Seismic Testing Program

Test Summary

Seismic Testing was completed on 4"/DN100, 8"/DN200, and 16"/DN400 Victaulic grooved mechanical pipe couplings and fittings installed on standard wall carbon steel pipe. The testing proved that Victaulic couplings are most suitable for use on piping systems subjected to earthquakes. The test program was developed in accordance with an internationally recognized current shake table standard for testing nonstructural building components. The piping assemblies were subjected to input amplitudes of ±3"/76mm in both x and y horizontal directions, input accelerations of up to 1.3g and a frequency range of 1.3 to 33Hz. Braced rigid and flexible sections performed flawlessly under the test conditions which saw peak accelerations of the piping to be recorded at over 7g's. The water filled assemblies were pressurized to 200 psi/1375 kPa for the duration of all tests and no pressure loss or leakage was noted during or after any of the tests.

Victaulic Company

Victaulic, founded in 1925, is the world leader in mechanical pipe joining systems. Victaulic introduced a radical concept in joining pipe—a mechanical bolted coupling that would engage into grooves and uses an elastomer gasket to seal the joint.

The grooved piping method, which dramatically reduces the amount of installation time as compared to welding, threading or flanging is used extensively in HVAC, plumbing, fire protection, mining, industrial utilities, oilfield piping, plus water and wastewater systems.

Victaulic products are found in major landmarks and buildings the world over. With the ability to provide both rigid and flexible joints the Victaulic system provides design versatility not found on other types of pipe joining systems

Victaulic in Seismic Conditions

The use of Victaulic flexible grooved couplings in areas subject to seismic events has been traced back to the early 1940's where they were used to provide stress relief at equipment connections. Since that time grooved products have become a standard joining method due to their unique design benefits in being able to provide both rigid and flexible pipe joints based upon a specific system's design requirements. Victaulic products have had many years of successful performance in areas that have experienced seismic events such that they have become the standard method for joining pipe on many projects in seismic areas. There have also been a number of in-house and third party tests performed in order to qualify the performance capabilities of Victaulic products when subjected to adverse conditions such as seismic events, shipboard piping systems and high pressure cycling. The results of these various tests have proven the reliability and integrity of Victaulic products under these adverse conditions.

Purpose of Testing

Victaulic realized the need for state of the art testing on our products in order to demonstrate conformance to new code requirements and prove they provide a sustainable system that will withstand the forces generated during a seismic event and maintain system integrity when subjected to real time seismic events. Testing was designed to provide analytical data in support of the successful "real-world" performance during past earthquakes.

Piping or building damage occurs due to differential movement between the pipe and the building; and at locations where the piping crosses a building seismic joint, where piping crosses between two separate structures, or piping is supported or fixed to independent support structures within a building, (IE: supported from the roof truss then drops into racks). The former is addressed, within a given "structural area", by fixing the pipe (seismically bracing) to the building structure so it moves in concert with the building. Bracing and clearances must be designed for the specified seismic accelerations and amplitudes of movement. The latter is addressed, where piping crosses from one "structural area" to another. Piping should be installed with a flexible component (seismic isolation assembly) sufficient to accommodate the differential movement that will occur between pipes that are joined but supported from or anchored to different "seismic structures". The flexible element permits these structures and the piping attached to each structure to move independently within the building, without damaging each other, or other equipment, during the seismic event.

The goal of this testing was to demonstrate the suitability of Victaulic Grooved Mechanical Couplings and Fittings to be used to install and maintain operational integrity of piping systems during seismic events. The test program was designed to show seismic performance in two conditions sited above. First, testing was conducted to prove that rigid or flexible Victaulic couplings installed on code compliant braced piping will maintain full performance when subjected to seismic events. Second, testing was conducted to confirm the ability of our flexible couplings in seismic swing joints or in offset pipe configurations, to provide sufficient freedom of movement in order to accommodate the differential movement of pipe between structures or at building seismic separation joints.

Seismic Tests

ATLSS Testing Facility

Lehigh University's ATLSS Lab, Advanced Technology for Large Structural Systems a national engineering research center, was chosen to perform the required testing. The ATLSS Center is a member of the Network for Earthquake Engineering Simulation (NEES), established by the US National Science Foundation as a national networked collaboration of geographically-distributed, shared-use experimental research equipment sites. The Lehigh NEES Equipment Site was developed with the capabilities to perform real-time testing using effective force method, pseudo-dynamic testing method, or the pseudo-dynamic hybrid testing method for the testing of large-scale structural components, structural subassemblages, and superassemblages under earthquake excitations. Thus it is well suited to perform and analyze simulated real-time multi-direction earthquake effects on piping systems. Victaulic and Lehigh consulted with an internationally recognized designer and supplier of seismic bracing systems, who provided the design support for the hanging and bracing of the pipe test assemblies.

Test Requirements

The test program was developed in accordance with current shake table testing standards. Artificial ground motions were developed for this test program. These randomly generated ground motions were generated to satisfy a specified minimum response spectra.

