intended as a basic guide for engineers in maximizing installation of Petroflex HDPE pipe:

- ASTM D2321. Standard recommended practice for underground installation of flexible thermoplastic sewer pipe, should be used as a guide for determining the method of placing and compacting the backfill.
- AASHTO T-99. Standard proctor density.
- 75% standard density is easily achieved even in poor soils.
- 85% standard proctor density should be a conservative minimum.
- At 90% standard density, laying depth for HDPE i s almost unlimited.
- A full footprint = 70% density.
- A full heelprint = 80% density.
- A corner heel impression while walking = 90% density.
- Coarse sand washed into place = 90% density.
- Fine sand or soils flooded with water = 80% density or greater.
- Dry sand or gravel vibrated into place = 90% +.
- Clean select graded sand will achieve 90% + just by dumping around the pipe.

NOTE: If the soil requires mechanical compaction, it may be more economical to envelope the pipe with sand. If the native soil is of very poor quality, the trench should be overexcavated about 1/8 the diameter or three inches, whichever is greater, and backfilled with sand insuring placement under the pipe haunches. Ponding of the soil is usually adequate.

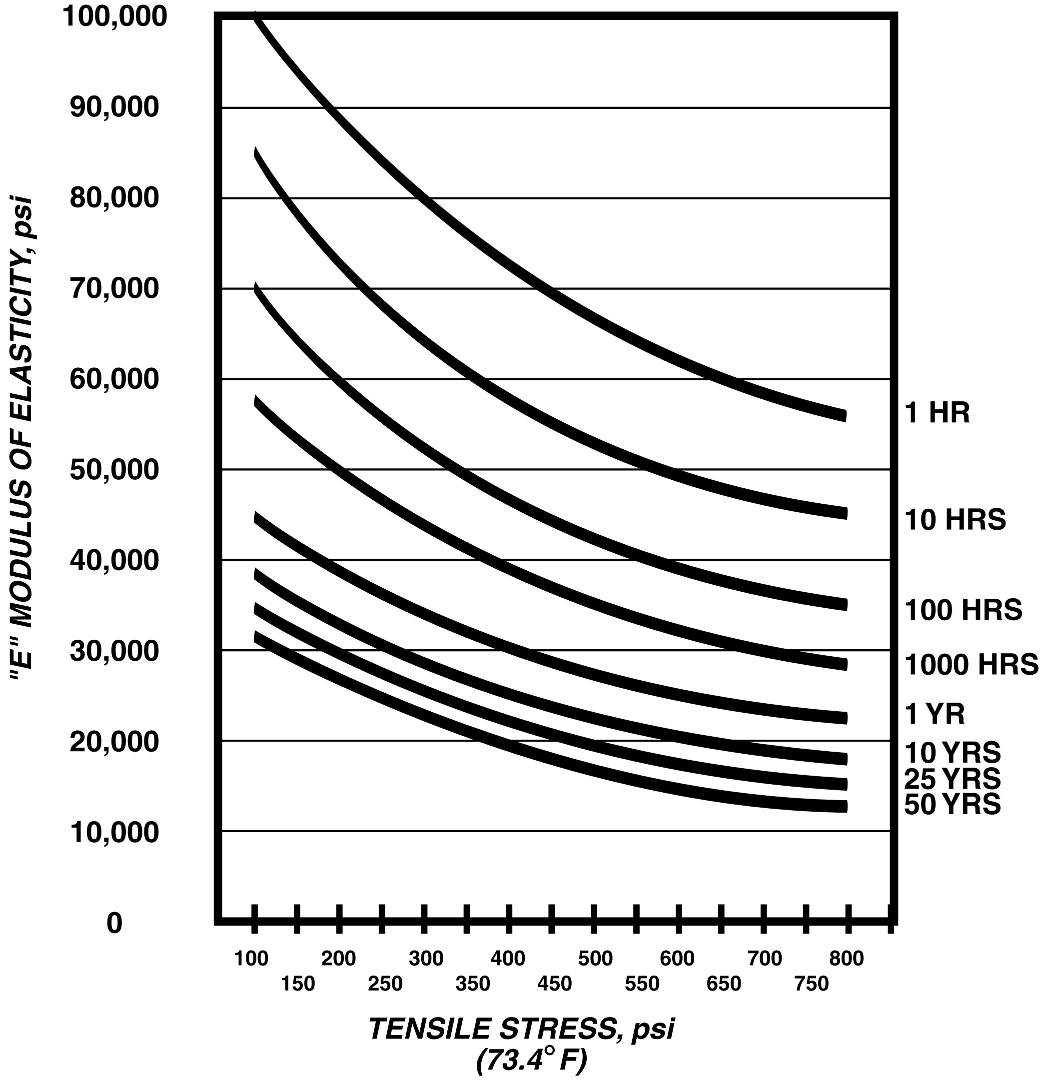
- Consider a burial depth below the local frost line.
- No overland traffic - minimum cover = 18" or one diameter, whichever is greater.
- Truck traffic = minimum 36" or one diameter.
- Heavy truck/locomotive traffic - minimum of five feet or greater.
- Density of dry soil = 100-120#/cu. ft.
- Density of water saturated soil = 125-140#/cu.ft.

