Briefing Paper 5

Seismic Response of Nonstructural Components

Part C: Proper Anchorage of Cladding and Equipment

Introduction

This Briefing Paper 5, *Seismic Response of Nonstructural Components*, consists of three parts that discuss how earthquakes affect a variety of nonstructural building components, and how they should be anchored or braced to resist seismic forces. Part A defines the types of systems and equipment that can be affected, describes the way they respond to earthquake motions, and discusses various anchorage systems and their limitations. Part B describes the vulnerability and proper retrofit anchorage methods for suspended ceilings, interior gypsum walls, partitions, glazing, window walls, parapets and nonstructural masonry walls. This Part C describes the vulnerability and proper retrofit anchorage for other nonstructural components types: cladding and veneers, floor-or roof-mounted equipment, and suspended equipment, ducts, pipes and light fixtures.

Cladding and Veneers

Exterior cladding comes in many forms. Precast concrete panels are used extensively on modern buildings to provide a durable exterior weathering surface with excellent fire resistance. However, these panels are very heavy and require specially detailed connections to support the vertical loads. There must also be sufficient anchorage to resist lateral out-of-plane loads. They must also have connections designed to accommodate thermal, wind and seismic in-plane lateral movements of the structural elements to which they are attached (see Figure 1). The design, fabrication, and installation of precast panels and their anchorage is usually performed by a specialty contractor. The design must take into account the story drift criteria that were used by the designer of the building's structural system.

Lighter exterior cladding such as GFRC panels, prefabricated foam plastic core insulating panels with metal facings (EIFS), and aluminum or stainless steel sheets are in common use and rely on mechanical anchorage for their attachment and bracing. The attachments are usually designed by the installation contractor and must accommodate drift. However the backing (often a light-gauge metal stud wall) used to support these systems is usually not a part of the cladding subcontractor's work. This wall framing must also be designed to resist both the in-plane and out-of-plane lateral forces the cladding exerts, and to transmit those loads into the main structural system of the building.

Veneers fall into two general classifications: adhered and anchored. Thin veneer elements such as tiles or thin brick, terra cotta, or stone facings are often adhered to a solid substrate material, which is in turn attached to the building's exterior structural wall framing with fasteners. The fasteners must be appropriately sized and spaced to provide effective anchorage, and the substrate and adhesive material must be properly prepared and applied. Anchored veneers involve thicker units of brick or stone masonry and are usually anchored to a structural wall using a combination of metal pins, metal

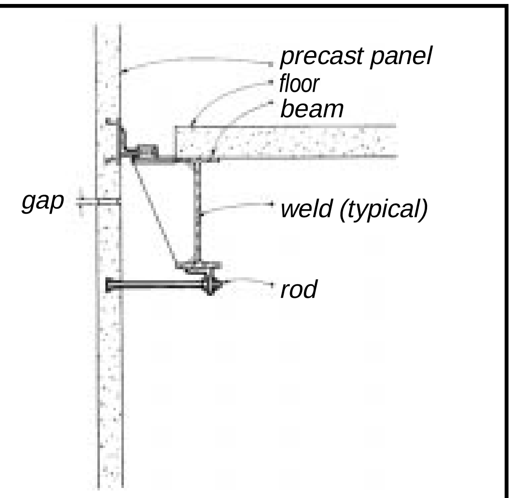

Figure 1. Typical connection for precast concrete units.

tabs, wire, screws, or proprietary mechanical fasteners.

These cladding and veneer elements are vulnerable in an earthquake when certain conditions are present.

- Joints in the cladding may not be large enough to allow for in-plane drift. In-plane movements can cause cracking of the veneer material, failure of attachments, or both.
- Anchorage or adhesion of the elements may be inadequately designed because the original standard attachments may not have been designed for earthquake forces.
- Because these elements are located on the exterior, exposure to water can deteriorate any concealed attachments. This deterioration is not easily detected.

Typical methods to prevent cladding and veneer damage are:

- Provide cladding joints with adequate gaps between individual pieces.
- Provide connections that accommodate drift.

