New Product, More Concerns
Polypropylene vs. Polyethylene

American Concrete Pipe Association
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An educational document from the American Concrete Pipe Association for users and specifiers

Public Risk for Industry Reward

According to the Plastics Pipe Institute (PPI), the plastic pipe industry has taken risks to come up with new products to "improve" the storm water industry and "these changes were very risky as they involved major redesigns and significant investments in equipment and tooling that if incorrect, would result in very expensive boat anchors for the manufacturers."[1] PPI mocks the very real concerns that these risks pose to the public, labeling them "scare tactics." The ACPA and prudent engineers consider those risks legitimate factors to be weighed in the decision to use or restrict the use of plastic products.

Throughout its history, the plastic pipe industry has developed a startling array of unsuccessful pipe products that have failed to live up to performance expectations. For example, Type D / honeycomb profile HDPE pipe is no longer made due to numerous fundamental performance problems. HDPE open bottom chambers experienced field performance issues and have seen significant redesign. Plastic pipe industry representatives minimize this history with the excuse "we don't make it that way anymore." Unfortunately, the use of these products has caused real expense and danger to the public.

The newest plastic pipe product on the market is polypropylene (PP) pipe. Engineers can choose between the risk of failed performance, or protecting the public welfare and safeguarding against failure. Obviously, the easiest choice would be to completely prohibit using PP in any situation. However, if you choose to calculate the risk, consider these precautions if your agency is considering a PP project:

- Due to installation sensitivity, plastic pipe systems should be directly designed for each installation by a third party licensed professional engineer. Don't rely on pipe designs prepared by a plastic pipe manufacturer. This is a conflict of interest.
- Require installers and inspectors to use ASTM D2321 installation criteria. ASTM D2321 is the nationally recognized and most comprehensive practice for the installation of HDPE pipe in sewers and other gravity flow applications.
- Require extended warranty bonds that offer protection of your project beyond the standard manufacturer's warranty.
- Conduct and evaluate post-installation inspections for pipe deflection, buckling, cracking, and other problems.

Even with the above safeguards significant engineering concerns remain. A few are listed below.

Deflection Concerns

In a manufacturer's press release, an HDPE producer states, "While ADS officials are confident that their existing corrugated HDPE products are equally adept at performing the drainage functions of their concrete and steel counterparts, language in certain codes and standards have set a 5 percent deflection limit in various applications."[2] This 5% deflection criteria was established by AASHTO[3] in order to ensure that the product would serve the public as intended. To ensure long term deflections don't exceed the 5% criteria, a near perfect installation and backfill are required.

Polypropylene has approximately 1.5 times the elastic modulus, or toughness, of HDPE. However, the yield stress of PP is very similar to HDPE, and thus the PP pipe will reach its capacity at a lower strain level (and therefore lower deflection level) than HDPE pipe. In other words, a PP pipe with an equivalent profile to currently-produced HDPE pipe would deflect less with the same applied force, due to its stronger modulus of elasticity. But if the PP pipe is improperly installed like many HDPE pipelines have been, design forces will be exceeded. If allowed to deflect to the 5% limit of HDPE, PP would likely experience a brittle failure. Therefore, a smaller post-installation deflection limit of 3% would be more appropriate for PP.

Oxidation Concerns

Another concern to keep in mind is that "polypropylene is one of the most susceptible polymers to thermal and photo oxidation."[4] Oxidation, or chemical chain degradation, of PP is caused by UV radiation breaking down particular carbons. UV light causes embrittlement, loss of strength and surface damage to the product.[5] PP is also susceptible to the same oxidation that HDPE experiences. Thus, neither product should be manufactured without antioxidants, and additional antioxidants must be added each time the material is reprocessed or reground to prevent brittleness in both products.

While antioxidants are vital to the service life of both HDPE and PP, utilizing the proper amount and type of antioxidants is even more important in PP due to the vulnerable carbon found in the polymer. While carbon black is a common antioxidant, the press release states that the industry's new PP pipe product will be grey[1] – an indication that carbon black is not utilized. Choosing the right antioxidants for this product will be critical.

