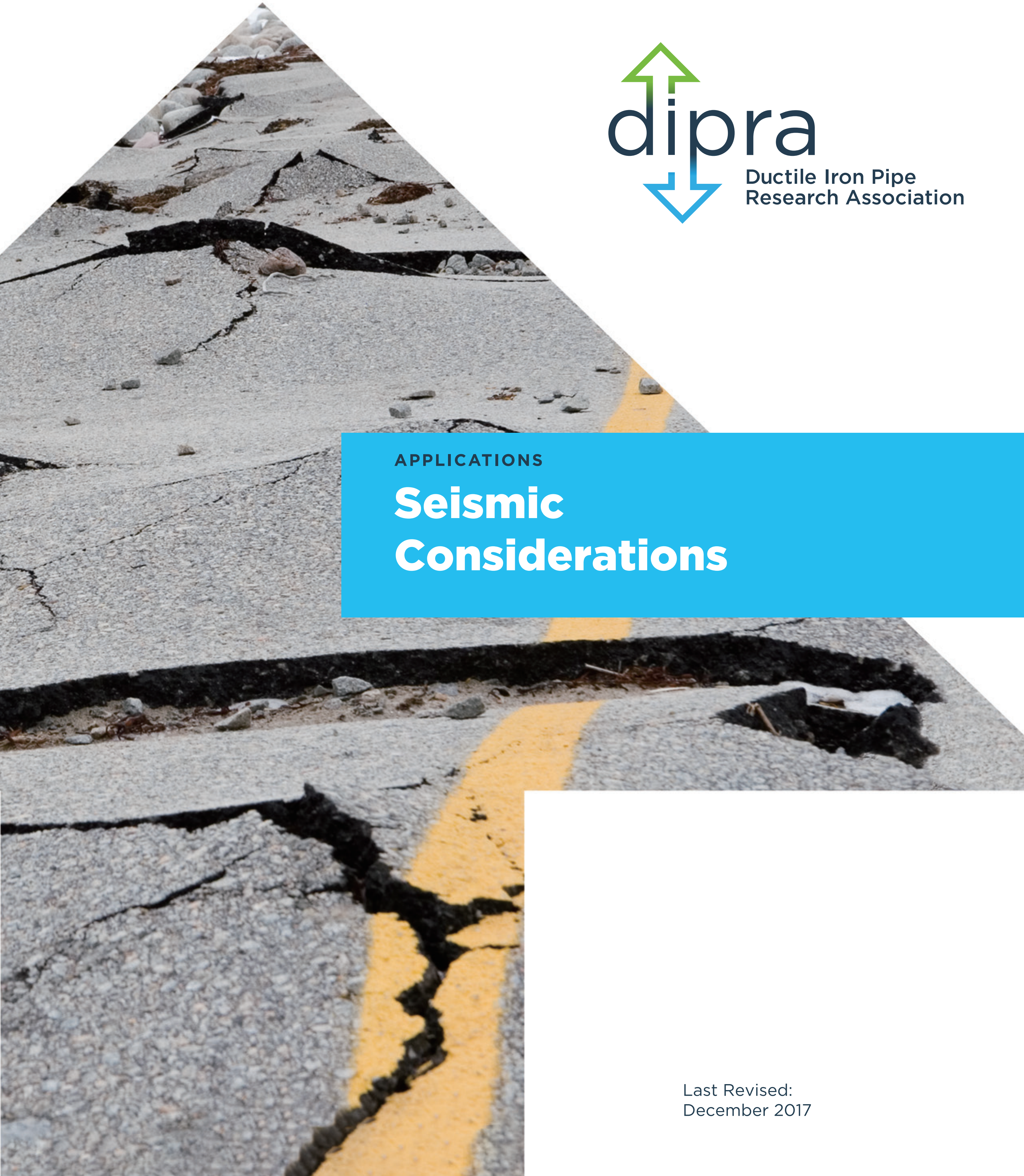
Strength and **Durability** for **LiFe**®



dipra
Ductile Iron Pipe Research Association

APPLICATIONS

Seismic Considerations

Last Revised:
December 2017

According to the U.S. Geological Survey, more than 4,500 earthquake events of magnitude of 2.0 or greater occurred in North America in 2017. Most of these were minor, but 31 measured 5.0 or above on the Richter scale. At 5.0, the energy released in the earth is the equivalent of 200 tons of TNT.

