Who is Responsible for the Support of Nonstructural Elements?

By Richard Hess, S.E., SECB

This is a story about an orphan for whom no one wants to accept responsibility. On most building projects, the architect primarily claims responsibility for the appearance and utility of building, the structural engineer is responsible for making the building's structural elements capable of resisting the anticipated loads and forces, and the M.E.P. (mechanical, electrical, plumbing) engineers are responsible for making their systems function so that the building's occupants can operate therein. However, in many cases, the bracing and supports for nonstructural elements are not designed by these top-level professionals.

The Los Angeles City Blue Ribbon Task Committee, established in 1994 in the wake of the Northridge earthquake, defined nonstructural elements to "include all elements which are not part of the primary lateral force resisting system or which do not contribute to the direct load path of both the gravity as well as the lateral force resisting system." The State of California Seismic Safety Commission Report to the Governor on the same event defined them in this manner: "Structural elements – beams, girders, flooring, roofs – hold buildings up. Nonstructural elements are attached to provide specific functions," some of which are essential for the use or operation of the building and some of which may serve a nonessential purpose but can cause disruption and injury by their dislocation. Some nonstructural elements are vulnerable to acceleration or to forces applied to them, such as pieces of equipment; others are susceptible to building drift, such as suspended ceilings or partitions. Still others, like glazing, may be vulnerable to both drift and acceleration.

Building codes have come a long way in the past century in providing the framework wherein design professionals can produce the plans required to build a safe, sustainable building – that is, until an earthquake knocks the contents or M.E.P. elements loose, or wind or flood removes the enclosure and sends the inner parts of the building off their supports.

A common way for design professionals to avoid liability for the problem lies in the form of the ubiquitous "performance" specification or the concept that some of these things are to be installed by the occupants.

With a performance specification, the architect or engineer transfers the responsibility for design and coordination to the contractor, who then may transfer it to subcontractors, who may or may not hire a structural engineer to design the supports for certain elements without having control over the other interactions of nonstructural or structural elements in the building.

Figure 1: Destruction of Office Contents during Earthquake. Photo by James Malley, courtesy of EERI.

Figure 1 shows an office that was hit by the Northridge earthquake in 1994. This occurred at 4:13 a.m. No one was present to have to be pulled out from under the mass of cabinets and partitions. Fortunately, in this case, no permanent damage was done to the building structure itself. That was not the case shown in *Figure 2*, where warehouse storage racks loaded to 60% of capacity nearly caused collapse of the building during that same Northridge earthquake. Who was responsible for securing these elements?

Buildings designed (and built) to recent codes have demonstrated a marked improvement in resisting the forces of wind and earthquake; not so for nonstructural elements. In EERI's *Earthquake Spectra* (Supplement C to Volume II, April 1995), it was observed that "the 1994 Northridge earthquake caused more nonstructural damage than any other U.S. earthquake to date," and "with regard to some problems, such as anchorage of equipment or safety-wire supports for light fixtures, the difference between the older and newer installation techniques is night-and-day; bad performance vs. good performance. With regard to other components such as elevators, piping, and glazing, many of the same examples of poor performance that surfaced in the 1971 earthquake were seen again." It also noted, as an example of the lack in adequate improvement of design and retrofit requirements for these elements, that there were 688 cases of derailment of elevator counterweights in 1994 compared to 674 in the 1971 San Fernando, California, earthquake, which was of similar magnitude. Based on my observations and experience, dislodged or broken elements are often re-installed in exactly the same way as they were before the event, only to fail again in a subsequent earthquake.

After any disaster, there is a swarm of contractors into the area of devastation to take advantage of the surge in available work. I often hear it said by homeowners and facilities managers that these contractors know how to fix things that are broken because they have actually done it many times before. The difference between most contractors and engineers, who know the construction site at least as well as they know their computer, is that the former do not generally study reports of the causes of damage that occur and lessons learned in order not to repeat mistakes. However,

Figure 2: Storage Rack Collapse during Earthquake. Photo by Mark Pierepiekarz, courtesy of EERI.

the caveat is that engineers must be familiar with construction and spending significant time attending seminars for professional development is critical.

After Northridge, Los Angeles City implemented task forces for various structural areas, including nonstructural elements, in which improvements to the Code were presented. Improvements were made in requirements for some elements, including ceilings and glazing; however, to date, structural bracing requirements for many mechanical elements were not made a part of the building code. (An article on the subject of elevators and escalators is planned for a future issue of STRUCTURE.®)

Figure 3: Hospital Conduit Supports.

As with many nonstructural elements, a strict mechanical code exists to ensure safety in operation of these elements. Although force levels are provided, the detailed requirements, which most engineers now seem to need, are usually not in the Building Code where the complete load path is evaluated by the structural engineer for bracing to resist seismic or other lateral forces or caused displacements. Contractors know to screw equipment down to a roof or a floor, but often nothing is done to complete the load path to a structural element that can secure it. There are excellent recommended standards, such as SMACNA (Sheet Metal and Air Conditioning Contractors' National Association), that give useful details for bracing ducts and conduits; however, the implementation of providing supports may be left to the contractor, who is chosen on the basis of low bid and who may lack engineering capability to deal with the complicated networks of ducts and conduits found in hospitals and commercial buildings where interferences dictate the configuration of supports (*Figure 3*). Often, the supports provided by one contractor are cut or removed by another in order to make room for another element.

