VCP Performance in Seismic Events

Vitrified Clay Pipe (VCP) is a segmented rigid conduit uniquely suited for gravity flow applications. The chemically inert corrosion and abrasion resistant properties of VCP make it ideal for gravity sanitary sewer collection systems.

Crudely manufactured clay pipe from 2,000 to 4,000 years ago, are still in existence today. These ancient clay pipe were hand rolled or packed in a form, then dried and baked in the sun or in a wood fired oven. The jointing systems of these ancient pipe were also quite crude, but generally allowed for some flexibility.

While there is no recorded history of the performance of these ancient pipe in seismic activity, the fact they are still intact, in the ground today along the Anatolian plate, in the area of Istanbul, is evidence these crudely manufactured and installed clay pipe have survived many significant seismic events.

Today, in the United States, there is an estimated 5 Billion linear feet of VCP in-service, some over 200-years old. Significant evolution in the pipe material and joint systems during this time dramatically improved seismic performance.

Product Evolution

Pipe manufactured prior to the 1950s were extruded using steam driven presses and were commonly glazed to keep absorption rates at a minimum. During the 1950s, the three-edge bearing strength standards for VCP nearly doubled with the wide acceptance of the new Extra-Strength pipe. This tight, dense pipe body eliminated the need for surface glazing. These advances were the result of hydraulic extruders with vacuum chambers, an increase in wall thickness and greater temperature controls throughout the firing process. Accurate temperature controls resulted in a consistent vitrified clay product.

Most clay pipe manufactured and installed prior to the clean water act of 1972 utilized a "rigid type," field-applied jointing material consisting of mortar, tar or oakum. The modern day, factory applied leak-free, root-free, and flexible compression joint became commonplace nationwide in the early 1970s.

In-service seismic performance data and reporting is rare for wastewater pipeline collection systems. A significant consideration to be aware of when assessing VCP after seismic events is date of manufacture and installation of the pipe. Strength standards (per ASTM and Greenbook) and jointing specifications have advanced dramatically over the lifecycle of much of the pipe currently in-service in the U.S. The date of manufacture provides significant insights as to the pipe strength and type of jointing system that would have been employed.

1971 San Fernando, CA Earthquake

The Los Angeles Section of the ASCE conducted a study of the damage immediately following the February, 1971 San Fernando earthquake. As of this date, Los Angeles had over 6,000 miles of sanitary sewers. However, only those sewers in the northern portion of the City were affected by the quake. In order to limit the area of investigation and obtain useful information, an arbitrary boundary was established around the impacted area. Within this area there were approximately 110 miles of sanitary sewers, almost all of which is VCP, ranging from 8- to 21-inch diameters with native soils predominately a sandy loam. Depth of pipe ranged from 6 to 52 feet; there was no correlation found between depth and damage to VCP sewers.

Emergency repairs and cleaning were conducted by city crews in the first few weeks after the quake to keep the system as functional as possible. The Corps of Engineers reconstructed approximately 3,700 feet, or roughly 0.6%, of sanitary sewer in the impacted area within thirty days after the quake.

For all sizes of VCP, the rigid-jointed pipe suffered two to three times as much damage (as a percentage of total) than the flexible jointed pipe. Generally, the larger the size, the greater the advantage provided by the flexible joints.

Polyurethane "Seismic" Compression Joint for Bell and Spigot Pipe

At the time of the San Fernando event, the joint design for clay pipe up to 12-inches in diameter was made of a soft PVC that required compression over the entire mating surfaces. The "flexible" jointed VCP documented within this report was predominately this soft PVC compound. This material was used in the early factory applied VCP joints for about an 8-10-year period. The ASCE report recommended; "The typical plastic compression joint could be modified to be more earthquake-resistant by placing a bead of the plastic material on the seat of the bell or on the spigot end to reduce damage due to hammering."