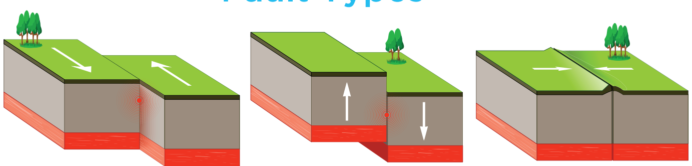
The experiences of utilities in the aftermath of the more significant earthquakes led to the conclusion that, in seismic events, there is no better pipe material available than Ductile iron pipe.

Effects of Earthquakes

Permanent Ground Deformation

Earthquakes are caused when rock underground suddenly breaks along a fault. This sudden release of energy causes the seismic waves that make the ground shake, with the most damaging quakes causing permanent ground deformation. These loadings are temporary, but they are substantial.

Fault Types



There are various forms of ground deformation, the most important ones being liquefaction, ground rupture, landslides and avalanches. Shaking and ground rupture are the most noticeable effects of earthquakes, resulting in potential damage to infrastructure, above and below ground. Soil liquefaction occurs when the shaking of the ground causes water saturated granular soils to act as a liquid—the ground actually flows. Damage results to above-ground structures because their foundations are lost; and underground structures are damaged through a loss of support and flowing ground movement.

Ruggedness and Durability

The rugged durability of Ductile iron pipe comes from its inherent strength (60,000 psi ultimate tensile strength, 42,000 psi yield tensile strength, 96,000 psi ultimate bending strength) combined with a standard wall thickness design (ANSI/AWWA C150/A21.50) to produce a pipe whose wall thickness can be as much as twice the thickness required to sustain the everyday loads it will experience.

Shaking

Fault

Liquefaction

This is evidenced from reports of pipe failures after major earthquakes such as San Fernando, CA (1971), Managua, Nicaragua (1972), Miyagi-Ken-Oki, Japan (1978), Mammoth Lakes, CA (1980), Northridge, CA (1994), Kobe, Japan (1995), and Christchurch, NZ (2011) to cite some of the more significant examples. Ductile iron pipe outperformed other pipe materials during these events because of its strength and flexibility.

In fact, as Game 3 of the 1989 World Series began in San Francisco, the Loma Prieta Earthquake shook the Bay Area. The area that was most heavily impacted by this earthquake reported a total of 69 water main failures. At this time, Ductile iron pipe accounted for roughly 20% of the water pipes in this system, and had no reported failures after the earthquake. However, all other water pipe materials in the this impacted area did report failures due to the effects of the earthquake.

Joint Flexibility and Restraint

A contributing advantage to Ductile iron pipe is in its joints. The standard push-on joint is flexible, allowing slight changes in direction without using fittings. This flexibility also limits beam bending along the length of a Ductile iron pipeline.

This flexibility is useful under seismic events, allowing some lateral movement. Earthquakes also introduce forces that try to elongate or compress a pipeline along its length, which can be addressed using restrained joints and specialized couplings at discrete locations.

Restrained Joints

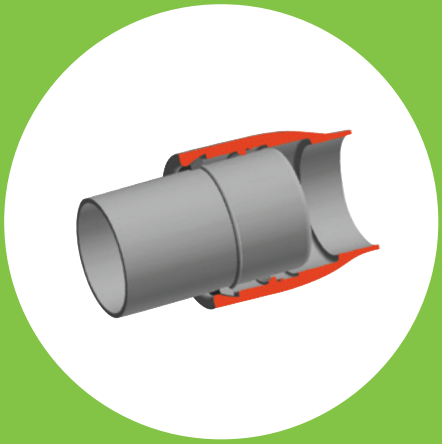
Special restrained joints for Ductile iron pipe have been used for years. These joints maintain deflection, with the added benefit of preventing joint separation. Where large deformations are anticipated, the “ball and socket” restrained joint provides up to 15 degrees deflection and can be used in combination with expansion sleeves.

DIPRA member companies have also developed special joints that can facilitate the design and use of Ductile iron pipe in seismic areas. These seismic joints offer greater deflection and expansion/contraction capabilities when compared to conventional restrained joints.

