

Final Report

Sacramento County Sanitation District No. 1

Engineering Sustainability of Piping Materials

Vitrified Clay Pipe (VCP) and Polyvinyl Chloride (PVC) Pipe:

A Comparison

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February 28, 2002

Introduction

The Sacramento County Sanitation District No. 1 (CSD-1) is considering revising the engineering design standards in its new trunk sewer design manual to include allowed use of polyvinyl chloride (PVC) sewer pipes. Historically, CSD-1 has specified exclusive use of vitrified clay pipe (VCP) for small diameter sewer piping applications. Inclusion of PVC pipe is being considered to allow designer selection of the piping material best suited for each application and to limit market restrictions that can be caused by reliance on one type of piping material.

Prior to including a new piping material into its infrastructure design standards, CSD-1 staff felt it prudent to investigate issues related to PVC piping manufacture and use.

Those issues are:

1. Engineering sustainability of PVC pipe in sanitary sewer applications.
2. Comparison of energy requirements to manufacture VCP and PVC pipe.
3. Generation of toxicants in the manufacture, use, and destruction of VCP and PVC pipe.

CSD-1 staff contracted with the Office of Water Programs, California State University, Sacramento to conduct an independent literature study of the three issues listed above. The report describing the results of the study of engineering sustainability of piping manufactured from vitrified clay and polyvinyl chloride follows.

Background

Sewage collection piping is an important part of any community's infrastructure. It must function reliably and have good longevity to provide the level of service expected by the public. The components required to assure that expected level of service are: good engineering design, selection of high quality piping materials, proper installation of piping and backfill, and a good monitoring and maintenance program. This report will

Engineering Sustainability of Piping Materials

evaluate competing piping materials used in modern sewage collection systems to compare the expected engineering sustainability of pipes made from those materials.

Engineering sustainability, in this case, refers to the reliability of a particular piping material for longevity and maintenance-free service. Longevity is important because the cost to replace sewage collection piping is significant and the process is extremely disruptive to the community. Maintenance-free service is important because of the potential public health and environmental impacts that occur when sewage collection piping fails to function properly and causes sewage spills. For these reasons, it is in a community's best interest to purchase and install sewage collection piping made from materials that will provide the greatest engineering sustainability for the lowest cost.

Evaluation of Literature

CSD-1, like most community sewerage agencies in North America and Europe, has historically specified use of VCP for small diameter, gravity flow sewage collection piping. VCP has established a long, successful track record for providing longevity in sewage collection service. Many communities report service life of 100 years for VCP (Jeyapalan et al., 1988 and Potter, 1988). VCP also has established a good record for providing low maintenance service, but is subject to problems resulting from fractures and poor joint integrity (Malone, 2001). Both problems can result in blockages from tree root intrusion and in infiltration of groundwater and exfiltration of sewage. Many communities, looking for improved performance in their sewage collection piping, have been specifying PVC pipes since the 1970s (and some since the 1960s) in North America (Bauer, 1990; Brindley, 1981) and since the 1960s in Europe (Alferink, et al., 1995).

PVC sewer pipe has proven its superior hydraulic integrity in service applications throughout the U.S. for the 20 - 30 years it has been in use. PVC pipe is a flexible material and is therefore not subject to crack formation and fracture when subjected to the stresses inherent in underground service. The gasketed joints used in PVC pipe, and in newer VCP, have also proven to be far superior, with respect to hydraulic integrity, to the

Engineering Sustainability of Piping Materials

mortared joints historically used for VCP. The hydraulic integrity and resistance to root intrusion make PVC pipe an attractive choice to maintenance managers responsible for sewage collection system operation.

Besides hydraulic integrity and resistance to root intrusion, other maintenance issues require evaluation. For piping to remain serviceable, it must maintain its hydraulic capacity and its structural integrity. In large sewage collection systems with long transit times, like CSD-1, piping can be vulnerable to acid-induced corrosion when sewage turns septic from lack of oxygen. Acid-induced corrosion can destroy pipes made from concrete or metal. VCP has very good corrosion resistance properties, as long as the vitrified inner wall layer remains intact. PVC pipe is inert to acid corrosion attack. This property has been demonstrated by research experiments in which PVC pipe has been immersed in concentrated sulfuric acid and load stressed for periods up to two years (Sharff, 1994). The pipe was inert to any chemical or corrosive degradation effects from the acid and maintained its new-condition physical and structural properties.

Piping must be able to resist deformation and collapse in order to retain its hydraulic capacity. VCP is a rigid product with the structural integrity required to resist deformation and collapse under soil overburden and traffic loads. Large forces from heavy loading or from differential settlement are well resisted by VCP and excessive loads tend to induce fracture type failures rather than deformation.

