Earthquake Protection for Fire Sprinkler Systems

Who is Responsible for What?

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Sprinkler Age has published several articles on earthquake protection for sprinkler systems. The September 2003 article presented the steps to determine whether or not earthquake protection is required for a particular project. The November 2003 article discussed the relationship between using the *Building Construction and Safety Code* (NFPA 5000); the *International Building Code* (IBC); American Society of Civil Engineers (ASCE) 7, *Minimum Design Loads for Buildings and Other Structures*; and NFPA 13, *Standard for the Installation of Sprinkler Systems*. Then, in the May 2004 article we gave an example of how to calculate force factors used to design earthquake protection based on building code criteria. This article will focus on who should be responsible for each step in the analysis and design of building earthquake protection. It will also offer some suggestions on how to make the process as seamless as possible.

Who is Responsible?

Who is responsible for determining whether or not earthquake protection is required for the sprinkler system? Well, we can answer that question by answering some other questions. Who is responsible for determining whether or not Type II construction can be used in the building? Who is responsible for determining whether or not fire alarm systems and fire sprinkler protection are required for a building? Who is responsible for determining whether or not earthquake protection is required for a building? It is most certainly not the fire sprinkler contractor. These are engineering issues that must be addressed at the "building code level." This is long before bid documents are sent out to a general contractor (GC), much less a subcontractor such as a sprinkler system installer. It is the building design team's (A/E's) responsibility to address these issues.

The charging criterion (IBC:1614.1, NFPA 5000:35.10, ASCE 7:9.1.2.1) requires every building to be designed and constructed to resist the effects of earthquake motions. This applies regardless of type of building or location. It is the A/E's responsibility to evaluate each building to determine whether or not earthquake protection is required for the building and its systems. The determination depends on several variables including seismic use group, mapped maximum considered earthquake spectral response acceleration, site class, design spectral response acceleration, and seismic design category (SDC).

If earthquake protection is required for the building, chances are it will also

be required for the sprinkler system. However, there are some scenarios in which the building may require protection, while none of its systems will. Buildings assigned an SDC of A or B have to meet certain requirements, but sprinkler systems installed in those buildings are exempt from earthquake protection. If the building is assigned an SDC of C, protection must be provided for the sprinkler system, but there will be special allowances as discussed later in this article.

Assuming that your project is not in a seismic design category A or B building, what should you expect from the building design team? Well, does the cement contractor evaluate the building loading to determine how deep to place the foundation footers? Does the steel erector evaluate the roof loading to determine the minimum dimensions of the girders, joists, and purlins? The answer to both of these questions is "no." The A/E is responsible for these items. Likewise, they are responsible for evaluating the building and setting certain parameters for the sprinkler system installer to use in laying out the earthquake protection. I'd like to give you some suggestions as to exactly what the building design team should be providing to the GC and its subcontractors. The following formula is given in ASCE 7 to determine the force used to design the earthquake protection (sizing the braces). There are several variables in this formula that are outside the scope of work for a typical sprinkler system installer. If the building design team does its job with this formula, the sprinkler contractor will be given a formula that will look amazingly similar to the formula from NFPA 13. Let me show you.

From ASCE 7:

$$F_p = \frac{0.4 a_p S_{DS} W_p \left(1 + 2(z/h)\right)}{R_p / I_p}$$

F_p = seismic design force

S_{DS} = design short period spectral acceleration (determined by A/E, assume 1.3171 for this example)

a_p = component amplification factor (1.0 for sprinkler systems)

I_p = component importance factor (1.5 for sprinkler systems)

R_p = component response modification factor (3.5 for sprinkler systems)

W_p = component operating weight (determined by sprinkler contractor)

z = height of attachment point with respect to the base (determined by sprinkler contractor)

h = average roof height with respect to the base (determined by sprinkler contractor)

Filling in the constants and assumption determined by the A/E we have:

$$F_p = \frac{0.4(1.0)(1.3171) W_p \left(1 + 2(z/h)\right)}{3.5/1.5}$$

or

$$F_p = 0.2258 W_p \left(1 + 2(z/h)\right)$$

The z/h factor at the end of the equation is significant only in multi-story buildings. In single-story buildings where seismic braces are attached to the roof structure, z/h is essentially 1. In single story buildings the equation becomes:

$$F_p = 0.6774 W_p$$

Does this look familiar? The equation from NFPA 13 is:

$$F_p = 0.5 W_p$$

NFPA 13 uses the 0.5 force factor regardless of geographical location unless a local authority stipulates a higher value, whereas the ACSE 7 force factor varies as site-specific aspects vary. Nevertheless, it boils down to a familiar equation as shown above.