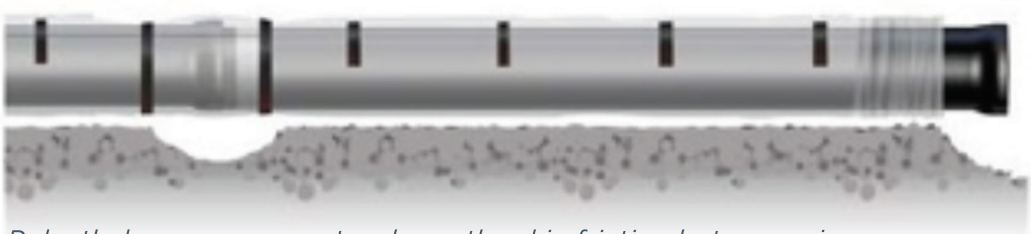
Available Ductile Iron Seismic Joints

American Earthquake Joint System

McWane Seismic Joint



U.S. Pipe TR-XTREME®



Polyethylene encasement reduces the skin friction between pipe and soil thereby assisting pipe movement in seismic events.

Seismic Preparedness

Geographical areas where significant ground deformations occur include areas around known fault lines. Past experience may be a useful point of reference, but areas prone to seismic activity are documented through resources such as the United States Geological Survey. In addition, areas of potential liquefaction, landslides, and fault rupture, etc., can be identified.

Mitigation

Several methods can be used to mitigate the effect of ground movements on underground pipeline infrastructures. Although not always possible, one obvious way is to avoid areas where significant deformations may occur. This can include the use of Horizontal Directional Drilling (HDD) to install a pipeline below the depths where soil liquefaction could result. Geotechnical mitigation can be used to limit lateral spread by installing earth-retaining structures. Also, installing gravel columns, grouting, etc., can reduce liquefaction susceptibility. During the design stage, a proper geotechnical evaluation and earthquake vulnerability assessment can help identify areas where special seismic designs are needed. Ductile iron pipe can be provided with restrained joints, expansion/contraction couplings and, where required, special seismic joints. Also, to minimize friction between the pipe and soil, Ductile iron pipelines can be installed using polyethylene encasement. This simple addition helps to reduce pipe strain during seismic events.

International Standards

In 2006 the International Standards Organization (ISO) developed the first and only seismic design standard, ISO 16134, “Earthquake- and subsidence-resistant design of Ductile iron pipelines.”

This standard recognizes the inherent strengths of Ductile iron pipe to withstand seismic loadings and added design considerations to prevent joint separation and accommodate expansion and contraction. The standard discusses qualitative design considerations and design resistance calculations.

Japanese Experience

Japan is located in the Ring of Fire, an area surrounding the Pacific Ocean that is noted for the number of earthquakes and volcanic eruptions that occur and is subject to an earthquake every five minutes. There are approximately 2000 earthquakes a year that can be felt by people in Japan.

In the 1995 Kobe earthquake, Ductile iron pipe barrel failures were virtually non-existent and there was no damage to Ductile iron pipelines that had been installed using a seismic joint.

Kobe, Japan Water Pipeline Damage Rates

Failures/km

		Pipe Material					Liquefaction		
Type of Failure	Average*	Ductile Iron	Cast Iron	PVC	Steel	Asbestos Cement	0%	50%	100%
Barrel	0.15	0.00	0.63	0.38	0.34	1.24	0.13	0.25	0.22
Fitting	0.06	0.00	0.31	0.17	0.03	0.04	0.04	0.17	0.08
Pulled Joint	0.47	0.47	0.49	0.33	0.00	0.37	0.33	0.76	1.22
Joint Failure	0.06	0.00	0.06	0.55	0.07	0.08	0.04	0.13	0.04
Total	0.74	0.47	1.49	1.38	0.44	1.73	0.54	1.31	1.56
No damage to specially designed seismic joint Ductile iron pipe									

*Average computed on the basis of the total number of failures divided by the total length of pipe.

BALLANTYNE DONALD. “Seismic Vulnerability Assessment and Design of Pipelines.” Journal (American Water Works Association), vol. 102, no. 5, 2010, pp. 88-97.