The ICC Evaluation Service, Inc. report AC156 "Acceptance Criteria for Seismic Qualification by Shake-table Testing of Nonstructural Components and Systems" was used to develop the testing protocol. This document establishes the minimum requirements for shake-table tests of non-structural components which includes piping. This document specifies a minimum response spectra that is derived from the code specified nonstructural component design seismic load. The response spectrum of the input motion to the shake testing was greater than the minimum spectrum specified in AC156.

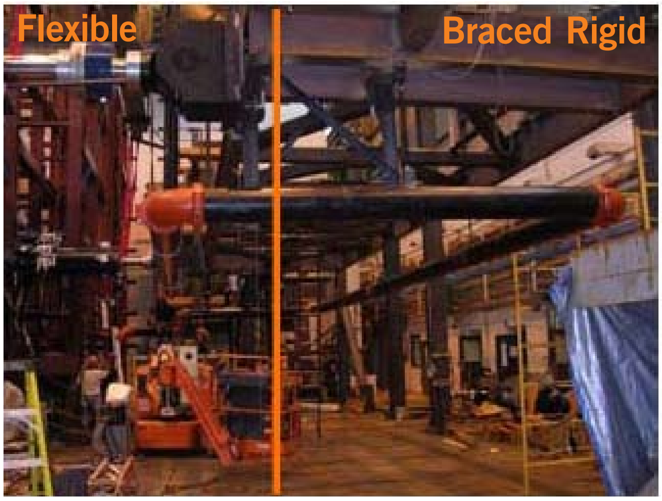
The minimum response spectra specified in AC156 were based upon the seismic design loads specified in the current building codes. The 2006 International Building Code (IBC) was used for this test program. The IBC 2006 references seismic loads as specified in ASCE 7-05 "Minimum Design Loads for Buildings and Other Structures" by the American Society of Civil Engineers. The design of the piping and other nonstructural components was based on the equivalent static load method, similar to that used for building design.

Test Configuration

A test configuration was developed that could accommodate a large pipeline and impose the required motions. The tests required the capability of imposing large accelerations, displacements and velocities on the piping and couplings. A horizontal truss was designed to serve as a rigid diaphragm or "building ceiling" from which the piping would be supported. The seismic motion was imposed on this "ceiling" which in turn was transferred to the piping. Three NEES actuators were used to impose the seismic motion required in both the longitudinal and transverse directions. To record all pertinent test data accelerometers, displacement sensors, and strain gauges were strategically placed in pre-determined locations to provide an accurate record of the testing program.

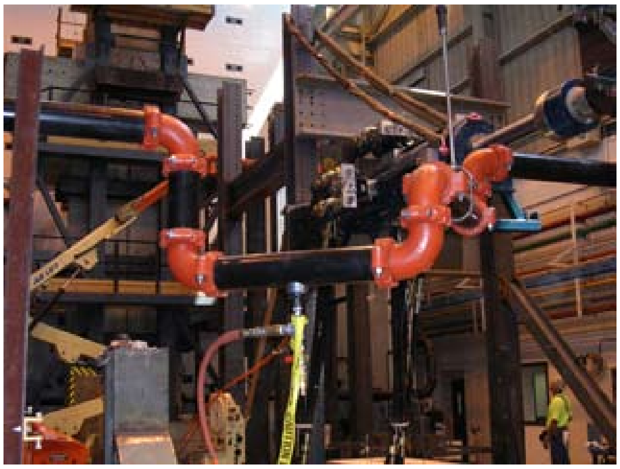
The piping layout consisted of a 40'/ 12m run (consisting of two 20'/6m pipe lengths) with a 90° elbow and then a 10'/3m run on either end, all joined with Victaulic Style 07 or W07 rigid couplings. This section of piping was seismically braced in accordance with standard industry code requirements and was referred to as the "braced rigid zone". On each end of the "braced rigid zone" there was a "flexible zone" comprised of a Victaulic seismic isolation assembly. These displacement assemblies were then connected to the ATLSS reaction wall that allowed no movement. Therefore, movement of the piping in the "rigid zone" generated relative displacements in the seismic isolation assemblies.

Rigid Zone Piping

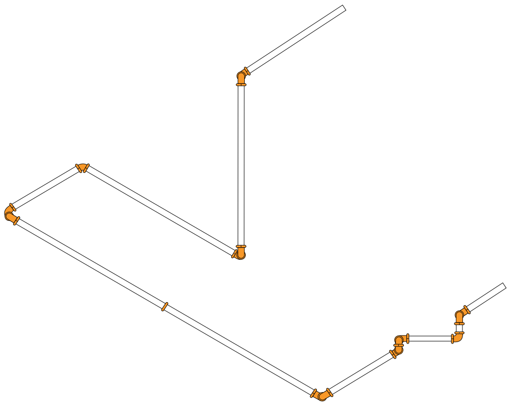


Seismic Tests

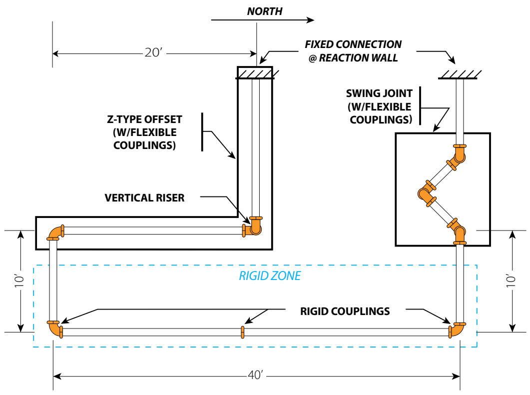
Seismic Swing Joint



Seismic Loop



Seismic Loop- Rigid/Flexible Zones



Two different seismic isolation assemblies were utilized, one on each end of the "rigid zone". One assembly was a Z-Type offset configuration and the other was a seismic swing joint. Both of these configurations used the deflection and rotational characteristics of Victaulic Styles 77 and W77 flexible couplings to accommodate the differential piping movement between the "rigid zone" and the reaction wall.