To evaluate cladding and veneer fasteners, expose a sample of concealed anchors to examine their current condition and the quality of the original installation. Retrofit with supplemental anchors as necessary. Test adhered veneer at sample locations to determine its current condition and strength. Remove and reattach deteriorated areas.

Floor-Mounted or Roof-Mounted Equipment

Various pieces of equipment in a building, primarily electrical and mechanical equipment, machinery, and fluid-filled tanks are mounted on the floor or roof (see example in Figure 2).

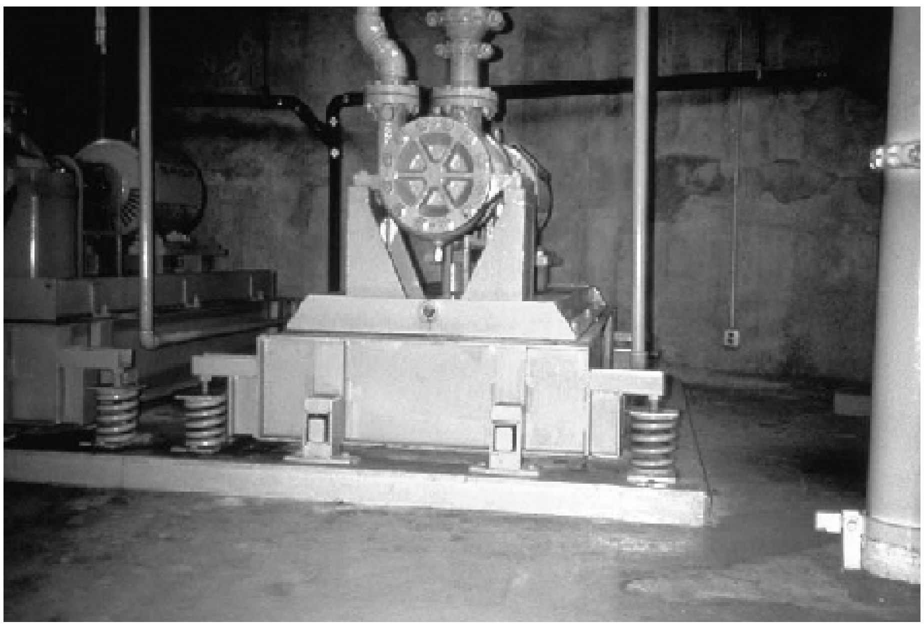

Figure 2. Mechanical equipment with snubbers.

These components are normally heavy and sometimes large in size. Several conditions can increase the seismic vulnerability of this equipment.

- If not properly restrained, equipment, machinery, and fluid tanks will tend to slide. Massive objects in motion during earthquakes can cause injuries and damage adjacent objects. The motion can also damage connected piping, ductwork, and electrical conduits, which in turn may lead to other serious damage caused by fires, hazardous fluid spills, and water leaks.
- Equipment mounted on vibration isolators is particularly vulnerable, because the isolators permit resonance during earthquake motions making equipment more difficult to restrain.
- Tall, slender objects with a high center of gravity can fall over if not adequately anchored.

Typical methods to prevent damage to floor-mounted or roof-mounted equipment are:

- Anchor equipment to the structure to resist sliding and overturning forces, as shown in Figure 3.
- Provide seismic snubbers for equipment mounted on vibration isolators.

- Provide flexible piping, conduit, and connections for utility hook-ups that can accommodate all anticipated movement.

Suspended Equipment, Ducts, Pipes, and Light Fixtures

Suspended equipment, conduits, ducts, and pipes that are hung from the structure tend to be less massive than floor-mounted equipment. However, the mass of hung objects can be greater than expected. For example, an eight-inch diameter fire sprinkler main filled with water will be much heavier than the weight of the piping alone. Suspended light fixtures, which are comparatively light, can cause serious injury when they fall. Vertical hangers alone cannot adequately restrain these components. All of these suspended components need to be braced for movement in both horizontal directions, and the vertical hangers must increase resistance to upward movement.

These components are vulnerable when the following conditions are present.

- Bracing is inadequate to prevent the component from swinging.
- Inadequate clearance from other more stationary objects results in pounding damage. Pounding damage may in turn cause fire and water damage.
- Insufficient provisions for differential movement between two separate buildings or between structurally separated parts of a building.