Summary

Resilience can have many meanings in a pipeline's history. So often, we ask pipelines to do things that couldn't have been imagined at the time they were designed and installed. Ductile iron pipe has the inherent strength to withstand the kind of incredible stress that natural disasters, such as earthquakes, can place on an infrastructure. Much of the storied success of Ductile iron pipelines was achieved using standard designs, its strength and durability providing a primary defense. Today, with awareness of the potential for seismic loadings growing and the need to keep pipelines in service during those events, additional features such as restrained joints, expansion couplings, and polyethylene encasement become a part of a properly designed Ductile iron pipeline. Adding to the arsenal of defenses against severe earthquake loadings, DIPRA member companies all offer special seismic joints.

There is a record of success for Ductile iron pipe in significant earthquakes throughout the world. These are lessons learned. With proper seismic designs, to include the newest available seismic mitigation appurtenances, your Ductile iron pipeline can provide the confidence that can only come from installing the best possible pipe material.

For more information contact DIPRA or any of its member companies.

Ductile Iron Pipe Research Association

An association of quality producers dedicated to the highest pipe standards through a program of continuing research and service to water and wastewater professionals.

P.O. Box 190306
Birmingham, AL 35219
205.402.8700 Tel
www.dipra.org

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Visit our website, **www.dipra.org** and click on the YouTube icon for informational videos on Ductile iron pipe's ease of use, economic benefits, strength and durability, advantages over PVC, and more.

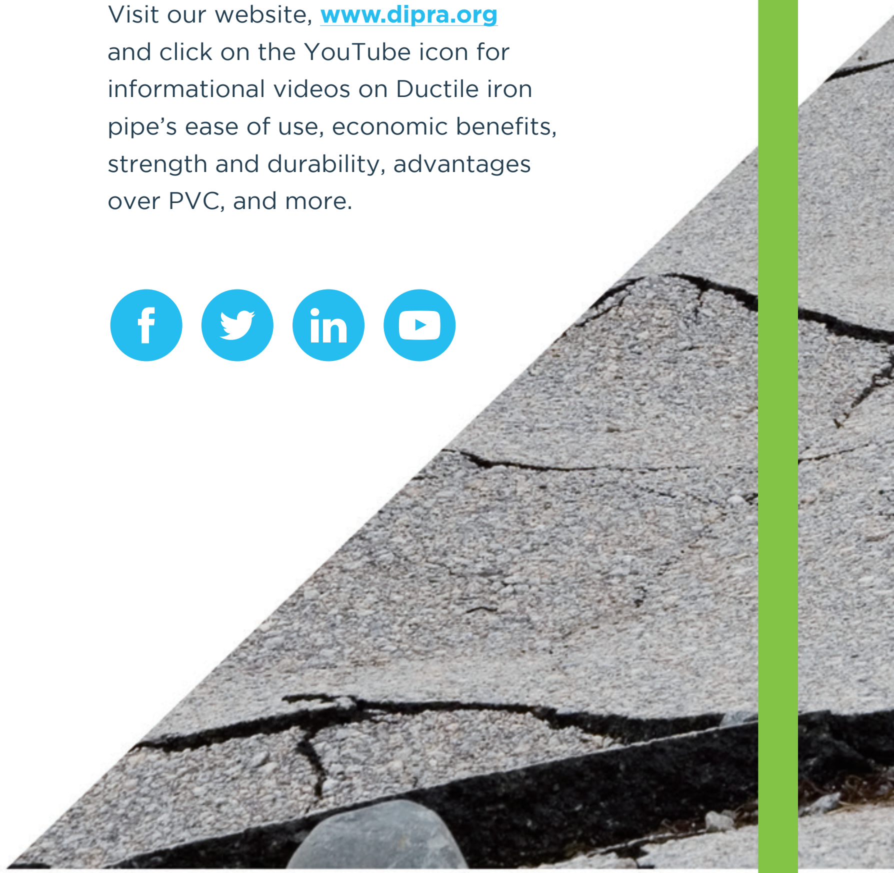
Member Companies

AMERICAN Ductile Iron Pipe
P.O. Box 2727
Birmingham, Alabama 35202-2727
www.american-usa.com

Canada Pipe Company, Ltd.
55 Frid St. Unit #1
Hamilton, Ontario L8P 4M3 Canada
www.canadapipe.com

McWane Ductile
P.O. Box 6001
Coshocton, Ohio 43812-6001
www.mcwaneductile.com

U.S. Pipe
Two Chase Corporate Drive
Suite 200
Birmingham, Alabama 35244
www.uspipe.com



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