The best way to protect against oxidation failures is to require a specific antioxidant package and routine testing to ensure the desired life span is achieved.

Sub-freezing Concerns

Have you ever left a plastic bucket outside during the winter, and found that it cracks or breaks far more easily than it would in the summer? What you experienced was the phenomenon known as the glass transition. Each polymer has its own glass transition temperature, or T_g for short. As the polymer cools and approaches its glass transition temperature, it becomes increasingly hard and brittle, like glass.[6] Not only is PP damaged by UV rays, it also becomes increasingly brittle with colder temperatures and has a glass transition temperature of 14°F.[7]

This relatively mild transition temperature should be of concern where the water table is at risk of freezing, or a shallow buried culvert where ground temperatures dip below freezing.

Flotation Concerns

Final installation conditions should always be considered during design. The plastic pipe industry has always claimed that its product is lightweight and therefore easy to install. While being lightweight may help the contractor, PP has a specific gravity of 0.90 compared to a specific gravity of 0.94 for HDPE. Thus, any installation benefit is greatly outweighed by the fact that the plastic pipe product can float in a high water table, a flood situation, a wet trench, or even where flooding is used to consolidate the backfill.

HDPE is well known to float, and this new PP product will be even more susceptible to the risk.

Hydraulic Concerns

Another claim by the HDPE industry is superior hydraulic flow due to a smooth inner liner. The hydraulic performance of HDPE pipe tends to be more in line with a corrugated pipe, such as corrugated metal pipe, than a smooth pipe like concrete. One hundred percent of installed HDPE pipelines suffer from corrugation growth[8], or plastic deformation in the pipeline's liner due to the transfer of stress from the outer corrugated wall to the inner liner. As shown in the photo, PP pipe experiences corrugation growth similar to HDPE.

Thus, corrugation growth should be taken into consideration when evaluating the hydraulic performance expectations for PP.

Meltability & Flammability Concerns

Meltability is as much of a concern as flammability since both can result in collapsed pipe. Melt temperature indicates the onset of dripping, and the deformation of a plastic material creating moving and falling flaming elements.[9] Both HDPE and PP will melt at temperatures above 340° F and ignite at temperatures above 772° F.[9] As a reference, a candle flame burns at an average of 1,800° F.[10]

Many state DOTs require concrete end treatments, concrete aprons and non-flammable end segments to minimize the flammability and meltability concerns, but these measures do not eliminate them. Some DOTs have experienced road failures caused by burning pipe during actual fires, and have implemented limits on the use of thermoplastic pipe in at-risk areas.

The risk of flammability should not be underestimated. There are numerous cases of HDPE pipe catching fire and collapsing that demonstrate the serious potential for melting and burning. This should be carefully considered when specifying HDPE or PP that will be installed under roadways. Pipelines under roads usually have open access, making them susceptible to arson and other fire sources.

Serious Concerns or Scare Tactics?

The plastic industry may call these issues scare tactics, but the issues raised above are all concerns that a prudent engineer should evaluate when determining whether to specify HDPE or PP pipe.

References

1. *Risk versus Progress, Standing Still Means Falling Behind*, Tony Radoszewski, January 2007.
2. *ADS Has High Expectations for New PP Pipe*, Matt Griswold, April 25, 2008.
3. AASHTO LRFD Bridge Design Specification, Section 12, 4th Edition, 2008
4. *Property Comparison Between Polypropylene and High Density Polyethylene Pipe*, J. Scheirs, March 2003.
5. *Why Use Antioxidants*, Ciba, 2008, http://www.specialchem4polymers.com/tc/Antioxidants/index.aspx
6. *The Glass Transition*, 2005 http://pslc.ws/macrog//tg.htm
7. *Polypropylene* 2001, http://www.polymerprocessing.com/polymers/PP.html
8. Evaluation of HDPE Pipelines' Structural Performance, University of Texas at Arlington, http://www.uta.edu/ce/aareports2.php
9. *Flammability of Plastic Pipe*, J. G. Quintiere, December 2008
10. *Flame*, http://en.wikipedia.org/wiki/Flame, September 22, 2010.