Typical methods to prevent suspended equipment damage are:

- Provide bracing in both horizontal directions and appropriate hangers to prevent upward motion due to swinging (see Figure 4).
- Provide an adequate gap to prevent pounding against adjacent components or surfaces. This is particularly important where pipes pass through walls and floors.
- Provide flexible joints where pipes and ducts connect separate structures.

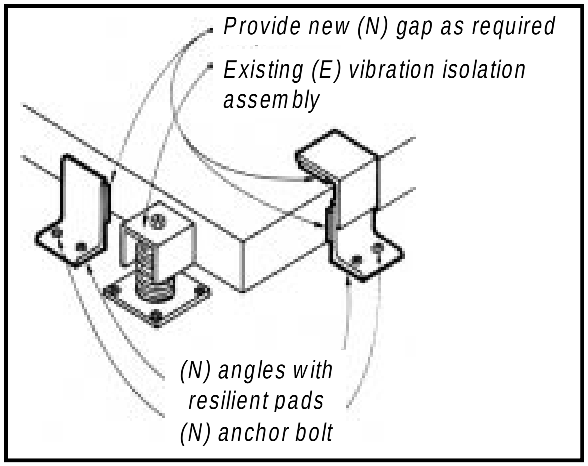

Figure 3. Seismic restraint added to existing equipment.

Resources for Additional Reading

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BAREPP, 1985, *Reducing The Risk of Nonstructural Earthquake Damage: A Practical Guide*. Bay Area Regional Earthquake Preparedness Project, Second Edition, Report BAREPP 85-10, Oakland, California.

CSSC, 1995, *Turning Loss to Gain*, Chapter III, California Seismic Safety Commission, SSC Report No. 95-01, Sacramento, California.

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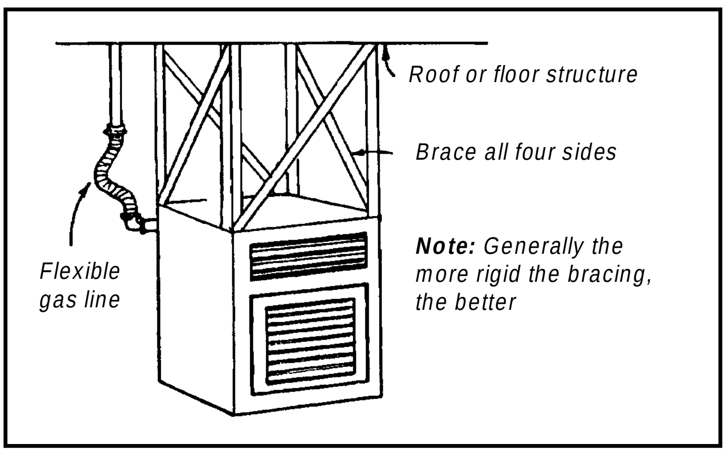

Figure 4. A roof-hung mechanical unit with seismic bracing and flexible connection.

Reconnaissance Report, *Earthquake Spectra*, Supplement C to Volume 11, Earthquake Engineering Research Institute, Oakland, California.

Behr, Richard A., 1996, Seismic Test Methods for Architectural Glazing Systems. *Earthquake Spectra*, Volume 12, No. 1, Earthquake Engineering Research Institute, Oakland, California.

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NIST, 1996, *State of the Art Report on Seismic Design Requirements for Nonstructural Building Components*, National Institute of Standards and Technology, Report NISTIR 5857, Gaithersburg, Maryland.

Soong, T.T., Chen, G., Wu, Z., Zhang, R.H., and Grigoriu, M., 1996, *Assessment of the 1991 NEHRP Provisions for Nonstruct and Recommended Revisions*, Multidisciplinary Center for Earthquake Engineering Research, Technical Report NCEER-93-0003, State Univeristy of New York at Buffalo.

About this Briefing Paper Series

Briefing papers in this series are concise, easy-to-read summary overviews of important issues and topics that facilitate the improvement of earthquake-resistant building design and construction quality.

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