4"/DN100 Test Assembly

8"/DN200 Test Assembly

16"/DN400 Test Assembly

Seismic Tests

Three pipe sizes were selected for testing: 4"/DN100, 8"/DN200 and 16"/DN400. Each size was tested individually as a complete layout. A number of tests were performed on each piping assembly to demonstrate the ability of Victaulic couplings to handle a variety of seismic demands. The same couplings and pipe were used for all three tests. These tests included a static displacement test, sinusoidal sweep test and shake tests. The piping was water filled and pressurized to 200 psi/1375 kPa throughout the duration of all tests.

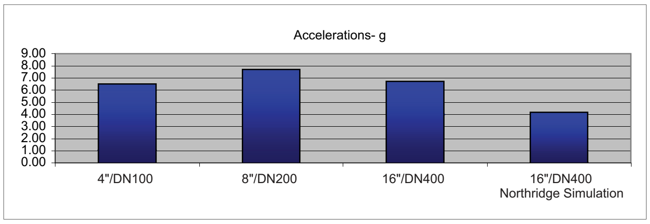
The static displacement test subjected each assembly to ± 4"/102mm of movement in both x and y horizontal directions. The sinusoidal sweep test subjected each assembly to a sinusoidal acceleration record with a frequency range from 1.3Hz to 33Hz. The shake tests subjected each assembly to three levels of seismic motion. The maximum inputs during the shake tests were ± 3"/76 mm of horizontal movement and 1.3g acceleration.

Two additional tests were performed. The first involved the 8"/DN200 piping assembly. Following the shake tests, the rigid couplings were replaced with flexible couplings and all tests performed again. The second involved the 16"/DN400 piping assembly. Following the standard program tests, a real-time multi-directional hybrid simulation of the Northridge Earthquake was performed. This testing was performed in order to study the response of the piping system installed in a three story building subjected to a real earthquake. Two tests were performed during this testing. First the assembly was subjected to ½ of the calculated amplitude of the Northridge Earthquake. Second, the assembly was subjected to 1.07 times the calculated amplitude.

Test Results

Performance of the Victaulic couplings was excellent. There was no evidence of any pipe joint leakage throughout all of the tests. The 200 psi/1375 kPa internal pressure was always maintained. The piping and couplings exhibited a very robust behavior even after the failure of a large number of seismic bracing elements.

The peak accelerations recorded per assembly were as follows:



4"/DN100 Assembly – 6.51g
8"/DN200 Assembly – 7.70g
16"/DN400 Assembly – 6.71g
16"/DN400 Northridge Earthquake Simulation – 4.17g

The performance of the seismic isolation assemblies was also excellent. All differential motions were accommodated. It should be noted that the loads measured in the actuators were very low which indicates that the stiffness of the isolation assemblies was minimal. This is desirable in minimizing the loads and stresses induced to seismic braces or anchor points.

Richter scale Values

While many of us associate the "Richter Scale" with earthquakes, the "Richter Scale" is a measurement of the energy released during the seismic event and not a building or piping system design tool. It is a useful tool for comparing relative strengths of different seismic events, but cannot be used to directly predict the motion or forces that a particular building or piping system will experience during seismic movements.

Structural engineers design buildings and piping systems to withstand displacements and accelerations caused by seismic ground motion which is not solely based on the energy released, but also on factors such as site soil properties, building type/construction, and proximity to the earthquake epicenter and others. The movements of the buildings themselves and the infrastructure within the buildings may vary considerably from a given ground motion due to the building size and shape, construction method (e.g., steel, concrete, wood-frame), natural frequencies and specific locations within the building. Piping systems are designed and implemented per the displacements and forces specified by the structural engineer. These design parameters are a function of the natural frequencies of the building, site seismicity, and the proposed location of the piping system within the structure. It is for this reason that our testing parameters were based on a frequency range encompassing historical recordings and accelerations that were above the typical values recorded, and not based on any "Richter Scale" value, nor can the test parameters be correlated to any specific "Richter Scale" value.

The magnitude of accelerations/displacements expected to be caused by a given earthquake at a given site is not only a function of the amount of energy released (the Richter magnitude), it is also a function of the following:

1. Distance to the epicenter (smaller distance means larger forces/displacements)
2. Soil condition (softer soil often means larger forces/displacements)
3. Building type (the construction type and height/width of the building affects the natural frequency which changes how the building/piping will respond to the earthquake)

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