SEISMIC DESIGN FOR FIRE SPRINKLER SYSTEMS

Part 2: The fundamentals of seismic design and the design features involved.

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In the first part of this series (*PS&D* September/October 2005), I discussed the "if" aspect of seismic design for fire sprinkler systems. The article reviewed International Building Code (2003) Section 1614 where the requirement for seismic design is made and each of the six exemptions to this requirement. Now it is time to discuss how to actually do this in your sprinkler system designs.

Let's first review the process thus far. IBC Section 1621 references a document called ASCE 7, which is published by the American Society of Civil Engineers and used by structural and civil engineers for building component design criteria, among other things. ASCE 7 Chapter 9.6, "Architectural, Mechanical and Electrical Components and Systems," is where the exemption for fire sprinklers is found if the Seismic Category as determined in IBC is an A or B. (Remember that fire sprinkler systems in Seismic Category C cannot be exempt from the seismic restraint requirement because they are considered life safety systems and therefore are given a higher rating than standard mechanical and electrical systems.)

Having determined that seismic design is required, the "how" of the process begins.

A WORD ABOUT TERMINOLOGY

While almost everyone is familiar with the concept of sway bracing, it is important to standardize the language of this design process. For years specifying engineers and other entities have referred to seismic design by simply stating "provide earthquake bracing as required" or "sway bracing shall be provided as required in NFPA 13 [*Standard for the Installation of Sprinkler Systems*]" or "when bracing is required, it shall be installed per NFPA 13."

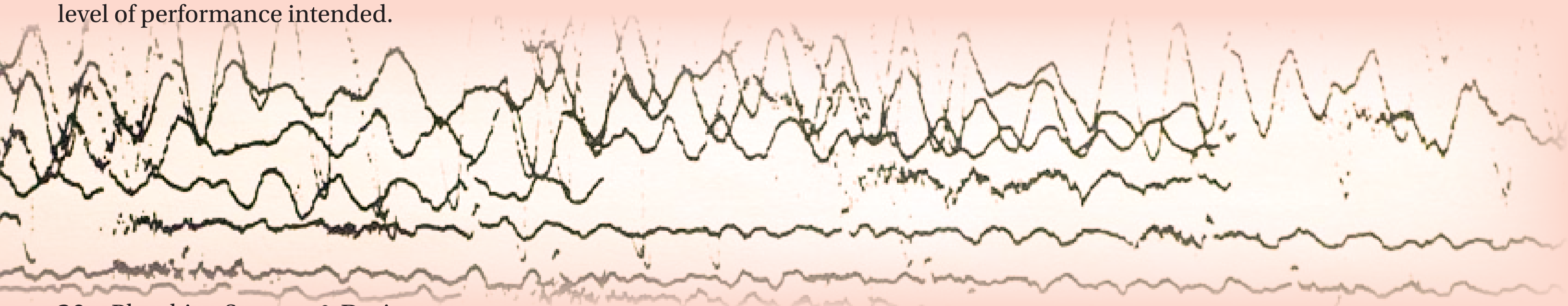
I must stress that you immediately remove any such canned or standardized language in your company's specifications. Such vague wording is very misleading. Seismic design for fire sprinkler systems includes several components in addition to bracing. While bracing is one of the most familiar methods, it certainly does not provide the necessary restraint for a system to meet the level of performance intended.

In fact, when reporting on the conditions found after the Northridge, Calif., earthquake in 1994, Factory Mutual reported to the NFPA 13 Committee that two major conclusions were very apparent. First, a fire protection system can be adequately protected to mitigate potential damage from earthquakes only when provided in a systematic manner with the necessary features incorporating sway bracing, flexibility, clearances, and anchorage where needed. Second, omission of only a few of the critical components necessary for adequate earthquake protection may create conditions in which significant earthquake damage may result in substantial water damage. The necessary shutdown of the system to stop further water damage subsequently creates a fire protection system impairment. So let's start using the term *seismic design* rather than something as narrow as *sway bracing* or *earthquake bracing*.

