Earthquake Design Considerations for Office, Retail, Light Industrial, Healthcare, School and University Buildings

An Online Continuing Education Course for Engineers

Course Number: S-4010

Credit: 4 Hours / 4 PDH / 4 CPD

DESIGN AND PERFORMANCE ISSUES RELATING TO COMMERCIAL OFFICE BUILDINGS 6

6.1 INTRODUCTION

Commercial office buildings represent a large building segment and house the core of American business operations. Corporate headquarters, banks, law firms, consulting firms, accountants, insurance companies, non-profit organizations – the list is almost endless – use office space in buildings around the country to house their operations. As these companies make decisions about the buildings that they construct or office space that they lease, seismic considerations can easily be factored into the decision process.

The following are some unique issues associated with commercial office buildings that should be kept in mind during the design and construction phase of new facilities:

- Protection of building occupants is a very high priority.
- Occupants are predominantly work-force, with high daytime "8 am to 5 pm" occupancy.
- Most office building occupants are generally familiar with the characteristics of their building; a small percentage of occupants may be

disabled to some degree and visitors will generally not be familiar with the building.

- Office buildings change their interior layouts frequently, to respond to tenant needs, fluctuations in work-force or organizational changes.
- Ensuring the survival of business records, whether in electronic or written form, is essential for continued business operation.
- Closure of the building for any length of time represents a serious business problem.

6.2 OWNERSHIP, FINANCING, AND PROCUREMENT

Commercial buildings may be owner operated, particularly if owned by national or global corporations, but many are developer owned (at least initially) housing tenant (lease holder) operations. In many instances the developer and building designers provide an empty "shell," which is fitted out according to the tenants' planning, spatial and environmental needs; design and construction is generally undertaken by the tenant's consultants and contractors. This tends to split the responsibility for interior nonstructural and other risk reduction design and construction measures between the building designers and contractor, and a multiplicity of tenant designers and contractors.

Financing for these facilities is typically through private loans. The effective life of an office building is 20 to 30 years, after which major renovation and updating is normally necessary. Interior renovation is usually on a much shorter interval, particularly for rental office structures.

6.3 PERFORMANCE OF OFFICE BUILDINGS IN PAST EARTHQUAKES

The seismic performance of modern office buildings designed to recent codes (adopted since the late 1970s) has been good as far as providing life safety. However, the recognition by building owners that satisfactory life-safety code-level performance may still encompass considerable damage (see Figure 6-1), along with repair costs and possible business interruption of the building for weeks or even months, even in a moderate earthquake, suggests that some performance-based design strategies may be useful.

Figure 6-1 Typical earthquake damage to contents and nonstructural components in a modern office building. (photo courtesy of the Earthquake Engineering Research Institute)

Where severe structural damage has occurred in commercial office buildings, it has generally been to older buildings, often the result of configuration irregularities. Figure 6-2 shows an older medical office building, which had a vertical irregularity that caused one floor to pancake during the 1994 Northridge earthquake in Southern California; a failure resulting from inadequate attachment of heavy nonstructural walls in an older 5-story office building is shown in Figure 6-3.

Newer office buildings have also been damaged, most notably the more than 100 welded steel moment-frame buildings (healthcare and residential structures as well as commercial, higher education and industrial buildings) that failed during the 1994 Northridge earthquake. The damage occurred primarily at welded beam-to-column connections, which had been designed to act in a ductile manner and to be capable of withstanding repeated cycles of large inelastic deformation.

While no casualties or collapses occurred as a result of these failures, the incidence of damage was sufficiently high in regions of strong motion to cause wide-spread concern by structural engineers and building officials. Initial investigations showed that in some cases, 50% of the connections were broken and very occasionally the beam or column was totally fractured. Possible causes focused on incorrect connection

Figure 6-2 Exterior view of medical office building severely damaged by the 1994 Northridge earthquake. (C. Arnold photo)

Figure 6-3 Partially collapsed end-wall in 5-story office building caused by severe earthquake ground shaking. (C. Arnold photo)

design, incorrect fabrication, poor welding techniques and materials, and the impact of the need for economy on design strategies and construction techniques.

As a result, a large research program was initiated, sponsored primarily by FEMA, to identify the problems and arrive at solutions. Many structural specimens were tested in university laboratories. New guidelines for these types of structures have been developed (SAC, 2000a, b), but remedial measures have resulted in more costly designs and extended approval procedures, with the result that many engineers have avoided welded steel moment-resistant frames in recent projects.

RESOURCES

Resources for the Seismic Design of New Steel Moment-Frame Buildings

1. FEMA 350, *Recommended Seismic Design Criteria for New Steel Moment-Frame Buildings* (SAC, 2000a)
2. FEMA 353, *Recommended Specifications and Quality Assurance Guidelines for Steel Moment-Frame Construction for Seismic Applications* (SAC, 2000b)

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6.5 SEISMIC DESIGN ISSUES

The information in this section summarizes the characteristics of commercial office buildings, notes their relationship to achieving good seismic performance, and suggests seismic risk management solutions that should be considered.

Seismic Hazard and Site Issues

Unusual site conditions, such as a near-source location, poor soil characteristics, or other seismic hazards, may lead to lower performance than expected by the code design. If any of these other suspected conditions are geologic hazards, a geotechnical engineering consultant