Questions about the structural integrity of PVC pipe have been raised for many years by the clay pipe industry and potential end users of PVC pipe. Because buried pipe and backfill is an engineered system designed to distribute loads to prevent pipe damage, concerns have been raised about the ability of a flexible pipe material to resist loads without deformation and collapse. Researchers have investigated this subject extensively. The investigators found that the plastic properties of PVC pipe enable it to self-relieve induced long-term stresses while retaining the ability to resist short-term stresses such as those induced by traffic loads (Janson, 1981 and 1996; Moser et al.,

Engineering Sustainability of Piping Materials

1990). This property reduces the probability of fracture-type failure due to long-term stresses.

Whereas PVC pipe has many desirable properties, it is not without potential problems. The City of Hartford, CT, which began installing PVC sewer pipe in 1962, reported problems with excessive pipe deflection in some of its early projects due to poorly designed and/or constructed trench and backfill systems (Brindley, 1981). Engineers and contractors constructing some of these early PVC piping projects used designs and techniques used for VCP, which resulted in the excessive deflections. VCP, because of its structural rigidity, is more forgiving of poor backfill design or construction. Subsequent development of pipe/backfill systems designed for flexible pipe have minimized the deflection problems (Brindley, 1981; Molin, 1985).

Brindley also reported damage to PVC sewer pipe that resulted from long-term exposure to gasoline from an adjacent leaking underground storage tank (an unlikely event in California due to the recent wholesale replacement of underground fuel storage tanks). This damage is an example of events that are difficult to envision when planning for use of particular materials, but events that, nonetheless, can occur. It is also an example of communities being able to benefit from the experiences of other communities.

It is the experience of other communities that have pioneered the use of PVC sewer pipe that can help answer the most challenging question about its engineering sustainability, longevity. PVC pipe has been in use for less than 40 years. Therefore, it is impossible to cite examples of proven longevity of 100 years as can be done with VCP. The best method to collect evidence for predicting PVC pipe longevity is to remove pipe from the ground that was installed in some of the pioneering projects and to test that pipe to see how it is faring. Several such studies have been conducted (Alferink et al., 1995; Bauer, 1990; Moser et al., 1990).

Bauer reported on one such study conducted on 15 year old pipe in Dallas TX. Prior to excavating the pipe, Dallas sewer crews conducted closed circuit television (CCTV)

Engineering Sustainability of Piping Materials

inspections, before and after cleaning, measured pipe deflections, and researched original construction records to determine backfill methods and materials. Forty feet of 10-inch diameter pipe was removed and sent to the Utah State University lab for testing. The pipe passed all of the tests for new piping, including flattening the pipe to 40 percent of its diameter without breaking. Dallas sewer crews reported that the pipe was functioning well and that field deflection was within specifications, despite 15 years of service under a city street. They also reported that they had discontinued CCTV inspections of all of the PVC pipes in their system because experience had shown such inspections to be unnecessary for PVC pipes.

Other investigations have been conducted and led researchers to conclude that the expected longevity of PVC sewer pipe is greater than 50 years (Janson, 1996; Potter, 1988). The projected longevity of PVC by these investigators is less than that of VCP. However, it must be noted that investigators are limited to projections for PVC longevity because it has been in service for less than 40 years. One investigator extrapolated favorable elastic modulus values at 100 years, suggesting PVC longevity may approach that of VCP (Janson, 1996).

Discussion

VCP is a good product with a proven track record of engineering sustainability in sewage collection applications. Its rigid construction provides structural integrity to the engineered, buried pipe systems designed to prevent deflection and collapse. VCP also has good corrosion and abrasion resistance properties, contributing to its sustainability. When VCP is subjected high loads from sources such as excessive traffic loading, differential settlement, or seismic activity, it is prone to crack and fracture. Cracks and fractures can result in loss of hydraulic integrity and blockages resulting from root intrusion.

Communities looking for alternatives to VCP have turned to PVC pipe for their small diameter sewer applications. The advances made by the PVC pipe industry into the

Engineering Sustainability of Piping Materials

sewage collection pipe market have eroded the market share of the clay pipe industry. The clay pipe industry has responded by challenging the quality of PVC pipe, challenges which must be addressed to justify inclusion of PVC in a community's infrastructure. Responding to those questions is the purpose for this literature evaluation and report and the reason for its emphasis on issues relating to PVC pipe performance.

To justify inclusion of PVC pipe in its infrastructure investments, CSD-1 staff and management must be assured of its engineering sustainability with respect to the VCP currently used. Evidence in the literature indicates engineering sustainability for PVC pipe that is competitive with VCP. PVC pipe appears to have advantages over VCP in its ability to provide very low maintenance service. PVC has excellent resistance to corrosion, root intrusion, cracking, and fractures. At least on large community that routinely CCTV inspects its sewer piping has reported suspending inspections of PVC pipe due to lack of need. The structural integrity of PVC pipe to resist deflection and collapse is good. PVC pipe responds to forces differently than its rigid clay counterpart. However, proper engineering design of the pipe/backfill system can assure the necessary structural integrity to resist loss of hydraulic capacity.