THE OBJECTIVE OF SEISMIC RESTRAINT

Understanding the purpose behind seismic design is the next step in the process. As with other aspects of sprinkler system design, plenty of gray areas make following the rules difficult. I believe that a designer must understand the overall objective behind a code or standard to better provide a solution for those times when the rules do not readily apply.

The objective of seismic design for a fire sprinkler system is twofold. The first goal is to minimize stresses in piping by providing flexibility and clearances at points where the building is expected to move during an earthquake. The second is to minimize damaging forces by keeping the piping fairly rigid when supported by a building component expected to move as a unit during an earthquake, such as a floor/ceiling assembly. The idea is to design a system that gives and moves as the building is designed to move. You want the system rigid where the building is rigid and flexible where the building is flexible. According to the standards, the systems attached to the structure of the building all should work together as one unit.



That being the case, let's look at each element required to make this happen. NFPA 13 Chapter 9.3 is where all the standard installation requirements for seismic design can be found. The chapter is organized by each required category: couplings, separation, clearance, and sway bracing.

COUPLINGS

The first element is couplings. The general idea is to provide rigid couplings throughout the system except at locations where the piping is installed vertically. In fact, if flexible couplings are installed on piping running horizontally, a lateral sway brace is required to be included within 24 inches of the coupling. (Please note that this applies only to piping that is 2½ inches and larger.) So it stands to reason that you do not want to install flexible couplings anywhere other than where they are required.

Following are the coupling requirements as listed in NFPA 13 (2003). (Nos. 2 and 4 are taken from the 2002 edition.)

1. Within 24 inches (610 millimeters) of the top and bottom of all risers, unless the following provisions are met:
   a. In risers less than 3 feet (0.9 meter) in length, flexible couplings are permitted to be omitted.
   b. In risers 3-7 feet (0.9-2.1 meters) in length, one flexible coupling is adequate.
2. Within 12 inches (305 millimeters) above and within 24 inches (610 millimeters) below the floor in multistory buildings. When the flexible coupling below the floor is above the tie-in main to the main supplying that floor, a flexible coupling shall be provided on the vertical portion of the tie-in piping.
3. On both sides of concrete or masonry walls within 1 foot (0.3 meter) of the wall surface, unless clearance is provided in accordance with Section 9.3.4.
4. Within 24 inches (610 millimeters) of building expansion joints.
5. Within 24 inches (610 millimeters) of the top and bottom of drops to hose lines, rack sprinklers, and mezzanines, regardless of pipe size.
6. Within 24 inches (610 millimeters) of the top of drops exceeding 15 feet (4.6 meters) in length to portions of systems supplying more than one sprinkler, regardless of pipe size.
7. Above and below any intermediate points of support for a riser or other vertical pipe.

It is the practice in my company to include a sheet note on the drawings that says, "All couplings shall be rigid type unless noted otherwise." In the design of the system, we use some type of symbol designation to indicate that the couplings are to be flexible. The coupling requirements are usually stricter in in-rack sprinkler systems, standpipe systems, systems that are multilevel, and riser assemblies.

SEISMIC SEPARATION

The second element involved is seismic separation. Building separation is a critical aspect of design for structural engineers. The building codes require buildings to be structurally separated once they reach a specific length and/or square footage. Where a building is separated, no part of the structure is connected at that point. In other words, while the building may appear to be one complete structure, it is structurally separate such that the two parts move independently of each other.

