

HYDROSTATIC DESIGN BASIS FOR THERMOPLASTIC PIPES

The Hydrostatic Design Basis (HDB) test is used for the purpose of determining the long-term strength characteristics of a plastic pipe. The Plastics Pipe Institute states on page 1 of Technical Report TR-4/90 the following:

"The term hydrostatic design basis (HDB) category refers to the estimated long-term strength in the circumferential, or hoop, direction of a pipe or tube."

Some plastic pipe representatives have made the general statement that *"since our pipe is intended for a gravity flow condition only and not for a pressure system, there is no need for pressure rated materials."* This is a very deceptive statement that misleads the design engineer. The HDB test does not relate to a particular end use of the product. **The test is simply a means to evaluate the long-term material characteristics.**

It is a well established fact that high density polyethylene will have a decrease in tensile strength in the range of 70 percent and a decrease in the modulus of elasticity of 80 percent over a 50 year period. PVC can have a decrease in tensile strength in the range of 47 percent and a decrease in the modulus of elasticity of 65 percent over a 50-year period.

The American Association of State Highway and Transportation Officials (AASHTO) states in their Design Manual, Sections 18.4.3.1 and 18.4.3.2, the following mechanical properties for design purposes:

AASHTO - SECTION 18

SOIL-THERMOPLASTIC PIPE INTERACTION SYSTEMS

18.4.3.1 Polyethylene

18.4.3.1.1 Smooth wall PE pipe requirements – ASTM 714

Mechanical Properties for Design

Initial		50 Year	
Minimum Tensile Strength	Minimum Mod. of Elast.	Minimum Tensile Strength	Minimum Mod. of Elast.
(psi)	(psi)	(psi)	(psi)
3,000	110,000	1,440	22,000

Minimum cell class, ASTM D 3350, 335434C

Allowable long term strain = 5%

18.4.3.1.2 Corrugated PE pipe requirements – AASHTO M 294

Mechanical Properties for Design

Initial		50 Year	
Minimum Tensile Strength	Minimum Mod. of Elast.	Minimum Tensile Strength	Minimum Mod. of Elast.
(psi)	(psi)	(psi)	(psi)
3,000	110,000	900	22,000

Minimum cell class, ASTM D 3350, 315412C

Allowable long term strain = 5%

18.4.3.1.3 Ribbed PE pipe requirements - AASHTO F 894

Mechanical Properties for Design

Initial		50 Year	
Minimum Tensile Strength	Minimum Mod. of Elast.	Minimum Tensile Strength	Minimum Mod. of Elast.
(psi)	(psi)	(psi)	(psi)
3,000	80,000	1,125	20,000

Minimum cell class, ASTM D 3350, 334433C

Allowable long term strain = 5%

OR:

Initial		50 Year	
Minimum Tensile Strength	Minimum Mod. of Elast.	Minimum Tensile Strength	Minimum Mod. of Elast.
(psi)	(psi)	(psi)	(psi)
3,000	110,000	1,440	22,000

Minimum cell class, ASTM D 3350, 335434C

Allowable long term strain = 5%

18.4.3.2 Poly (Vinyl Chloride) (PVC)

18.4.3.2.1 Smooth wall PVC pipe requirements - AASHTO M 278, ASTM F 679

Mechanical Properties for Design

Initial		50 Year	
Minimum Tensile Strength	Minimum Mod. of Elast.	Minimum Tensile Strength	Minimum Mod. of Elast.
(psi)	(psi)	(psi)	(psi)
7,000	400,000	3,700	140,000

Minimum cell class, ASTM D 1784, 12454C

Allowable long term strain = 5%

OR:

Initial		50 Year	
Minimum Tensile Strength	Minimum Mod. of Elast.	Minimum Tensile Strength	Minimum Mod. of Elast.
(psi)	(psi)	(psi)	(psi)
6,000	440,000	2,600	158,400

Minimum cell class, ASTM D 1784, 12364C

Allowable long term strain = 3.5%

18.4.3.2.2 Ribbed PVC pipe requirements - ASTM F 794

Mechanical Properties for Design

Initial		50 Year	
Minimum Tensile Strength	Minimum Mod. of Elast.	Minimum Tensile Strength	Minimum Mod. of Elast.
(psi)	(psi)	(psi)	(psi)
7,000	400,000	3,700	140,000

Minimum cell class, ASTM D 1784, 12454C

Allowable long term strain = 5%

OR:

Initial		50 Year	
Minimum Tensile Strength	Minimum Mod. of Elast.	Minimum Tensile Strength	Minimum Mod. of Elast.
(psi)	(psi)	(psi)	(psi)
6,000	440,000	2,600	158,400

Minimum cell class, ASTM D 1784, 12364C

Allowable long term strain = 3.5%

As an example of HDB rated material, AASHTO requires a minimum cell classification of 315412C for Corrugated PE Pipe. The sixth number of the cell classification denotes the minimum Hydrostatic Design Basis requirement of 1,000 psi resin material. The following is the cell classification numbers for HDB as per ASTM D 3350:

0	not pressure rated *
1	800 psi
2	1,000 psi
3	1,250 psi
4	1,600 psi

*** A zero (0) classification would allow the use of a material that could theoretically have little or no strength in 50 years.**

It should be noted that the AASHTO design requirements are principally for culverts, which are a non-pressure system, and Section 18.4.3.1 specifies a HDB rated material for all HDPE products. The 50 year data is obtained from HDB testing. PVC materials do not have a HDB material rating included in the cell classification, but requires HDB testing to establish and verify the 50-year performance data.