The final issue with regard to engineering sustainability of PVC pipe is longevity. Whereas, VCP has been around for a very long time and ample evidence of 100 year longevity can be cited, PVC sewer pipe is a relatively newer product, which must rely on extrapolations for projections of its longevity. Based on their investigations, several research scientists have projected PVC longevity of greater than 50 years.

Conclusions

1. Vitrified clay pipe is a good product with a proven track record of engineering sustainability in sewage collection applications. It has proven longevity of 100 years.

Engineering Sustainability of Piping Materials

2. PVC sewer pipe has been in existence for 30-35 years. Its longevity has been projected, based on assessment of existing pipe service, to be greater than 50 years.
3. Vitrified clay pipe has a rigid structure that resists forces well. When subjected to excessive loads it can crack and fracture, compromising hydraulic integrity and providing a conduit for root intrusion and subsequent blockages.
4. PVC sewer pipe is classified as flexible pipe. Its flexible properties enable it to respond to excessive forces without fracturing, thereby maintaining its hydraulic integrity.
5. Vitrified clay pipe is highly resistant to corrosion and chemical attack. It provides low maintenance service, with the exception of areas prone to root intrusion.
6. PVC sewer pipe is essentially inert with respect to corrosion and chemical damage. It provides excellent service with very low maintenance demands.
7. Both VCP and PVC pipe are excellent products with good engineering sustainability evidence in the engineering literature. Each product has its inherent relative strengths and weaknesses. Published evidence indicates that both products can provide a community with long, reliable service.

References

Alferink, Frans, Guldbaek, Erik and Grootoonk, Jeannette (1995), *Old PVC gravity sewer pipes; long term performance*. Plastics Pipe Conference, September 1995

Bauer, Dennis E. (1990), *15 year old polyvinyl chloride sewer pipe; a durability and performance review*, Buried Plastic Pipe Technology (Proceedings), Dallas, TX, September 1990, American Society for Testing and Materials, Philadelphia, PA, 393-401.

Brindley, Robert H. (1981), *Plastic sewer pipe – maintenance and operation*, Proceedings of the International Conference on Underground Plastic Pipe, New Orleans, LA, March 1981, American Society of Civil Engineers, New York, NY

Janson, L.E. (1996), *Long term behaviour of buried poly(vinyl chloride) sewer pipes*, Plastics, Rubber and Composites Processing and Applications, **25(4)**: 186-190.

Engineering Sustainability of Piping Materials

Janson, Lars-Eric (1981), *Plastic gravity sewer pipes subjected to constant strain by deflection*, International Conference on Underground Plastic Pipe, American Society of Civil Engineers, New York, NY, 104-116.

Jeyapalan, Jey K. (1990) *Advances in pipeline materials and design in Europe and North America*, Proceedings of the International Conference on Pipeline Design and Installation, Las Vegas, NV, March 1990, 1-16.

Jeyapalan, Jey K. and Kallas, Bacher (1988), *Priority integrated pipe evaluation*, Pipeline Infrastructure (Proceedings), Boston, MA, June 1988, American Society of Civil Engineers, New York, NY, 1-9.

Jeyapalan, Jey K., Saleira, Wesley E., Al-Shaikh, Abdullah, Balasubramaniam, Bala K and Jurgens, John (1995) *Underground pipeline materials, design, and construction: what have we learned during 1985-1995? Where do we go from here?* Advances in Underground Pipeline Engineering (Proceedings), Bellevue, WA, June 1995, American Society of Civil Engineers, New York, NY, 25-41.

Malone, John (2001) *Interim report on conditions of large diameter sewer system relative to pipe material*, Business correspondence from John Malone, PE (URS Corporation) to Paul Kinshella, PE (Phoenix, AZ wastewater engineering division), May 15, 2001.

Molin, Jan (1985) *Long term deflection of buried plastic sewer pipes*, Advances in Underground Pipeline (Proceedings), Madison, WI, American Society of Civil Engineers, New York, NY, 263-277.

Moser, A.P., Shupe, O.K. and Bishop, R.R. (1990) *Is PVC pipe strain limited after all these years?* Buried Plastic Pipe Technology (Proceedings), Dallas, TX, September 1990, American Society for Testing and Materials, Philadelphia, PA, 159-170.

Potter, John C. (1988) *Life Cycle Costs for Drainage Structures*, Technical Report GL-88-2, Department of the Army, US Army Corps of Engineers, Washington, DC

Sharff, Phillip A. and DelloRusso, Steven J. (1994) *Effects of acid environment and constant deflection on PVC sewer pipe*, Buried Plastic Pipe Technology: 2nd Volume (Proceedings), New Orleans, LA, February 1994, American Society for Testing and Materials, Philadelphia, PA, 149-163.