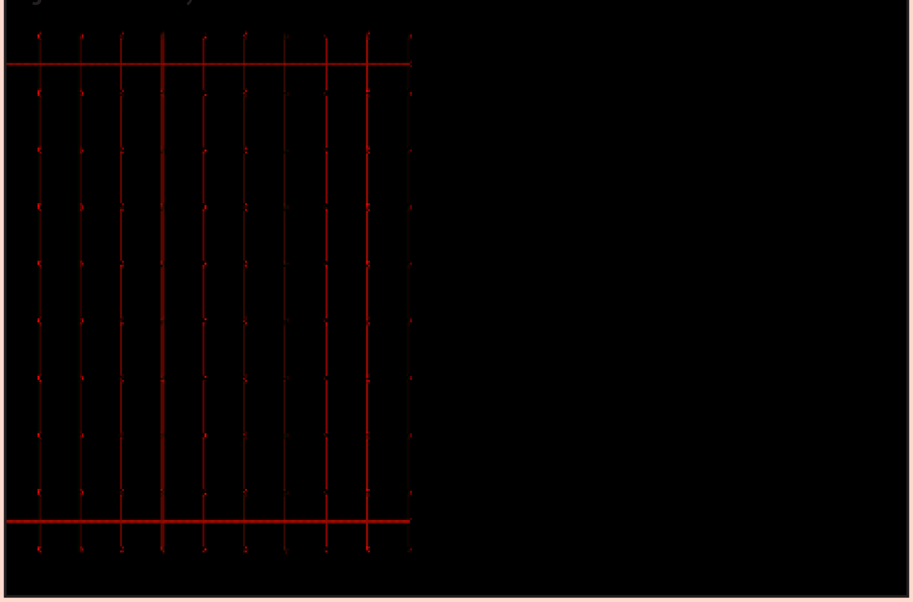
You usually can identify this occurrence by reviewing the structural drawings. You will find two column grid bubbles that are very close together, usually 12 inches apart. You will see two beams or other structural members running side-by-side, parallel to each other for the entire width of the building. If you look at the details you will see that no part of the structure at that point is connected. From the foundation up through the roof, the two parts are completely separate. The only thing that makes the building appear whole is the siding and roof coating that are applied.

A separation should not be confused with a building expansion joint. While an expansion joint is designed to allow the building to move, it certainly does not provide the magnitude of movement that a separation is designed to allow. Expansion joints also have coupling requirements, but NFPA 13 requires a specific type of assembly to be used with building separation. Many contractors and designers have seen pictures of this assembly, but I have found that few have investigated its purpose or actually used it.

This section includes only one statement, but its effects are far reaching. In fact, this one requirement can completely dictate the type of piping configuration you will use for the system. If this section is overlooked during the estimating process, complying with the requirement in the field most likely will use up most of the profit. This section requires that separation assemblies with flexible fittings be installed, regardless of size, where piping crosses building seismic separation joints.

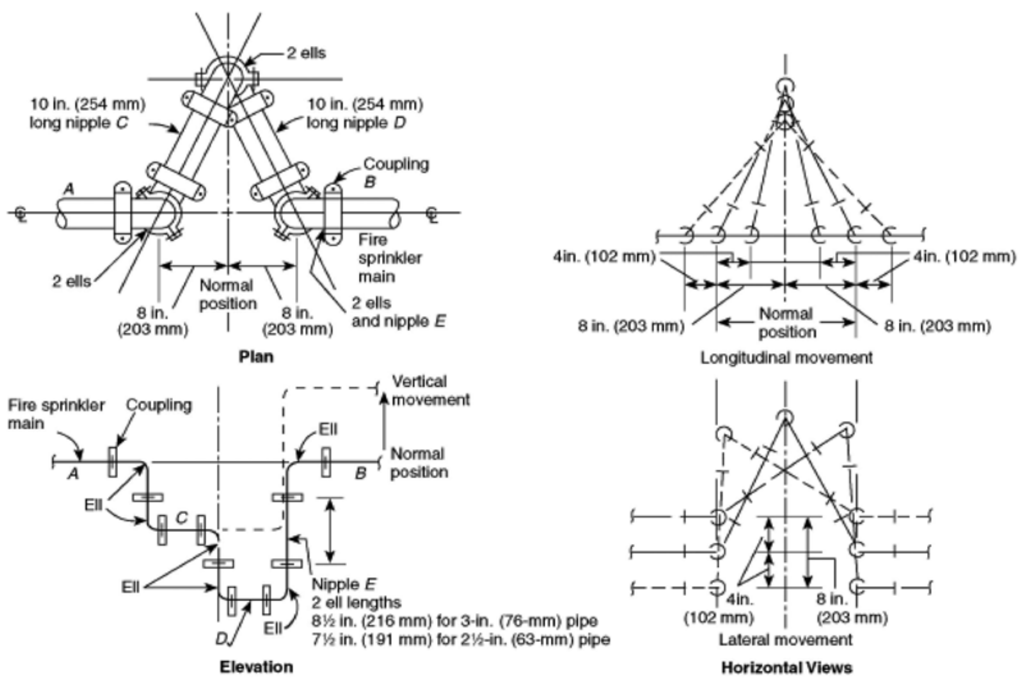
The magnitude of this requirement is best explained by considering a gridded system. This type of piping configuration involves the installation of a primary main on one side of the building and a secondary main on the opposite side. The mains are connected with a series of branch lines that run perpendicular to each main (see Figure 1). Since seismic separation applies to all pipe sizes, a seismic separation assembly is required at every location that these grid branch lines cross a required separation. If you look at what this involves, you will better understand what is at stake (see Figure 2). Six 90-degree ells added to each branch line will be included in the hydraulic calculations, and their presence most likely will increase the branch-line size at least one size, making the system even more expensive.

