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Fiberglass Tank and Pipe Institutes response to “Evaluating large-diameter PVC versus fiberglass for sewer projects,” published by the PVC Pipe Association (Uni-Bell)

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Executive Summary

The document “Evaluating large-diameter PVC versus fiberglass for sewer projects,” published by the PVC Pipe Association (Uni-Bell) seeks to demonstrate the equivalence of pipe stiffness between PVC and FRP and makes claims that mischaracterize the materials themselves and the ASTM standards which govern the use of the material in sewer projects.

Discussion

The document claims that “FRP can withstand only small deflections before the material fails, while PVC pipe can endure significant deflections with no material failure.” It should be noted that the basis for comparison is an allowable long-term deflection of 5% for FRP and 7.5% for PVC. It should also be noted that AASHTO LRFD Section 30 limits deflection to 5% for flexible pipes, including FRP and PVC.

It is important to consider how each pipe responds to deflection from an understanding of fundamental material properties and structural design.

PVC has a higher elongation at break, lower tensile strength, lower flexural strength, and lower modulus of elasticity. Because of the decreased modulus, to achieve the pipe stiffness of FRP, the thickness of the PVC pipe wall needs to be increased significantly. For the example of pipe stiffness 46, corresponding to SDR35, this means that in the 36” diameter PVC is more than 80% thicker than FRP. The design engineer must concede flow capacity to accommodate the smaller ID of PVC, but that reduction is necessary to match pipe stiffness. In the 36” example, this represents a 6% loss in flow capacity, when compared to FRP of the same diameter, OD, stiffness, and smoothness (Hazen Williams coefficient).

FRP has a higher tensile strength, flexural strength, modulus of elasticity, and therefore a lowered elongation to break. Because of these material properties, FRP can maintain a thinner wall and larger ID across increasing stiffness classes, when compared to unreinforced thermoplastics, like PVC.

The principal material difference between thermoplastics (PVC) and thermosets (FRP) is that thermoplastics can be repeatedly melted and reshaped, or depolymerized with heat, solvents, or UV radiation, while thermosets undergo a permanent chemical change when cured, are thermally stable, with higher rigidity. PVC softens at elevated temperature, directly affecting the modulus of elasticity and by extension the pipe stiffness. Installation temperature is a critical factor when installing viscoelastic thermoplastics, like PVC.

The typical cell class for the resin used to manufacture large diameter PVC Gravity Sewer Pipe is 12454, where the first digit lists the requirement for base resin, second digit impact strength, tensile strength, modulus of elasticity, and deflection temperature under load. The class 12454 corresponds to a base resin of poly (vinyl chloride) homo-polymer, impact strength of 0.65 ft-lb/in, tensile strength of 7,000 PSI, Modulus of Elasticity of 400,000 PSI, and a Deflection Temperature Under Load of 158 F. The Deflection temperature under load or heat deflection temperature is the maximum temperature at which PVC can maintain its shape and structural integrity under load; ASTM D1784. These different cell class combinations have different moduli and different strain tolerances, some classes are more brittle than others.

The claims made with respect to allowable deflection and modes of material failure (or absence of material failure per the document's claims) are inconsistent with ASTM D3262, ASTM D3034, ASTM F679, and the elastic properties, and failure modes of each material.

Pipe stiffness is measured for PVC and FRP at 5% deflection using the test method in ASTM D2412; ASTM D3034 (8.8); ASTM F769 (8.4); ASTM D3262 (8.3). Both materials are required to establish that the pipe being produced meets the minimum pipe stiffness through lot testing at ambient temperature (73.4 +/- 3.6 degrees F) and with a loading rate of 0.5 +/- 0.02 inches per minute. The claim that FRP needs to be specified at a higher stiffness to match the performance of PVC at ambient temperature is not substantiated; though the wall thickness of PVC pipe needs to be increased to achieve the same pipe stiffness of FRP due to the lower mechanical properties of PVC, both materials test pipe stiffness using the same method from the same standard. Elevated temperature may require the use of a PVC pipe with higher wall thickness (higher stiffness class) to account for softening.

While FRP can be manufactured in stiffnesses higher than SN72 (pipe stiffness 72), higher stiffness pipe is typically offered in jacking pipe products and the higher stiffness is used to achieve higher allowable jacking loads, not deflection. PVC does not have a product that matches SN72, the next available class SDR26 has a pipe stiffness of 115. Should a project adopt the requirements for deflection of flexible pipe per AASHTO, and a required pipe stiffness of 72 is determined through the evaluation of all relevant inputs, then PVC would offer the next higher stiffness product, or PS 115. This case would not require that PVC is specified at a higher stiffness, only that the required stiffness would dictate a different pipe class.

The basis for the recommended deflection limit of 7.5% in ASTM D3034 (Appendix 2) and ASTM D679 (Appendix X3) appears to be defined as the design limit with a factor of safety of 4 applied to it, as the document implies – It should be noted this is a short-term safety factor. The factor of safety for FRP referenced at "2" represents a long term, 100-year value. The document directly compares a short-term factor of safety to a long-term factor of safety; FRP short term factor of safety is also in the range of 4.

ASTM D3034 (8.6) and ASTM F679 (8.4) do require quality control testing using ring bending (flattening), the threshold for which is 40% deflection without evidence of splitting, cracking, or breaking. “60% of the original diameter” as described in the document is equivalent to 40% deflection. The rate of loading required in the ASTM standards corresponds to the time to completion of the required deflection in 2 to 5 minutes. This is a significantly higher rate of loading than that specified in ASTM D2412, the standard which governs stiffness testing for both FRP and PVC and lot quality testing of deflection for FRP. PVC is a viscoelastic material; its mechanical response is dependent on the rate of loading. A higher rate of loading minimizes time-dependent deformation, or creep.

The ring bending test detailed in ASTM D3262 is conducted at two levels, a deflection level to verify against surface cracking (Level A) in the liner and a deflection level to verify against structural failure (Level B). The deflection limits for Level A and Level B are detailed in ASTM D3262 (6.4.1). For SN46, Level A deflection is 10.4%, Level B deflection is 17.4%. These levels are lot quality control and ASTM D3262 requires that pipe manufactured to this specification meet the deflection limits without failure. When continuing ring bending beyond Level B and to failure, recorded deflections typically range from 25% to 30%, or higher, in the pipe stiffness class of 46.

The example created to demonstrate a scenario that exceeds the allowable long-term deflection of 5% neglects to consider other inputs that are dependent on the classification of native soils, e.g., soil density, which decreases as soils become less cohesive. Soil modulus, not pipe stiffness, is the variable which exerts the greatest impact on deflection as it’s calculated using the Iowa Equation.

Installation design should always be engineered to satisfy the specific conditions and circumstances that are present. Pipe Stiffness is not the only consideration to accommodate challenging soils, other considerations include embedment, trench width, sheeting, and geo-fabrics.

Conclusion

The document presents a skewed comparison, favoring PVC by selectively highlighting perceived and imagined weaknesses of FRP while omitting critical considerations that should influence material selection. A comprehensive engineering evaluation should include:

- Objective performance comparisons based on real-world conditions, including project requirements such as flow capacity.
- Acknowledgment of long-term durability and maintenance costs.
- Evaluation of key material properties relevant to buried sewer applications.

For an unbiased material selection process, engineers should rely on third-party research and project-specific conditions rather than industry-sponsored promotional materials.