Abrasion Resistance of HDPE Corrugated Pipe

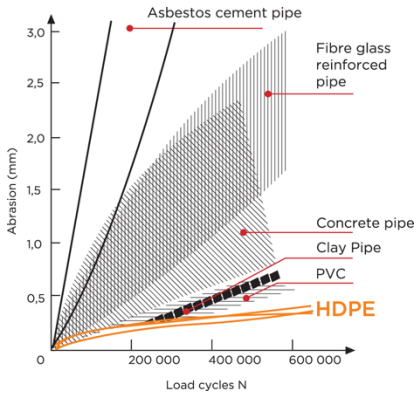
Abrasion is the reduction in thickness of a pipe's inside surface material due to the mechanical action of erosion. During normal operating conditions, gravity flow pipes can be subjected to abrasive bed loads containing gravel, rocks and/or sharp stones. Abrasion rates can be further accelerated when an abrasive bed load is combined with acidic effluent. Abrasion is most common in the pipe invert.

Abrasion rate is a function of fluid velocity and particle characteristics of the suspended fines. Abrasion rates increase with fluid velocity and pipe diameter. In most highway applications such as culverts and surface water drains, velocities are less than 6 m/s (20 ft/s) and in sewer pipes, flow is even slower and less abrasive.

LABORATORY TESTING

Several documented studies were performed to determine the wear rates of pipe materials in controlled laboratory settings. One of the most important is the Darmstadt Test (Ref. 1) developed by Dr. Kirschmer of The Institute of Technology in Darmstadt, Germany. A test section of 1m pipe was tilted back and forth with a frequency of 21.6 cycles/min while containing an abrasive slurry of 46% by volume of quartz sand (particle size 0-30 mm) in water. The resultant velocity over the surface of the pipe was 0.36 m/s. Results showed that both polyethylene and polypropylene outperform clay and concrete pipe (Ref. 1).

FIGURE 1: Abrasion Loss of Various Pipe Materials



Another well documented laboratory trial is the Erosion Study conducted by the Saskatchewan Research Council (Ref. 2). The abrasion performance of a plastic pipe was compared to that of steel and aluminum pipes. Tests were performed on samples of 50 mm (2 in) pipe using a 40% by weight mix of course sand (particle size 0.55 mm) and fine sand (particle size 0.30 mm) in a water slurry in a closed loop system at a controlled temperature. Tests were conducted for 3 weeks at 4 m/s and 6 weeks at 2.1 m/s. Results were extrapolated to obtain annual wear rates, shown in **Table 1**.

TABLE 1: Extrapolated Annual Wear Rates of Plastic and Metals under Abrasive Slurries

Material	Wear Rates (mm/year)			
	Course Sand		Fine Sand	
	2.1 m/s (7 ft/s)	4.6 m/s (15 ft/s)	2.1 m/s (7 ft/s)	4.6 m/s (15 ft/s)
Steel	0.65	1.81	0.04	0.02
Aluminum	1.81	7.48	0.14	0.86
Polyethylene	0.06	0.46	nil	0.06

Results showed that wear rates for polyethylene were significantly less than for the other materials tested.

Storm drainage systems often carry both acidic and abrasive effluent. A study performed by California State University (Ref. 3) investigated the effects of abrasive and acidic flow on pipe wear of various materials. Tests were performed using both neutral (pH = 7) and acidic (pH = 4) mediums. Sections of 300 mm diameter pipe were filled with an abrasive slurry consisting of 13-19 mm crushed quartz and 51mm minimum river run quartz gravel. Two thirds of the abrasives were crushed quartz with the remainder being river run gravel in order to best simulate working site conditions. Pipe ends were capped and the pipe was attached to a rocking apparatus and rotated through an 83 degree arc, constituting one cycle. A total of 50,000 complete cycles were used in the tests. An average fluid velocity of 0.9 m/s was maintained. Conditions were monitored in order to maintain consistent pH and aggregate levels throughout the experiment. Tests were completed after a specified number of rotations.

The study compared the durability of a 300 mm (12 in) smooth interior polyethylene pipe and that of a non-reinforced concrete pipe of the same size. The loss of wall thickness was measured for both pipes. Results are summarized in **Tables 2a and 2b**.

TABLE 2a: California State University Abrasion Resistance Test – Neutral Conditions (pH = 7)

	Initial Wall Thickness (mm)	Expendable Wall Thickness[1] (mm)	Max. Loss of Wall Thickness (mm)	Remaining Wall Thickness[2] (%)	Visual Results
Polyethylene Pipe 300 mm, smooth interior	2.8	0.89	0.53	40	Liner showed some evidence of wear. Liner perforation did not occur.
Concrete Pipe 300 mm	54.6	13	20	< 0	Steel reinforcement would have been exposed.[3]

NOTES:
1. The thickness of the wall that can abrade before reaching failure.
2. Presented as a percentage of the expendable wall thickness and is an indication of the amount of service life remaining.
3. Tests intended to use reinforced concrete pipe as per construction applications, however non-reinforced was used.

TABLE 2b: California State University Abrasion Resistance Test – Acidic Conditions (pH = 4)

	Initial Wall Thickness (mm)	Expendable Wall Thickness[1] (mm)	Max. Loss of Wall Thickness (mm)	Remaining Wall Thickness[2] (%)	Visual Results
Polyethylene Pipe 300 mm, smooth interior	2.8	0.89	0.61	31	Liner showed some evidence of wear. Liner perforation did not occur.
Concrete Pipe 300 mm	54.6	13	30.5	< 0	Loss of wall thickness was much higher than in neutral conditions. Significant amounts of reinforcement would have been exposed.[3]

NOTES:
1. The thickness of the wall that can abrade before reaching failure.
2. Presented as a percentage of the expendable wall thickness and is an indication of the amount of service life remaining.
3. Tests intended to use reinforced concrete pipe as per construction applications, however non-reinforced was used.

Trials indicated that even under harsh acidic conditions, the polyethylene pipe did not show liner perforation and the wear rate increased by only 15% leaving over 30% remaining of the liner thickness. The concrete pipe showed significant wear. In acidic environments the wear increased by over 50%. If tests had been performed using reinforced concrete pipe, the reinforcement would have also been exposed and the pipe would have failed even sooner than in a neutral environment.

Available scientific literature overwhelmingly confirms the superiority of HDPE pipe's abrasion resistance when compared to that of other pipe materials. As mentioned in the MTO Gravity Pipe Design Guidelines (Ref. 4): "The long-chain molecules that make up the polymer chain are able to resist the impact of heavy bed loads", or abrasive fluids. Along with its high resistance to aggressive chemicals with a pH range of 1 to 14, HDPE pipes outperform other pipe materials and ensure a longer product life in most hostile environments.

References:

1. Kirschmer, O., "Problems of Abrasion in Pipes", Steinzeugin Formationen, 1966, No. 1, pp 3-13.
2. Hass, D.B. and Smith, L.G., "Erosion Studies – A Report to Dupont of Canada Ltd.", Saskatchewan Research Council, E75-7, September, 1975.
3. Gabriel, Lester. "Abrasion Resistance of Polyethylene and Other Pipes." California State University, Sacramento, California, 1990.
4. Ontario Ministry of Transportation "Gravity Pipe Design Guidelines", April 2014.