Understanding the Hazard

Lack of Earthquake Bracing on Sprinkler Systems

Natural Hazards

Earthquake ground-shaking can cause damage to fire-protection systems when features that resist seismic forces or accommodate movement, such as bracing and flexibility, are absent or inadequate.

UTH topic categories:

- Construction
- Equipment
- Fire Protection
- Human Element
- **Natural Hazards**
- Process Hazards

This series of publications is designed to help you understand the everyday hazards present at your company's facilities. For more information on how you can better understand the risks your business and operations face every day, contact FM Global.

The Hazard

While earthquakes cannot be prevented, the damage they cause can be minimized. News reports following earthquakes usually concentrate on visually striking structural failures in zones of severe ground shaking. But they largely ignore most of the buildings in the shaken area–those that remain standing but may have experienced some nonstructural damage, including breakage of sprinkler system components. If your buildings are among the majority with minor to moderate structural damage, protecting against further loss, from either a fire or water leakage, is a critical first step towards a quick recovery.

Sprinkler system earthquake damage can range from easily repaired minor leaks to the catastrophic failure of major system components, resulting in the release of thousands of gallons (liters) of water. In addition to exposing your facility to potential water damage, sprinkler system failure also may require it to be shut off at the very time when the facility is most vulnerable to fire.

Science of the Hazard

Most earthquake damage results from the sudden release of energy in the form of seismic waves (wave motion) and surface rupture (physical slippage) of the earth's crust. Of the two, seismic waves cause more widespread geographic damage because they radiate outward from the initial point of disturbance in all directions, like the waves from a pebble dropped into a pond.

As a seismic wave passes beneath a building, it oscillates in three dimensions, imparting horizontal motion in both a push-pull and a side-to-side cycle, and vertical or up-and-down motion (see illustration on page two). As the wave passes, it first moves the ground and base of the building, while all other parts of the building above ground level remain stationary. Within seconds, the upper levels also begin moving in the direction of the initial motion. However, the base will have reversed direction because of the wave's motion (push-pull); as a result, the base and upper levels oscillate, often moving in opposite directions.

As the cycle continues, the entire structure moves and sways. Because motion is directly related to an object's mass multiplied by its acceleration, the building and each component system's movement will be different when exposed to the uniform acceleration of a seismic wave. Unbraced sprinkler piping may hit walls, suspended ceilings and other building systems, thereby damaging sprinklers and resulting in leakage. Fittings can break due to twisting, and couplings can separate or leak due to excessive bending, rotation or movement.

What you can do at your facility

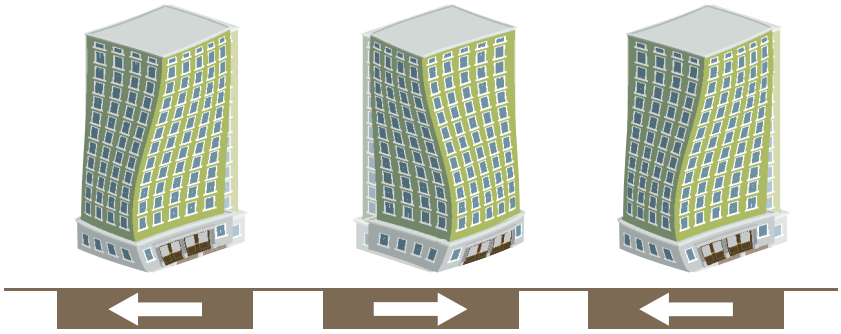
Now:

- Survey your existing fire protection systems to see if they meet the recommended minimum bracing, flexibility and clearance safeguards.
- Install earthquake shut-off valves where flammable gas or ignitable liquid is piped into buildings.
- Survey flammable gas or ignitable liquid equipment and piping inside buildings for adequate restraint and flexibility.
- Incorporate earthquake incident response into emergency-response team activities.

