Compare Polypropylene Pipe with other Plastic Pipes for Storm and Sanitary Sewer Applications

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Abstract: The purpose of this study was to compare the polypropylene (PP), PVC and polyethylene (PE) plastic pipes with respect to their properties, standards, test methods and applications. PP material properties were closer to PE. Several ASTM and AASHTO test methods are available for testing the performance of plastic pipes.

1. Introduction:

Polypropylene(PP) also known as polypropene was initially produced commercially about 60 years ago after the successful development of a suitable catalyst, which enabled the polymer to have the type of structural characteristics useful for various applications. Polypropylene (C_3H_6) belongs to a group of material called polyolefins. Composites based on these resins are relatively new as compared to other pipe materials (Karian, 1999). Increased interest in using this type of polymer is because of the remelt rheology and thermal behavior coupled with cost-effectiveness in a wide spectrum of applications (Karian, 1999). Based on the thermal stability, low density, chemical and environmental inertness and simplicity of recycling PP is becoming an attractive alternative material for not only pipes but also in various other applications (Karian, 1999).

2. Objectives:

To investigate the similarity and differences between PP pipes and other plastic pipes.

3. Discussion

- **Basic Chemistry:** The basic material used to produce the polyethylene (PE) pipe is ethylene. For the other two plastics, modified ethylene is used as the basic material. In the basic ethylene ($CH_2 = CH_2$), unsaturated carbon compound, one of the hydrogen (H) is replaced by Cl^- for PVC and by $(CH_3)^-$ for propylene. Hence PVC basic molecule has the highest molecular weight of 63 (CH_2=CHCl) as compared to ethylene of 28 and propylene of 42 (CH_2=CH-CH_3).
- **Material Characterization:** Polypropylene (PP) is a thermoplastic polymer similar to other plastic pipe materials such as polyethylene (PE) and polyvinyl Chloride (PVC). The density of PVC is 1.4 g/cm^3 (87.3 pcf) and is the highest of the three plastic materials. PE and PP plastics are lighter than water and PVC is heavier than water. PVC is about 55% heavier than PP. Of the three plastic materials, PP has the lowest. PVC material has the highest tensile strength of 7450 psi. The reported PE and PP strengths are very close and are 3600 psi and 3625 psi respectively. The tensile strength of PVC is more than double the strength of PE and PP. The specific strength of PVC is 12,300 lb-ft/lb. Also the specific strength of PP pipe is 9300 lb-ft/lb which is second highest. However the specific strength of PE is 8,700 lb-ft/lb. Hence the specific strength of PVC is only 43% higher than the PP. Modulus of elasticity of PVC is 420,000 psi. The reported PE and PP modulus are very close and are 130,000 psi and 130,500 psi respectively. The modulus of PVC is more than thrice the modulus of PE and PP. The specific modulus of PVC is 693,000 lb-ft/lb. Also the specific modulus of PP pipe is 334,000 lb-ft/lb which is second highest. However the specific modulus of PE is 314,000 lb-ft/lb. Hence the specific modulus of PVC is more than double that of PP. Ratio of modulus- to-tensile strength of PP and PE is 36 and PVC ratio is 56. Hence the PVC modulus-to-tensile strength ratio is 50% higher than PP. PVC has the least coefficient of thermal expansion. PP has the thermal coefficient close to PVC pipe when compared with PE. Hence the stresses induced in the PVC and PP pipes will be less than PE pipes.

• **Test Specifications:** The Polypropylene (PP), PVC and Polyethylene (PE) pipes have similar types of pipe wall configurations – corrugated single, double and triple wall pipes. Pipe diameter of PP pipe and PE pipe varied from 6 to 60 inch. Unlike PP and PE, pipe diameter of PVC varied from 4 to 60 inch which was of a larger range (ASTM F 678, F 1803). PP has three ASTM standards whereas PVC and PE have about ten ASTM standards because PP is a recent addition to the list of plastic pipe. Also there are AASHTO, Canada and German standards for PP pipes. PVC Pipes are covered by ASTM, AWWA and Canadian standards whereas PE pipes are covered by ASTM and AWWA standards. There are number of specifications to test and characterize the plastic pipes. PVC pipe alone has fourteen different ASTM test specifications. PE and PP have eight and three ASTM specifications respectively. There are also seven other ASTM specifications that can be used for all the plastic pipes. Also the CIGMAT joint infiltration test (http://cigmat.cive.uh.edu) is also a common test for the plastic pipes and other pipes. Hence for all the three pipes, there are about eight other standards (common) including CIGMAT standard. Both PVC and PE pipes have AWWA coverage. PP pipe has AASHTO specification.

• **Independent Testing:** In Utah State University, parallel plate test was done with 30 inch diameter standard N12 type pipe. The pipe stiffness at deflection of 2.5% and 10% are 39.5 psi and 33.6 psi respectively. The peak force at 40% deflection is 165 psi, whereas for super-pipe type, the pipe stiffness at deflection of 2.5% and 10% are 69.4 and 60.2 psi respectively. The peak force at 31.1% deflection is 274 psi. From Fobbe Technical Group parallel plate test on N12 and twin wall pipe, the pipe stiffness varied from 58.9 to 111.9 psi at 5% deflection. CIGMAT recently completed testing the double wall and triple-wall PP pipe joints of 30-inch diameter pipe. During this study, maximum water pressure applied was 7 psi.

4. Conclusion

Based in the literature review and also testing of the polypropylene pipe joints following conclusions are advanced.

1. Polypropylene pipes are relatively new plastic pipes in the market compared to PE and PVC pipes. The density and mechanical properties of PVC were higher than PE and PP. The density and mechanical properties of PE and PP are comparable, except the linear thermal expansion coefficient.
2. There are ASTM, AASHTO and German standards for testing and specifying the requirements for polypropylene pipes for sanitary and storm sewer applications. PVC pipe has the highest number of testing standards.
3. CIGMAT joint tests on 30-in diameter double wall and triple wall pipes have shown no leak at 7 psi infiltration pressure for joint rotation (2^o) and the shear load of about 3000 lbs at the joint.

5. Acknowledgements

This study was supported by the Center for Innovative Grouting Materials and Technology (CIGMAT) with funding from DOE/NETL/RPSEA (Project 10121-4501-01).

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