DESIGN AND PERFORMANCE ISSUES RELATING TO LOCAL SCHOOLS (K-12) 10

10.1 INTRODUCTION

Primary and secondary (kindergarten through grade 12) schools house thousands of America's children every school day. These buildings come in a variety of configurations and sizes and are constructed from all types of structural materials like steel, concrete, masonry and wood. As school districts make decisions about the buildings that they construct, seismic considerations can easily be factored into the decision process.

The following are some unique issues associated with kindergarten through grade 12 (K-12) schools that should be kept in mind during the design and construction phase of new facilities:

- Protection of children is an emotional societal issue and has very high priority.

- Occupancy density is one of the highest of any building type (typically 1 person per 20 square feet by code), with the exception of summer months, and after an earthquake, children are likely to be very frightened, creating difficulties for evacuation of a damaged structure.
- Occupancy by children is required by law, thus the moral and legal responsibilities for properly protecting the occupants are very great.
- School facilities are critical for immediate earthquake disaster shelter and recovery efforts.
- Closure of schools for any length of time represents a very serious community problem, and major school damage can have long-term economic and social effects.

10.2 OWNERSHIP, FINANCING, AND PROCUREMENT

Public schools are programmed and developed by the local school district. Financing is typically by local or state bond issues, possibly with the addition of federal assistance.

Public work must be competitively bid. Typically, contracts are placed for all site and building work, both structural and nonstructural. Equipment and furnishings and their installation are purchased separately from specialized vendors.

School districts typically try to emphasize high quality of design and construction and long facility life, though all districts are necessarily very budget conscious.

10.3 PERFORMANCE OF LOCAL SCHOOLS IN PAST EARTHQUAKES

There has been surprisingly little severe structural damage to schools, except in the Long Beach, California, earthquake of 1933, and there have been very few casualties. In California, no school child has been killed or seriously injured since 1933. This good fortune results primarily because all major California earthquakes since 1925 have occurred outside school hours.

Damage in the Long Beach earthquake was so severe that it was realized that if the schools had been occupied there would have been many casualties. As a result, the State passed the Field Act within a month after the earthquake. This act required that all public school buildings be designed by a California licensed architect or structural engineer, all plans must be checked by the Office of the State Architect, and construction must be continuously inspected by qualified independent inspectors retained by the local school board. The State Architect set up a special division, staffed by structural engineers, to administer the provisions of the Act. While time of day limited casualties, the Field Act, which is still enforced today, has greatly reduced structural damage.

In the Northridge, California, earthquake of 1994, State inspectors posted red UNSAFE placards on 24 school buildings, and yellow RESTRICTED USE placards on 82, although this was later considered overly conservative. No structural elements collapsed. There was, however, considerable nonstructural damage as shown in Figure 10-1. This was costly to repair, caused closure of a number of schools and, if the schools had been in session, would have caused casualties. The Field Act focused on structural design and construction, and only recently were nonstructural components included in the scope of the Act.

Figure 10-1 Nonstructural damage at Northridge Junior High where lights fell onto desks during the 1994 Northridge earthquake. (photo courtesy of the Earthquake Engineering Research Institute)

10.4 PERFORMANCE EXPECTATIONS AND REQUIREMENTS

Students and teachers within and outside elementary and secondary school buildings must be protected during an earthquake. Any damage that jeopardizes the provision of educational services impacts not only the facility but also the community, since the school is an important community center. Primary and secondary educational establishments are important community service providers and service interruption is a major problem. In addition to these general seismic performance expectations, the following guidelines are suggested as seismic performance objectives for elementary and secondary schools:

- The school should be capable of substantial use for shelter purposes within 3 hours of the occurrence of earthquake design-level ground motions.
- Emergency systems in the school should remain operational after the occurrence of earthquake design-level ground motions.
- Students and teachers should be able to evacuate the school quickly and safely after the occurrence of earthquake design-level ground motions.
- Emergency workers should be able to enter the school immediately after the occurrence of earthquake design-level ground motions, encountering minimum interference and danger.