Figure 1 Gridded System



The only currently known alternative to this assembly is a fitting assembly called a Metraloop, which provides the same movement

Figure 2 Seismic Separation Assembly



Source: NFPA 13 (2002)

in a more feasible manner. While the NFPA 13 assembly can take out as much as 5 feet or more depending on size, the Metraloop provides a more compact and easy-to-install alternative. While a grid usually is considered the most cost-effective piping configuration, you also should consider a series of center-feed, tree-type systems requiring only the bulk feed main to cross the separation once, rather than several times as with a gridded system. Remember: If you use the Metraloop, flexible couplings are required for its connection to the piping.

CLEARANCE

The third design element involved with seismic restraint is clearance. This feature includes provisions for piping that penetrates specifically concrete and/or masonry floor/ceiling and wall assemblies. Do not confuse this with penetrations through rated assemblies that are framed with wood or steel studs with gypsum board. This section has nothing to do with assembly ratings or the requirements for sleeves or fire caulking. Those are usually a function of other specification requirements and should not be in this section of your specification or drawings notes.

Like separation, this feature is simple but very expensive. This section requires a specific nominal annular space to be provided around the pipe penetrating the assembly. A 1-inch annular space is required around 1-3-inch pipe. A 2-inch space is required around pipes that are 4 inches and larger. Core drilling a 10-inch-diameter hole for a 6-inch pipe is not something most fire protection contractors are very eager to do. This process can be quite involved, and the cost of core drilling is tied directly to the size of the hole.

However, there is a less expensive way to accomplish this penetration. You will recall that I previously mentioned that flexible couplings also could be used as a solution for clearance requirements. This is where couplings prove their worth. In lieu of large clearances, the standard allows for a flexible coupling to be installed on either side of the assembly within 12 inches of the face of the penetration. By providing these couplings, standard hole diameters may be used. My experience is that contractors prefer this method to providing the larger holes.

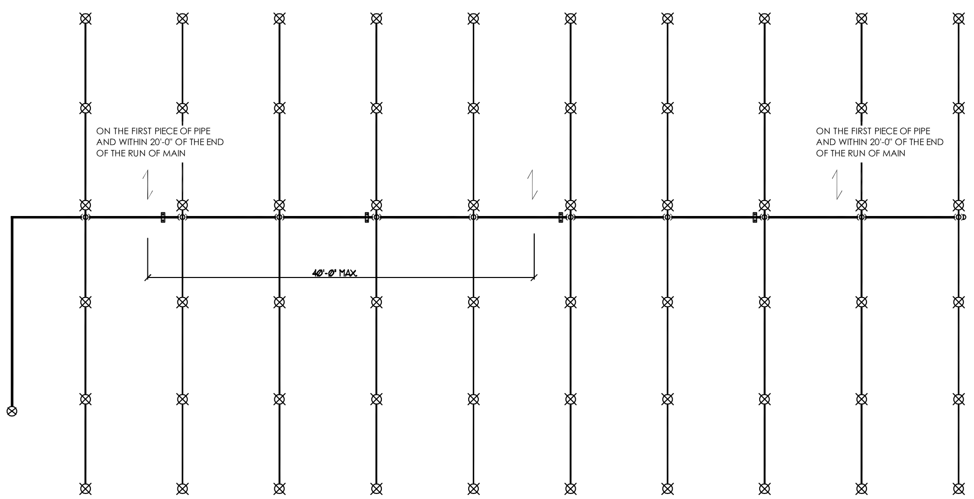
This section applies to all pipe sizes, so, like the separation requirements, consideration of the piping configuration is important. It is usually better to penetrate once into a concrete- or masonry-assembly room with main piping and then create a smaller tree-type system than it is to penetrate several smaller holes into the space simply to maintain uniformity. A prudent plumbing designer would discuss these types of design features with the architect during the design development phase to try to minimize the amount and/or configuration of these assemblies as well as the overall sprinkler system cost. Doing so also may help you gain a level of favor with the installing contractor.

