Fire Sprinklers

ASCE 7-02/05 reference section(s)		2001 CBC reference section(s)	Other standard reference section(s)
ASCE 7-02	ASCE 7-05	1632	2003 IBC 1621.1.1
9	13	1632.5	NFPA 13 (2002, 2007)
9.6.3.11.2	13.6.8.2		
	13.6.8.3		

Background

According to the 2000 NEHRP Commentary, "experience in past earthquakes has shown that, in general, piping systems are rugged and perform well in strong shaking motions" (BSSC 2001b, section 6.3.11). With respect to property loss caused either by damage to piping and bracing or by water leakage, fire sprinkler piping is similar to other pressurized water piping except that it is distributed more extensively throughout the building interior. Compared to other kinds of piping of similar overhead location and weight, fire sprinkler piping poses a comparable falling hazard, although the diameter of the main distribution lines in a fire sprinkler system are typically heavier than most of the potable water or HVAC water lines in a building. The characteristic of fire sprinkler piping that most sets it apart from other piping in ordinary occupancy buildings is its critical post-earthquake function, and this increases the degree of engineering attention this kind of piping should receive.

A complete fire sprinkler system includes components outside the purview of the structural engineer or building official, such as the underground supply lines and their sources of pressurized water in the local water utility system. Tall buildings may contain firewater storage tanks, and other components of the overall fire sprinkler system include alarms, gauges, and valves. In this article, the scope is limited to the piping itself in the building or industrial structure and its associated supports and seismic bracing.

Earthquake damage to sprinkler piping can take many forms. Outside or beneath the building, underground piping can break or buckle due to settlement or liquefaction-induced ground displacements, and damage elsewhere in the water utility system can prevent sufficient delivery of water volume and pressure. While back-up utilities are outside the scope of this article, some essential facilities such as Veterans Administration hospitals have been provided with their own on-site emergency water supplies to contend with utility outages, and such redundancy may be part of the scope of a performance-based design project. Inside the building, vertical pipes (risers) can break under large interstory drifts in the building. Hangers supporting the weight of the pipe can unseat from their attachment points. Fasteners connecting the hangers to the building structure can pull out under seismic loading. Sprinkler heads can break upon impact with adjacent structural or nonstructural components, such as ceiling panels. Couplings and pipe fittings can break or leak. Piping crossing separation joints that is not detailed for differential movement can be ruptured, as can pipes that are unintentionally restrained at locations where they pass through walls. Nearly all of these failure modes have been observed in past earthquakes, resulting in impairment of sprinkler systems and costly leaks, with the first well-documented report on such damage by Ayres, Sun and Brown (1973) on the 1964 Alaska Earthquake. Fire sprinkler piping damage in the US has been documented for several other earthquakes, including the 1971 San Fernando Earthquake (Ayres and Sun 1973); the 1989 Loma Prieta Earthquake (NFPA 1990); and the 1994 Northridge Earthquake (Ayres & Ezer Associates 1996), (Fleming 1998), (FSAB 1994), (Todd et al. 1994), (Reitherman and Sabol 1995). Extensive damage to fire sprinkler systems and resulting lack of functionality in the 1995 Great Hanshin (Kobe) Earthquake is documented in Sekizawa et al. (1998).

Design Issues

Piping that is hung from the floor or roof above and that is inadequately braced can sway under earthquake excitation and experience large displacements relative to its support points. This can cause impact damage to the piping and the sprinkler heads. Several cycles of large displacements can also cause the hangers to break or unseat from their supports, resulting in partial collapse of the sprinkler system. These types of damage are minimized by bracing. The pipe remains free, however, to vibrate between the brace points, and some braces may have little rigidity.

Braces must be designed for seismic loads generated by the vibrating sprinkler pipe and the weight of the contained water. Braced piping experiences smaller relative displacements but larger forces than unbraced piping. The fittings