10.5 SEISMIC DESIGN ISSUES

The information in this section summarizes the characteristics of local schools (K-12), notes their relationship to achieving good seismic performance, and suggests seismic risk management solutions that should be considered.

Seismic Hazard and Siting Issues

RISK CONSIDERATION

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.

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 suspected conditions are geologic hazards, a geotechnical engineering consultant should conduct a site-specific study. If defects are encountered, an alternative site should be considered (if possible) or appropriate soil stabilization, foundation and structural design approaches should be employed to reduce consequences of ground motion beyond code design values, or costly damage caused by geologic or other seismic hazards (see Chapter 3 for additional information). If possible, avoid sites that have restricted access.

Structural System Issues

Schools are a wide variety of sizes, from one-room rural school houses to 2000-student high schools. Each size will have its own code requirements and cost implications. A wide variety of structural approaches are available and careful selection must be made to meet the educational and financial program.

Traditional schools with rows of standard classrooms are relatively simple buildings, with few partitions since the structural walls can provide much of the space division. Classroom walls can act efficiently as shear walls but the school is likely to have very limited flexibility for space changes. The structure, as in all buildings, plays a background role in providing a safe and secure support for the facility activities. The structural problems are, however, relatively simple, and a well designed and constructed school should provide a safe environment.

Newer schools are usually one or two stories with light steel frame or mixed steel frame, wood and concrete or concrete masonry structures. When designed to code minimum requirements, these light and relatively long-span structures may have excessive drift characteristics. Excessive motion and drift may cause damage to ceilings, light fixtures, partitions, glazing, roof-top equipment, utilities and fire suppression piping. The structural design should pay special attention to drift control and to appropriate support of vulnerable nonstructural components and systems.

Urban schools are sometimes mid-rise (up to 4 stories), with reinforced masonry, reinforced concrete, or steel frame structures. For these structures, configuration irregularities, such as soft stories, may become critical. The structural design should focus on reducing configuration irregularities and ensuring direct load paths.

Larger schools may have long-span gymnasia or multi-use spaces in which wall-to-diaphragm connections are critical. These larger spaces may be used for post-disaster shelters. Seismic resistance must typically be provided by perimeter frames or walls. The structural design should pay special attention to reducing perimeter opening irregularities, and providing direct load path and appropriate structural connections. Larger schools also often tend to become more complex in layout because of new program needs, and the desire to provide a more supportive and attractive environment. The complexities in layout may introduce irregularities in plan shapes and require complicated framing. The structural design should focus on reducing plan irregularity, and providing appropriate structural connections.

Nonstructural System Issues

RISK CONSIDERATION

School occupants are vulnerable to nonstructural damage, particularly falling nonstructural components and systems.

School occupants are particularly vulnerable to nonstructural damage. Although school children may duck under desks and be safe from falling objects such as light fixtures and ceiling tiles, ceiling components that fall in hallways and stairs can make movement difficult, particularly if combined with power failure and loss of lighting. As discussed in the *Structural System Issues* Section, most traditional primary and elementary school buildings are relatively simple buildings, with few partitions since the structure provides the space division. Excessive motion and drift (sway) may cause damage to ceilings, partitions, light fixtures, and glazing. In addition, storage units, library shelving, and filing cabinets may be hazardous if not braced. Excessive drift and motion may also lead to damage to roof-top equipment, and localized damage to water systems and fire suppression piping and sprinklers. Heavy mechanical and electrical equipment may also be displaced.

Falling nonstructural components and systems present a significant potential for injuries to building occupants as shown in Figure 10-1. In addition to the injury potential and economic loss resulting from repair and clean-up costs, excessive service interruption can result from lighting fixture and water, mechanical, and electrical equipment damage. As discussed in the *Structural System Issues* Section, the structure should be designed for enhanced drift control to limit nonstructural damage. Lightweight hung ceilings should be avoided in light frame or large structures, and the safety of suspended lighting fixtures should always be verified. In general, the responsibilities within the design team for nonstructural component support and bracing design should be explicit and clear (Use Figure 12-5 responsibility checklist to facilitate this process).

DESIGN CONSIDERATION

Schools should be designed for enhanced drift control to limit nonstructural damage