HYDROSTATIC DESIGN BASIS TEST as per ASTM D 2837

The Hydrostatic Design Basis of thermoplastic material is the only standard method of testing to determine long-term strength characteristics.

Failure of thermoplastic material is defined as bursting, cracking, splitting, or weeping (seepage of liquid) of the pipe during the test period.⁽¹⁾

Suppliers of bulk resin materials can have their resin material tested and then certified by the HYDROSTATIC STRESS BOARD, a technical board associated with the Plastics Pipe Institute. Thermoplastic pipe producers can then certify their pipes to the design engineer or owner. Certification by the Hydrostatic Stress Board is inexpensive and is for a 5-year period of time.

ADDITIONAL PHYSICAL PROPERTIES AFFECTING HYDROSTATIC DESIGN BASIS

In addition to the Hydrostatic Design Basis, there are other physical properties that are inner-connected and have an influence on long-term strength characteristics.

There is a relationship between long-term strength and the Environmental Stress Crack Resistance (ESCR). In other words, pipes made with HDB rated resins give the consumer data of long-term material characteristics that are used in design.

Environmental Stress Cracking and Slow Crack Growth can affect the long-term physical properties of an installed pipe long before the end of the design life of 50 years.

ENVIRONMENTAL STRESS CRACK RESISTANCE (ESCR)

Environmental stress cracking (ESC) in thermoplastic pipe walls occurs when the installed pipe has deflected and resulting stresses have developed. ESC will develop differently in PVC than in PE, but it still occurs in both materials.

Chemical agents, such as soap and detergent solutions, some organic acids, aromatic and halogenated hydrocarbons, and wetting agents react adversely with stressed thermoplastic materials. **Many materials which may show excellent chemical resistance unstressed, may fail most rapidly when under stress and subjected to the above mentioned chemical agents and detergents.**

Most, if not all, PVC pipes have a moderate to high content of fillers added to the resin mix. Recently, fillers in some PVC pipes have been found to be as much as 50%, or higher, of the total mix, whereas PVC pipe produced in prior years typically had less than 10%. Fillers are generally calcium carbonate (limestone) coupled with a very small percentage of lubricants and colorants.

One problem with a high filler content in PVC pipes that does not get much attention is the bulking factor that occurs when the pulverized limestone is added to the liquid resin mix. If bulking occurs in a PVC mix, then this becomes the first trouble spot when stresses develop in the pipe wall. **Fillers which may improve initial performance are stated to have an adverse affect on long term performance.**

"The limestone does not chemically bond with other elements present; nor is there a physical bond to the other elements present. Thus, the limestone does not have any molecular relationship with the other elements present. The limestone exists as granules adjacent to other granules of resin. While there may be some cohesion of the granules when the pipe is extruded, there is no evidence of any long term assurance of the continuance of such cohesion."⁽²⁾

In PE pipes, one problem is the non-uniform wall thickness that can develop in the extrusion process. This non-uniformity causes stresses in the pipe wall, which can result in splitting of the pipe elements.

SLOW CRACK GROWTH (SCG)

A major concern for HDPE material should be polyethylene's *"capacity to be compromised through a very slow acting mechanism whereby when the material is subjected to a tensile stress of long duration, a crack will develop which then grows at a very slow rate until it becomes large enough to cause leakage, or structural failure."*⁽³⁾ This is called Slow Crack Growth (SCG).

"Extensive experience with polyethylene pipe has established that when pipe is subjected to slow crack growth (SCG) mechanism, failure can be caused by any long-lasting or repetitively induced stress; be it due to internal pressure, residual stress, point loading, bending, shear or thermal effects. Many field failures of PE pipe have been noted to occur through the SCG mechanism and they have been primarily in response to external loads and not to those induced by pressure."⁽³⁾

CONCLUSION

The only test procedure to establish long-term material properties is the Hydrostatic Design Basis test.

"There is no reliable basis for defining an ESCR which will ensure a minimum resistance to SCG. For this reason, polyethylene must have an established hydrostatic design basis (HDB) in accordance with ASTM D 2837."⁽³⁾

To insure against early failure of thermoplastic pipelines, a design engineer should insist on hydrostatic design basis resin, Cell Classification of "2" (1,000 psi) or greater, both in gravity and pressure applications.

It is critical that the design engineer examine all portions of the cell classification to assure a quality material is used for the design life of the pipeline and that the design is based on the 50-year mechanical properties.

While such HDB rated materials may give the consumer some assurance of long-term characteristics, they must also recognize processing of the resin into a finished product can also cause deleterious effects on potential performance as can ESCR and SCG.

⁽¹⁾ ASTM D 2837, para. 3.4.

⁽²⁾ Erdos, Lawrence, I., "Ambiguities and Inanitions of Current Plastic Pipe Specifications", ASCE Proceedings on Pipeline Design and Installation, March 1990.

⁽³⁾ Mruk, Stanley A., Executive Director of the Plastics Pipe Institute, March 1, 1991

ADDITIONAL REFERENCES

ASTM D 2837 Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials

ASTM D 1590 Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure

ASTM D 1785 Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80 and 120

ASTM D 3350 Standard Specification for Polyethylene Plastics Pipe and Fittings Materials

ASTM D 3915 Standard Specification for Poly (Vinyl Chloride) (PVC) and Related Plastic Pipe and Fitting Compounds for Pressure Applications

Technical Report TR-4/90, "Recommended Hydrostatic Strengths and Design Stresses for Thermoplastic Pipe and Fittings Compounds", Plastic Pipe Institute.

Technical Report TR-3/89, "Policies and Procedures for Developing Recommended Hydrostatic Design Stresses for Thermoplastic Pipe Materials", Plastic Pipe Institute.