SECTION 7 - Design to Maximize Student Safety

THE FIELD ACT

Introduction

Parents expect a safe and secure learning environment for their children. Public school safety encompasses many aspects of security such as protecting children from the abusive behavior of other classmates or the dangers of toxic chemicals. Prevention of injury or death due to natural forces such as wind or ground motion depends upon the structural integrity of public school buildings and the bracing and anchoring of furniture and other objects within the classrooms to prevent them from falling on the children. Parents should be able to assume that once their child enters a public school that the building will shelter the pupils from the powerful forces of nature. These are the reasons the Field Act was written and enacted.

History of the Field Act

In 1933 the lateral force resistant design of public schools, as well as other buildings throughout the state, was based on estimated wind loads. Engineers assumed that buildings designed to withstand wind forces would also be able to withstand earthquake forces. The magnitude 6.3 Long Beach Earthquake of March 10, 1933 destroyed 70 schools and another 120 schools suffered major structural damage. Luckily, the earthquake occurred when the buildings were unoccupied. Hundreds of children might have perished if the earthquake had occurred only a few hours earlier.

Although there had been previous earthquakes in urban areas of California (San Francisco in 1906 and Santa Barbara in 1925) the significance of the Long Beach Earthquake was that it drove home to engineers, public officials and the general public that the need to develop measures to resist the effects of earthquakes is a necessary part of public policy. The level of damage and the extent of the deaths and injuries in Long Beach were perceived as unacceptable outcomes for an event, which could be repeated at any time. The great number of collapsed public schools led to a public outcry for a remedy to the situation of housing public school students in structures that were unsafe in earthquakes. On April 10, 1933, the Field Act was enacted. The Field Act requires that the building designs be based on high level building standards adopted by the state and plans and specifications be prepared by competent designers qualified by state registration. The quality of construction was to be enforced through independent plan review and independent inspection. Finally, the design professionals, independent inspector and the contractor had to verify under penalty of perjury that the building was constructed according to the approved plans.

The Field Act, as adopted, applied only to new construction; not to existing pre-1933 school buildings. Legislation to cover the criteria for continued use or abandonment of these pre-1933 school buildings was enacted under the Garrison Act of 1939. These pre-Field Act buildings were not retrofitted to conform to current codes until funding was made available in the 1970's. It is no coincidence that the state provided funding shortly after the magnitude 6.4 San Fernando Earthquake of 1971. California is now grappling with the problem of evaluating and retrofitting thousands of school buildings constructed before 1976. School Districts contemplating projects on such a campus are well advised to contact their DSA Regional Office in advance of project submission.

Primary Successes

The Division of the State Architect (DSA) is the jurisdictional authority within the State of California that provides enforcement of the Field Act in order to provide safe schools. The DSA has been reviewing plans and overseeing the construction of public school buildings for over 70 years. In that time no pupil or teacher has been injured or killed due to the failure of a building from exposure to earthquake, snow, wind or other loads. A student did die due to injuries sustained by the failure of a wall, not approved by DSA, due to wind loads and dry rot of its posts. In the history of the Field Act, very few school buildings have been so severely damaged in an earthquake as to require demolition. Public awareness of the success of the school program has discouraged any change to the program that might weaken it.

Many policy makers hold the perception that aggressive review and construction inspection is very costly or are too time consuming. Frequently legislation is proposed and sometimes adopted that exempts certain categories of uses of school buildings from the Field Act requirements. In response to this perception, DSA undertook a study in 1992 to determine the cost difference between a Field Act enforced school building and a private school building constructed to the unamended code and enforced by local jurisdictions. The results show that the cost of the construction increased by less than four percent of the project cost. Most of the increased costs were associated with a requirement for continuous on-site inspection and more frequent testing. Less than 1.5% of the larger cost was associated with the stricter building code. The extra cost adds values such as fewer changes during design, owner protections against contractor errors, and safer construction.

The Program

The following is a list of elements and procedures that lead to safer building construction. The level of concern about conflict of interest or capability of designers, contractors and users dictates the level of enforcement necessary for each element. The public and policy makers also set the tone for safe public school construction. In California, where education is compulsory for children, there is a very strong desire to see that school children are not at risk when they attend school. In response to the public's aversion to this risk, the policy makers have written laws that have mandated rigorous enforcement of each of these elements to make sure schools are safe.

CALIFORNIA BUILDING CODE - Codes developed by a large cross section of researchers, engineers and stakeholders establish a minimal accepted standard to ensure safe design of buildings at a practical cost. The code not only establishes the minimum standards, but also is a condensed resource of all the research, analysis and learning from previous mistakes that went into its creation. Codes and standards also evolve as new building materials are developed or discovered that cost less yet resist the forces of nature at least as well as or better than the out-dated materials. Codes are like a recipe. There are great cooks that can cook without a recipe, but the vast majority need guidance just as the vast majority of engineers need the code to provide limits. The code used for California public school construction was the 2001 California Building Code (CBC) which was based on the 1997 Uniform Building Code (UBC) with stricter California amendments incorporated. The new CBC, based on the 2006 International Building Code (IBC), took effect in January 2008.

Even though some consider the California amendments to be too conservative, the real increase in materials and labor costs for these amendments is less than two percent of final cost of construction. Since the costs associated with the structure alone are less than 20% of the total construction cost, significant increases in the cost of the structure do not appreciably increase the cost of a building. Using a good code provides good benefit at a relatively low cost. Despite the knowledge that the current codes will improve once we incorporate lessons learned from future large earthquakes, school buildings constructed in conformance with modern code requirements in the vast majority of cases have met the performance goal for schools.