Another common practice is securing a piece of equipment "the way we have been doing it for many years." *Figure 4* shows the very common way that satellite antennae are supported against overturning and lateral movement by placing concrete blocks on the legs. Both earthquakes and wind produce uplift as well as lateral forces, and the code states that friction shall not be considered – to no avail. It gets even worse when someone moves some of the blocks to hold a door open. Another problem is the lack of structural observation of the placement of elements; as in *Figure 5*, which shows a storage rack post screwed into a loose cast iron grating.

So far I have referred to problems with nonstructural elements caused by earthquakes. This is because of the well-documented history of changes that have taken place in building codes due to an increasing awareness of the cost and risk to life that can result from inadequate supports for these elements. In other areas where the concerns are high wind and flooding hazards, the securing of nonstructural elements is no less important. Where bad experience has led to improvements in the building code and design practices, resulting damage has been markedly reduced. Unfortunately, experience is not always contagious, and neighboring locations not hit before have to learn the same lesson at a tremendous cost. In addition, new hazards occur and, because expectations increase, more attention must be paid to a more holistic evaluation of the nonstructural elements as a part of the building system, rather than isolated parts.

A major cause of damage during Katrina (2005) was from detached nonstructural elements turning into missiles that penetrated and destroyed the building's skin or its structural supports. Interior partitions are not designed to resist high wind, but when the exterior glazing of the New Orleans Hyatt Hotel was destroyed, the wind and rain quickly proceeded to turn these partitions into rubble. Similarly, in an earthquake, the building structure may withstand the imposed forces and the hung ceiling may be properly braced, and yet the building interior can be completely destroyed by water released from broken sprinkler piping or a storage reservoir located on the roof (*Figure 6*).

Figure 4: Unanchored Roof Antenna Base Anchorage.

I recently had a job (for an electronics subcontractor) to design bracing for several hundred communications cabinets in government multi-story buildings subject to seismic events. Although my client's personnel were very sophisticated in their area of expertise, they were unfamiliar with bracing requirements and the installers were low voltage (telephone wiring) contractors who were in the habit of screwing the base of the cabinets to whatever they were placed on (usually a raised floor), without anything else to resist overturning. The government agency required S.E. stamped design of bracing, but was exempt from municipal plan check and did not specify any controlling code or standard. I provided that based on my experience, and my client was able to obtain funding for the larger-than-anticipated cost of what I designed. The subcontractor told me, however, that he had installed, and was currently installing, a great many similar jobs in earthquake country without structural design.

In the final analysis, the real problem is not with what is explicitly stated in the building code; the responsibility must fall on the design professionals – the architects and structural engineers who produce the construction drawings for the building. They must stop ignoring, and pushing off to contractors, the design of supports for the nonstructural elements of the building.

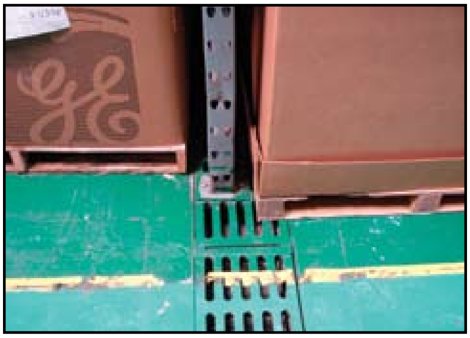

Figure 5: Uplift Resistance for Rack Overturning Provided by Heavy Crate Placed on Anchored Grating.

It is not as though designing all of these systems in conjunction with the building structure is a novel concept. The process industries, such as oil refineries, have been doing it since long before the advent of computers in engineering. At first it was with plain and isometric drawings; then physical models were used to locate all the pipes, ducts

Figure 6: Broken Fire Sprinkler Pipe and Water Damage. Photo by Bob Reitherman, courtesy of EERI.

and equipment to avoid conflict; and now, 3D computer models have been used for years to do this. It is a matter of managing and coordinating the designs of the various disciplines; not an easy task but well worth the effort.

The following words have been in place since the 1927 Uniform Building Code was written, and what they say was understood before that.

"Sec. 2302. (a) Loads. Buildings *and all parts thereof* (italics added) shall be of sufficient strength to support the estimated or actual imposed dead and live loads in addition to their own proper dead load, without exceeding the stresses noted elsewhere in this Code…"

That refers to all elements of the building, not just the ones to which we want it to apply.

It was noted in SPECTRA that there was more nonstructural damage in the 1994 Northridge earthquake than in any other. This fact, along with my observations over many decades, is indicative that two factors are working here; one is the contrast between the considerable improvement in the design of the building structure and the limited improvement in dealing with supports for nonstructural elements.

The second factor is even less understood. Our lives, and therefore our buildings, are much more dependent on sophisticated machines to control our environment and do our work than ever before; and this trend is accelerating. In the 1971 San Fernando earthquake, there were no desktop computers and much less sophisticated interior environmental controls to be damaged than in 1994. Think how much our dependence on these elements has increased between 1994 and 2007. It seems that everything is monitored and controlled by a computer now. What will happen when these elements are shaken loose and malfunction in the future? Chaos.

It is time for each of us to pay more attention to the design and construction of these elements and stop making excuses as to why someone else should be responsible.▪

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