Soon:

- If you have specific earthquake concerns, contact your FM Global client service team to learn about additional engineering service opportunities.
- Implement corrective measures as soon as possible to resolve any seismic upgrade recommendations for fire protection systems and fire following earthquake.
- Conduct earthquake-specific training with your emergency response team.
- Prevent future problems by requiring FM Global review of new construction projects, fire protection system installations, and modifications to existing protection.
- Develop minimum seismic design standards and specifications for all construction and new equipment installations.
- Develop an earthquake recovery plan.

Example of differential movement (in one dimension)



Earthquake force + inertia = the effect of seismic wave

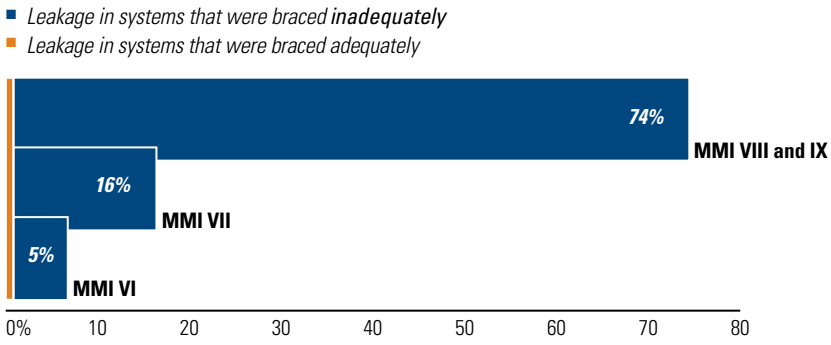
Sprinkler system breakage puts your fire protection out of service at the time you need it most. After an earthquake, the threat of a fire is greater due to the increased presence of ignition sources and, at some facilities, the release of flammable or ignitable material. One industry report estimates that a major earthquake in the San Francisco Bay area or the Los Angeles Basin (both in Calif., USA) may result in 500 to 600 fires requiring public fire service response.

Loss Experience

During a recent ten-year period, FM Global customers experienced hundreds of earthquake-related loss incidents. FM Global loss analysis indicated that sprinkler system failure accounted for more than 50 percent of the incidents.

The 1994 Northridge earthquake (Calif., USA, magnitude 6.7) showed that earthquake damage to sprinkler systems is strongly correlated with lack of adequate bracing on sprinkler system piping. Before that event, as part of its earthquake mitigation program, FM Global had surveyed 45 locations (comprised of 185 buildings) in the immediate area exposed to strong-to-severe ground shaking (VII to IX on the Modified Mercalli Intensity [MMI] Scale). Data collected afterward confirmed that damage to sprinkler systems from earthquake shaking is mitigated by systematic installation of sway bracing.

1994 Northridge Earthquake Sprinkler Leakage, Adequate vs. Inadequate Bracing



As illustrated here, the Northridge earthquake demonstrated that sprinkler systems can fail at earthquake intensity levels above MMI VI when not braced as recommended by FM Global.

The Rate of Sprinkler Leakage

How much water will be discharged from damaged sprinkler system components? We can estimate the volume of water discharged by referring to theoretical discharge tables for circular orifices.

For example, assuming a discharge pressure of 50 psi (3.4 bar), here is how long it would take for water to reach a depth of one ft. (30 cm) in a typical 14-ft. x 14-ft. (4.3-m x 4.3-m) room depending upon pipe diameter.

Pipe Diameter	Minutes
½ in. (12.7 mm)	37
1 in. (25 mm)	8.1
1 ½ in. (38 mm)	4.0
2 in. (51 mm)	2.7
4 in. (100 mm)	1.5
6 in. (150 mm)	1.3

(14 ft. x 14 ft. x 1 ft. = 196 ft.^{3} or 1466 U.S. gallons or 5550 liters.)

Mitigating Sprinkler Damage

Sprinkler systems can be protected from seismic damage by determining:

- Where it is best to secure the sprinkler system to the structure
- Where it is best to allow movement between the system components
- Where it is best to provide for some differential movement

It is important to remember that bracing, flexibility and clearance must be systematically installed to be effective.