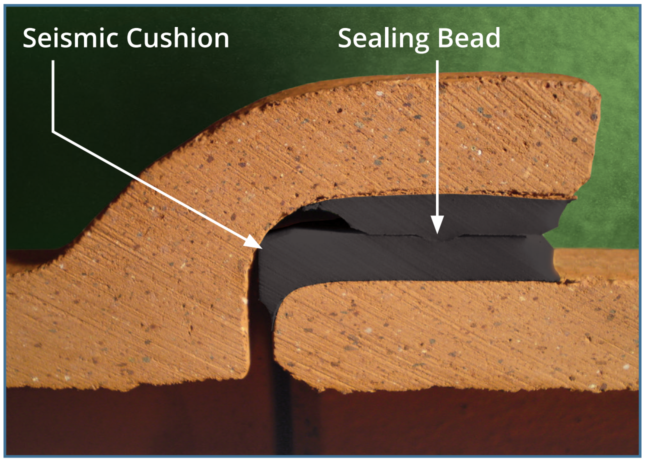

Figure 1: Polyurethane Compression Joint with Seismic Cushion

A polyurethane joint was developed in cooperation with the City of Los Angeles to address the shortcomings of the soft PVC joint. The joint was further modified after the San Fernando event with a "seismic cushion" as part of the spigot-end gasket. This flexible compression joint encompasses a raised bead molded within the bell-end gasket to provide a connection that allows for angular deflection, shear load resistance, axial compression, and pullout (see Figure 1). This became the first "seismic joint" design introduced to the industry.

Plain-End VCP with Rubber Compression Couplings

Another currently available flexible jointing system, is plain-end pipe with barrels joined by mechanical rubber compression couplings with stainless steel tightening bands (see Figure 2). These rubber couplings are equipped with either an internal or external shear load resistance device to maintain the flow line after settlement or ground movement. Like the bell and spigot joint design, this system allows for angular deflection, axial compression, shear load resistance, and some pullout.

Both of these jointing systems are in use today with common section lengths of 5 to 8 feet which varies by diameter. These relatively short sections increase the frequency of points of flexibility and allow movement for changes in earth conditions and loading without damaging the pipe or sacrificing joint integrity.

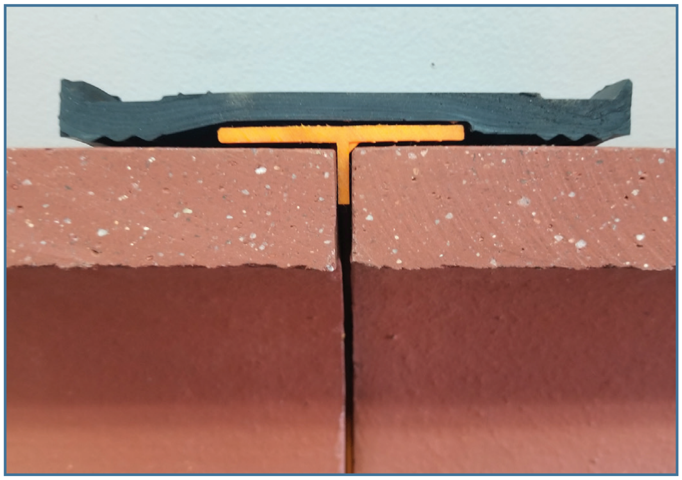

Figure 2: Plain-End VCP with rubber compression coupling, internal shear ring, and stainless steel tightening bands.

1989 Loma Prieta Earthquake

In *Practical Lessons from the Loma Prieta Earthquake*, Table 5-1 shows utility agencies in the San Francisco Bay Area. For each utility, an assessment of the earthquake's impact was made based on reported damage, response, and recovery. Available data on water and sewage pipeline failures were included. Of the estimated $10 billion in damage only 87 sanitary sewer repairs were reported by these utility agencies.

The San Francisco Marina District saw the worst of the damage. The concentration of damage was due to a nearly 100-foot thick mud underlayment. In 1912, the original lagoon in the District was filled with sand to prepare for the Panama-Pacific International Exposition. The ground in the Marina settled during the Loma Prieta quake by as much as 5 inches, with 73% of the buildings in the District becoming unsafe for occupancy. Clay pipe in the San Francisco collection system at that time survived both the 1906 and the 1989 earthquakes.

In another document on the funds spent by San Francisco for repairs after the Loma Prieta; *Analysis of Expenditures Made Relating to the 1989 Loma Prieta Earthquake*, San Francisco could not identify any major sewer problems directly attributable to the 1989 Loma Prieta Earthquake. This report, given three years after the earthquake, indicates they could not confirm if the condition of the sewer infrastructure was the result of damage sustained from the earthquake or if it was pre-existing.

The report shows $893 was awarded just for sanitary sewer repairs.

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