SWAY BRACING

The fourth and most commonly referenced seismic restraint design feature is sway bracing. Unlike in other plumbing systems, the water and pipe that comprise fire protection systems are lifesaving features. While the majority will never activate, fire sprinkler systems must perform when needed or people and property will suffer. With that in mind, it becomes obvious why the bracing of fire sprinkler systems has its own rules for spacing, location, and force factor criterion.

The process for laying out sway bracing starts much like that for laying out sprinkler heads. There are three types of braces: lateral, longitudinal, and 4-way. Lateral bracing is required to be spaced at a maximum of 40 feet between braces. We also are required to install a brace within 20 feet of each end of the run of main, which is half the allowable distance between braces. Finally, we must

Figure 3 Lateral Bracing



Want to Learn More?

Visit **www.psdmagazine.org** for an exclusive article detailing how to size sway bracing and the fastening components that go with them, including a descriptive real-life example detailing the entire process.

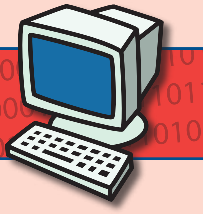
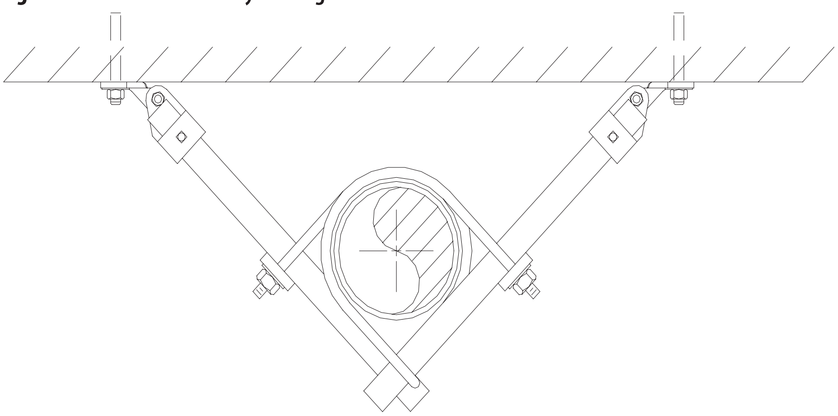