Although lack of proper bracing is the most significant cause of sprinkler system failure in an earthquake, several other driving factors behind sprinkler system damage were observed. These included the lack of flexibility where needed to allow for differential movement, a lack of adequate clearance resulting in impact damage to sprinklers and piping, and the failure of weak brace or hanger attachments to structural members (e.g., powder-driven fasteners). Damage resulting from these deficiencies can be prevented by systematically providing flexibility, clearance, and properly anchored sway braces and pipe hangers. In some cases, complete mitigation of fire protection system earthquake deficiencies may involve other measures such as anchoring water supply equipment, water tanks and storage racks.

Achieving Adequate Seismic Protection

Sprinkler systems can be protected from most seismic damage by systematically providing bracing, flexibility and clearance.

Bracing

Bracing prevents differential movement from occurring between the sprinkler piping and the building. It also ensures that major sections of the sprinkler system will move as a unit.

Flexibility

Even with the sprinkler system adequately braced to the structure, flexibility should be provided where piping spans two locations that can move in different directions during an earthquake (e.g., between floors or across a building seismic joint). Installing flexible couplings or a seismic separation assembly are two common methods of providing adequate flexibility.

Proper bracing at change in direction

Clearance

Clearance is necessary around sprinkler piping whenever it penetrates non-frangible walls or floors, or is in close proximity to other building elements. In addition, adequate clearance around sprinklers and vertical restraint on branch lines may be required to prevent sprinklers from impacting building components.

Seismic separation assembly

Other Considerations

Remedying other deficiencies can further reduce the risk of fire protection system earthquake damage. For example, bracing suspended ceilings; modifying marginal pipe hanger attachments; and anchoring water supply equipment, water tanks and storage racks, may be needed in some cases.

Need more information?

Ask your FM Global engineer or client service team about the following:

- Video clip demonstrating where to place sway bracing.
- Animations showing seismic effects on buildings and sprinkler systems.
- *Earthquake Checklist* (P9807)
- *Protecting Your Facility from the Dangers of Earthquakes* (P9505)

But What About…

…the cost of retrofitting?

The cost of providing adequate bracing at the time a sprinkler system is installed is typically less than an additional 3 or 4 percent. In many cases, it costs nothing at all. By contrast, retrofitting costs can vary widely depending upon what needs to be done. Typically, the cost of installing bracing ranges between US$100 and US$500 per brace. The cost of installing adequate flexibility and clearance is much harder to estimate because the project may involve the partial dismantling of the sprinkler piping. Your sprinkler contractor should be consulted to obtain cost estimates.

Retrofitting costs can be considerable. But the cost, in terms of direct property damage and business interruption, of a fire and/or flooding from ruptured sprinkler piping can be devastating.

…safety? That is my first priority, not sprinkler systems.

Mitigating deficiencies in your fire protection equipment before an earthquake ensures that it will be in service immediately following an earthquake, protecting not only the building and its contents, but also your personnel.

…the need to provide seismic protection if my facility is in an area with only a moderate level of seismic activity?

Earthquakes can occur almost anywhere in the world and at any time, so no location is entirely safe from seismic activity. However, some areas are definitely more earthquake-prone than others as indicated by FM Global's earthquake zone designations. That notwithstanding, do you really want to take the chance that a destructive earthquake will render your fire protection system useless when it is needed most in order to save the minimal extra cost of providing adequate seismic protection?

…differences between FM Global and other standards for water-based fire protection systems?

While most building and fire codes have seismic provisions, they may only provide a minimum level of protection and do not address the retrofitting of existing installations. FM Global provides standards for both new and existing installations to help you protect your facilities to the level of a Highly Protected Risk.

Don't Let This Happen To You...

Inadequately-braced sprinkler mains catastrophically failed in the 1994 Northridge, California USA, earthquake.

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