## SUMMARY:

When the primary backfill immediately surrounding the pipe is compacted to 85% or better density, wall crushing, wall buckling, and ring deflection limitations are seldom exceeded. By checking these design parameters, the engineer can calculate the safety factors involved and insure long term performance of HDPE pipe when the pipeline is not pressurized.

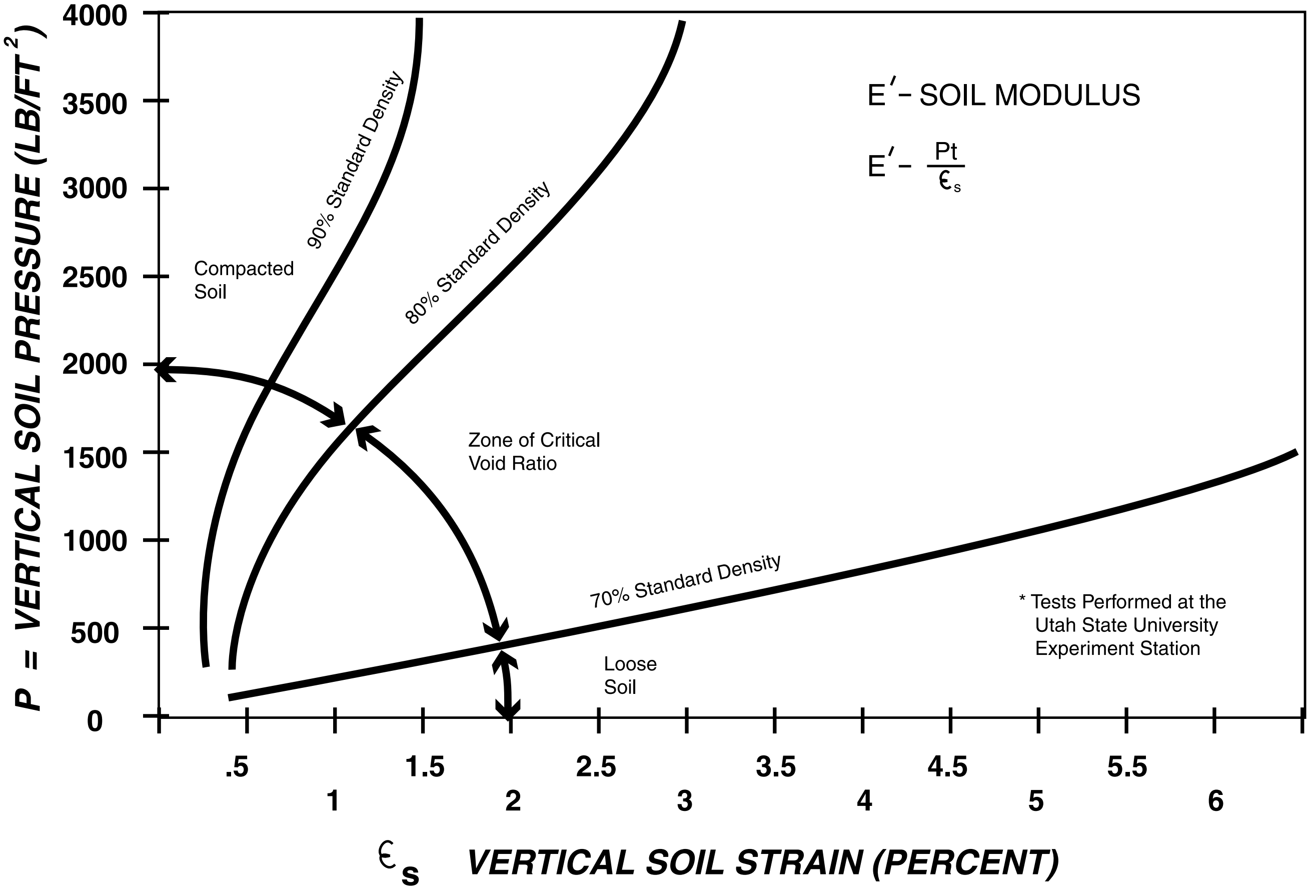
- Hoechst is a world wide supplier of chemicals, pharmaceuticals, and cosmetics. They have been supplying high density polyethylene material and testing it for over thirty years. As we have mentioned, some of this data is based on Hoechst's test data.