Also, don't forget about the maximum and minimum equations. ASCE 7 stipulates that the design force does not need to exceed:

$$F_p = 1.6 S_{DS} I_p W_p$$

Substituting the given and assumption we have:

$$F_p = 1.6(1.3171)(1.5)W_p$$
or
$$F_p = 3.1610W_p$$

It also stipulates that the design force is not permitted to be less than:

$$F_p = 0.3S_{DS}I_pW_p$$

Substituting the given and assumption we have:

$$F_p = 0.3(1.3171)(1.5)W_p$$
or
$$F_p = 0.5927W_p$$

To summarize this part: you should expect the A/E to determine the seismic use group, mapped maximum considered earthquake spectral response acceleration, site class, design spectral response acceleration, and seismic design category. Then they should notify the contractor in the bid documents whether or not earthquake protection is required and give a design equation in the form:

$$F_p = x.xxxxW_p$$

for single-story buildings, or

$$F_p = x.xxxxW_p\left(1 + 2(z/h)\right)$$

for multi-story buildings where $x.xxxx$ is provided by the A/E.

Again, we're talking about items the building design team (A/E) should be providing when the seismic design category is C, D, E, or F. ASCE 7 allows earthquake protection for sprinkler systems in accordance with NFPA 13, but also requires force and displacement requirements from ASCE 7 to be satisfied. Thus far, we've only discussed force and have not discussed displacement. ASCE 7 tells us that the seismic relative displacement is equal to the deflection at level A as determined by an elastic analysis minus the deflection at level B as determined by an elastic analysis. So, that leaves us comparing something from the code that can only be provided by other parties with something that is not explicitly discussed in NFPA 13. Using this as a basis for equivalency is not likely to produce a favorable outcome. This is an issue that must be resolved by the A/E building design team in defining the seismic force resisting system and the analysis procedure required by ASCE 7.

The A/E building design team cannot simply make a statement in the construction documents to provide earthquake protection in accordance with the building code. This is nothing more than passing the buck and provides no guidance to the users of those construction documents. As a minimum they should provide the force formula in a sprinkler contractor friendly form as mentioned earlier and provide any additional limitations or provisions as determined by the elastic analyses.

Code Update

One of the problems mentioned in the May 2004 article is that the current criteria from the building codes (ASCE 7 by reference) do not permit the use of NFPA 13 in designing earthquake protection for fire sprinkler systems. Well, it says that NFPA 13-designed earthquake protection is deemed equivalent provided the force and displacement requirements of 9.6.1.3 and 9.6.1.4 are satisfied. Sprinkler contractors who design earthquake protection using NFPA 13 are not accustomed to the force and displacement requirements of ASCE 7. So, it really doesn't help to allow NFPA 13 to be used to design earthquake protection, when in the same sentence the designer is required to carry out an evaluation that only a knowledgeable professional engineer can carry out.

In the latest ASCE 7 update cycle, there were actually proposals seeking to remove the reference to NFPA 13 altogether. Had this gone into effect, sprinkler contractors would have been forced to hire professional engineers to design earthquake protection for fire sprinkler systems. Fortunately, NFPA 13 was updated so that it could remain referenced in ASCE 7. Tentative Interim Amendment 02-1 was the result of this update. After further deliberation with those involved in the ASCE 7 update process, word has it that the reference to NFPA 13 will remain in ASCE 7, but will be modified. The good news is that the new wording will in effect allow sprinkler system installers to follow NFPA 13 without having to satisfy the force and displacement requirements of ASCE 7. The bad news is that this will only be permitted for SDC C. Remember, sprinkler systems in SDCs A and B are exempt from protection. Then, systems in SDC C are not exempt, but will be permitted to be earthquake protected using NFPA 13 criteria.

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