The enactment of enforceable and adequate codes, rules, or regulations is the first part of the structural safety equation. These rules must encompass a threshold of professional competency for an engineer, as well as minimum design and construction standards. The second part of the safety equation requires a process that assures compliance with these standards in the actual design and construction of school buildings. Flaws in either the standards or the system for enforcing them can lead to fatal consequences. The goal is to minimize the risk of design or construction that does not meet the minimum code requirements.

DESIGN - Higher performance objectives for building construction, in addition to collapse prevention, include additional protection to prevent minor injuries, limiting the amount of physical damage to the building, or assuring immediate occupancy and continuous operation for buildings that provide post-disaster emergency response. Policy makers generally decide what performance objective is desired based on their tolerance of risk and financial limitations.

In California, the performance objective for public schools is collapse prevention and minor risk of injury to the occupants, but allows some repairable structural damage. Since many school campuses have large gathering areas, food service capabilities for large numbers of people, many restrooms and sometimes shower facilities, the public can seek immediate shelter in the safety of a well-constructed school building.

What are the forces? What materials are available? How do beams, columns, foundations, walls, floors and roofs

work together to resist the loads without collapse? Designing buildings to resist the forces of nature, especially earthquakes, is a complex task and requires educated, experienced engineers to develop solutions. Licensing authorities can establish a minimum competency level for structural engineers, which provide further assurance that the design will be successful. Colleges and Universities have provided the basic education which, when combined with experience in building design, has produced individuals throughout the world with the talent to design safe buildings.

Reuse of Plans

Competent design can also be achieved by use of well-engineered standard plans (PDF - 5.28 MB). These drawings could then be used repeatedly, saving the costs of design and review. Similarly, designs that have been successfully used elsewhere could be "borrowed" and used. Use of plans for buildings that have already been constructed once will have some of the flaws identified which then can be corrected in the subsequent design. A fast growing school district in Northern California has been using essentially the same design for school campuses for over a decade with great success. The facilities planner said that money is being saved through steady improvements in the design based on the previous construction experience, more competitive bidding, and fewer corrections during construction.

Competent engineering is required and cannot be compromised in the creation of construction drawings and specifications. The cost of the structural design of a project is typically less than 2% of the entire construction cost. Good design provides tremendous benefit at little cost and, with independent inspection, is one of the two most highly recommended elements of the process that insures safe school construction.

GEOTECHNICAL HAZARD INVESTIGATIONS - Designers need to know the loads in order to design a building that will meet the performance objectives. A site-specific geologic hazard report can help in defining the design parameters. While it can be expensive, it provides accurate data to reduce the construction costs and identify unacceptable locations for building construction. The locations of areas where landslides are probable or surface rupture is evident could be determined in a geotechnical hazard investigation to prevent construction on unstable ground. Surface faulting can literally rip a building apart. Construction on or very near a known surface fault should never be considered. For earthquakes in some localities, the need to resist ground motion may be eclipsed by the need to mitigate or simply avoid liquefaction conditions. An area-wide conservative estimate of geotechnical hazards and soil conditions can provide substantial benefit at a lower cost than site-specific investigations. A geotechnical hazard investigation can vary from review of existing information to creating a report based on extensive on-site drilling, testing and soil analysis. A soils report should also accompany the investigation. The ground-structure interaction also needs to be understood.

CONSTRUCTION - Identify approved plans. To avoid substitution of unapproved drawings, contract documents should be stamped and signed by the approving agency or identified as the code complying documents. The benefit of independent review can be lost if approved plans are not properly identified. The contractor will use the stamped approved plans in order to construct the building and by the inspector to ensure that the contractor has constructed the building in accordance with them. Changes to the design before construction begins and during construction are commonplace. These changes also need independent review, approval and identification as for the approved plans.

NON-STRUCTURAL HAZARDS - There is a lack of emphasis in the code for design of non-structural elements. Many non-structural elements are located overhead and often come loose and fall when subjected to moderate earthquakes that do not affect the building's structure. The bodies of young children are much more susceptible to falling objects than are adults. Parts of the code do address non-structural hazards and DSA has published guidelines (PDF - 454 KB) for school districts regarding anchoring and bracing televisions, bookcases, etc. to assist them in identifying and mitigating these possible hazards. However, many of these protection devices are defeated as teachers make changes in their classrooms.

INDEPENDENT INSPECTION AND TESTING - The benefits of controlling the design are lost if the construction does not adhere to the approved plans. Even in areas where there are well-qualified, even certified, builders and experienced workers, portions of the structure are frequently built without being in conformance with the approved plans. One must be on guard against this. The performance of a building in strong earthquakes sometimes rests on what might appear to be a relatively minor detail. Just like a chain, the weakest link might fail, leading to

collapse. How often and how rigorously the testing and inspection takes place is dependent on several factors including complexity of the project, competency of the builder, competency of the workers, financial constraints and level of risk aversion.

Independent inspection can add about 2% to the cost of construction and provides great benefit for its cost. To achieve safe construction, independent inspection and testing of materials is a minimum requirement and cannot be compromised. Independent inspection provides a great benefit at little cost and is a highly recommended element of the process that insures safe school construction.

Conclusion

California, being an extremely active state, seismically, must make provisions to protect its student population from the dangers associated with ground movement through the structural design of school buildings. This was mandated by the Field Act and has been accomplished with great success in the 70 years since its passage.

In addition to structural design protections realized through the Act, school districts should also be aware of non-structural hazards and the special challenges of schools built prior to 1976. DSA Regional Offices are ready to help.

—Dennis Bellet

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