Figure 4 Plan View of 4-Way Bracing



Source: Tolco

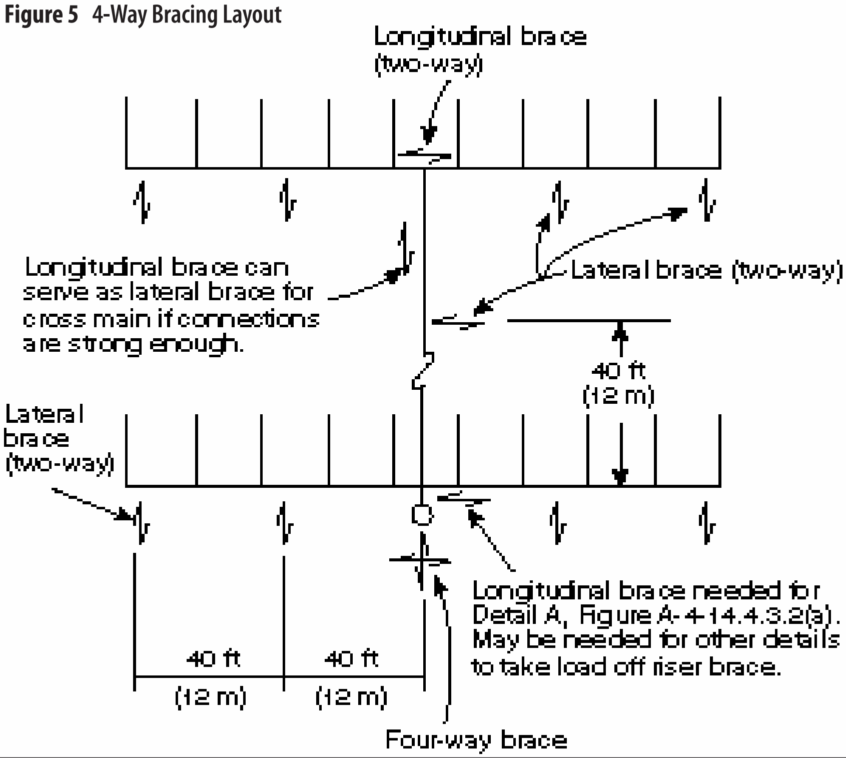
have a brace on the first piece of pipe on each end of the main. Figure 3 depicts an example of lateral bracing.

When applying the rules to each run of main piping, you'll want to try to maximize the distance between braces as much as possible. However, remember to leave room for the braces to be moved in either direction in case actual field conditions inhibit the fitter's ability to install the brace at the location shown on the drawing. Also, as the distance between braces grows, so does the total weight that each brace will be required to resist. If you are in a high seismic category or if the site soil or building importance dictates a high force factor, maximizing the spacing may not be cost effective.

Once the lateral braces are located, you lay out the longitudinal braces. The maximum spacing for these braces is 80 feet. As with lateral braces, you are required to install a longitudinal brace within half the allowable distance between braces, meaning you must have one brace within 40 feet of each end of the run of main. Normally there will be fewer longitudinal braces than lateral.

The final bracing that is required is referred to as 4-way bracing. Industry terminology for this feature has been diluted, so for the purpose of clarification, 4-way bracing is *not* where both a lateral and longitudinal brace are located. Rather it is a bracing assembly that is used to restrict the movement of pipe that is installed in a vertical position such as the riser piping at the fire service entry into the building. As you can see in Figure 4, this bracing usually is installed in the horizontal position and has specific attachments that are designed to meet the intended installation configurations. The brace must be located within 24 inches of the top of the riser.

Figure 5 4-Way Bracing Layout

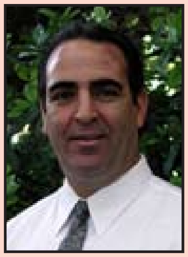


Source: NFPA 13 (2002)

Like many of the requirements of this standard, nuances and exceptions can be applied. Both lateral and longitudinal braces can serve each other's purpose if located within 24 inches of the end of the run of main (see Figure 5). Notice that the 4-way brace can be considered as the longitudinal brace as well. As a matter of design, I usually first lay out the bracing for each run of main independently, and then go back and consider the relocation of the braces at each end of the mains as a whole to apply these alternatives. Some designers have been taught to simply install a 4-way brace at every change of direction if sway bracing is required. Not only is this wrong, it is very expensive and does not accomplish the goal of seismic design. Bracing layout needs to be done with consideration of total weight and the ability of the fitter to actually have ceiling space to install the brace.

For example, in ceiling areas with an excessive amount of ductwork above the piping, it will be very difficult to run the sway brace up to the top chord of the structural member. If you have maximized the spacing, little can be done. Whereas if you have allowed for this condition ahead of time, the fitter can relocate the brace further down the main in one direction or the other without compromising the ability of the hanger to carry the weight that it was designed to resist. While it is not cheap, adding a brace to cut down the spacing is much less expensive than having field personnel trying to figure out how to make it work.

It is my hope that you see the importance of the "how" of the process of seismic design of fire sprinkler systems. As with any engineered system, especially life safety systems, understanding the overall goal and applying the standards by which we are intended to meet these goals is very important. Remember: Vince Lombardi said, "Excellence is achieved by mastering the fundamentals." **PSD**



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