***TIME DEPENDENT MODULUS OF ELASTICITY FOR POLYETHYLENE PIPE VS. STRESS INTENSITY (73.4° F)***




NOTE: The short term modulus of elasticity of HDPE pipe per ASTM D 638 is approximately 113,000 psi. Due to the cold flow (creep) characteristic of the pipe material, this modulus is dependent upon the stress intensity and the time duration of the applied stress.

## *PLOT OF VERTICAL STRESS-STRAIN DATA FOR TYPICAL TRENCH BACKFILL (EXCEPT CLAY) FROM ACTUAL TESTS.**




EXAMPLE
FIND: $E'$ @ 2000 PSF AND 80% DENSITY
FORMULA: $E' = Pt / \epsilon_s$
CALCULATIONS: $E'$ = 2000 PSF/.018 = 111111 PSF = 771 psi

NOTE: The curves shown on this chart are sample curves for a granular soil. If other types of soil are used for backfill, such as clay or clay loam, curves should be developed from laboratory test data for the material used. Soil pressures greater than 4000 psf may be examined by extrapolating the slope of the curve or by generating curves by testing at those higher soil pressures. Probable error of curves is about half the distance between adjacent lines.

Example: Problem

Given: 2” Sch 40
2.375” O.D.
.154 = min Wall
48” = depth

$$SDR = \frac{2.375}{.154} = 15.4$$

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$P_t$ @ 100#/cu.ft. X 4′ = 400#/ft.$^2$
400#/ft.$^2$ = 2.8 psi

Wall Crushing:

$$S_a = \frac{(SDR - 1)P_t}{2}$$

$$S_a = \frac{(15.4 - 1)2.8}{2}$$

$S_a$ = 20.16 PSI = Actual ring compressive hoop stress.

$$\text{Safety Factor} = \frac{CYS}{S_a} = \frac{1600}{20.16} = 79$$

**Wall Buckling:**

E = Modulus of Elasticity @ 50 Yrs. + 100PSI Tensile Stress
E = From Graph = 34,000 PSI
$P_c$ = Critical Collapse Diff. Pressure

$$P_c = \frac{2.32E}{(SDR)^3}$$

$$P_c = \frac{2.32\,(34{,}000)}{15.4} = \frac{78880}{3652} = 21.6 \text{ PSI}$$

**Soil Modulus = E′**

4′ deep @ 100#/cu.ft. = 400#/ft.$^2$ @80% Standard Density
From Graph = .002%

$$E' = \frac{400 \text{ PSF}}{.002} = 200{,}000 \text{ PSF} = 1389 \text{ PSI}$$

Example
Critical Buckling PSI: @ Top of Pipe

$$P_{cb} = 0.8\sqrt{E' \times P_c}$$

$$P_{cb} = 0.8\sqrt{1389 \times 21.6}$$

$P_{cb}$ = 138.6 PSI

Check for E′ (1389 from Graph) — Required to resist buckling.

$$E' = \frac{(P_{cb})^2}{.64P_c}$$

$$E' = \frac{(138.6)^2}{.64(21.6)} = \frac{19210}{13.8} = 1392 \text{ PSI} \approx 80\% \text{ density}$$

Safety Factor Wall buckling = E′ X (S.F.) Assume 2
$E'_{min}$ = E′(S.F.)
$E'_{min}$ = 1392 X 2 = 2784 PSI

Pipe Deflection:

$$\% \text{ Soil Strain } \varepsilon_s = \frac{Pt}{E'_{min}} \times 100$$

$$\varepsilon_s = \frac{2.8}{2784} \times 100 = 0.1\%$$

Maximum allowable ≈ 3.9%

Minimum diameter ↕ Due to Deflection:

2.375” OD X .1% = .002375

Min diameter = 2.372”

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