UTAH STUDENTS AT RISK

THE EARTHQUAKE HAZARDS OF SCHOOL BUILDINGS

A PRELIMINARY SURVEY

BY THE UTAH SEISMIC SAFETY COMMISSION AND STRUCTURAL ENGINEERS ASSOCIATION OF UTAH

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"Children have the right to be safe in school buildings during earthquakes."

– Western States Seismic Policy Council

1. Summary

Utah faces a serious risk of a major earthquake. The most serious threat is a magnitude-7 rupture of the Salt Lake City segment of the Wasatch fault that could kill 2,300 to 2,900 people, injure 30,000 to 40,000 more and cause damage and other losses totaling $37 billion. Other Utah faults also could produce strong, destructive quakes.

Schools are major public assets that warrant seismic protection, not just because our children and school teachers and staff are required to spend much of the day in them, but because they also provide temporary shelter during and after disasters. The ability to get schools open quickly after a major earthquake helps get society back to normal.

There is a need to understand the vulnerability of older school buildings to help protect the students, teachers and other employees who occupy our schools.

The Utah Seismic Safety Commission (USSC) and Structural Engineers Association of Utah (SEAU) used a method known as "rapid visual screening" to make a preliminary assessment of the earthquake safety of a sample of 128 school buildings out of more than 1,000 schools in the state of Utah. The Utah Schools Rapid Visual Screening Pilot Project was funded by $69,000 in grants from the Federal Emergency Management Agency (FEMA).

Of the 128 public and charter school buildings screened using these so-called "sidewalk surveys," 51 were determined to have an acceptable level of seismic safety, but 77 school buildings – or 60 percent – were found to require more detailed seismic evaluation to determine if they can withstand strong earthquakes or instead need to be retrofitted or replaced.

Of the 77 school buildings needing further evaluation, 46 scored poorly enough that the screening guidelines suggest they are at least 10 percent likely to collapse during a major earthquake, and the scores of 10 of those buildings indicate they are highly likely to collapse during the "big one."

The joint USSC-SEAU Committee on Rapid Visual Screening of Utah Schools wishes to express some caveats about this study. First, full rapid visual screenings – particularly including collection of school district records and drawings of buildings – were not completed on most buildings. Second, a basic effort was made to pick the sample of schools in this study based on the statewide proportions of schools of various ages, geographical locations and types (elementary, junior high, high and charter). Third, some of the numbers in this report may place focus on individual schools, but it is important to remember there is a statewide need for seismic evaluation and rehabilitation of schools. Fourth, with only 128 school buildings studied out of some 1,085 statewide, this report is hardly the final answer to the problem of schools that are vulnerable to earthquakes, but is meant to move the issue forward.

The findings do not include more extensive evaluations obtained by certain school districts and charter schools, nor do they take into account seismic rehabilitation that has been performed on a number of schools.

This pilot project highlights an urgent need to conduct rapid visual screening of all of Utah's 1,000-plus schools to determine which meet seismic safety standards and which require more detailed seismic evaluation of the possible need for seismic retrofitting or replacement.

Legislative action is needed to authorize a $500,000 project to screen all Utah school buildings for seismic safety and set priorities for which of these buildings require more detailed evaluations of their seismic safety.

Eventual retrofitting or replacement of vulnerable schools – like any other expensive infrastructure updating – may be done in phases over a period of years as part of the normal school construction process, and should not come at the expense of ongoing education budgets.

It is hoped that this survey of a sampling of Utah schools leads to rapid visual screening of all Utah schools for seismic safety, and to a broader goal of establishing a systematic program – for public and charter schools statewide – that deals with the very real problem of the earthquake safety of Utah's large number of older, seismically unsafe schools and other buildings.

2. The Problem: Utah School Children at Risk

It often is said that a major earthquake in Utah is not a matter of if, but when. Utah's family-oriented culture places great emphasis on children – children who spend much of their time in school. Yet school districts have struggled to make progress to protect children from the hazard – well known to earthquake scientists and engineers – posed by many school buildings, especially those constructed before modern building codes and made of unreinforced bricks or other masonry blocks.

Some school districts have taken steps to deal with buildings that are at seismic risk by replacing older facilities, rehabilitating existing ones and planning to rebuild others. But when the big quake occurs, the shortcomings of many other older school buildings may become tragically apparent. The problem was outlined in July 2010 by the Western States Seismic Policy Council, of which Utah is a member:

"Every community is required to educate children, and it is the responsibility of governmental agencies to design and construct safe buildings to house them. While current building codes and construction practices have recognized the effects of earthquakes and provide state-of-the-art design considerations, many older school buildings were built before these principles were understood.

Additionally, many existing buildings are constructed of materials such as unreinforced masonry, which are not in common use today due to their poor performance in past earthquakes throughout the world. These older buildings have not been properly graded or passed the test of seismic safety. Consequently, many students face significant seismic risk."

Most children don't have a choice about going to school; attendance is mandatory. So there is an implicit government obligation to ensure the safety of schools.

Probabilities of a Big Quake, and Its Human and Economic Toll

Prior to the implementation of modern seismic building codes about 1975 and even more stringent codes in 1997, many Utah schools were built using unreinforced masonry and other materials not allowed by today's codes. Without a full understanding of the implications of using these building methods, along with the lack of a major damaging quake in modern time, there was little pressure to do otherwise.

In recent decades, however, research has revealed a history of magnitude-7 earthquakes along the Salt Lake City segment and other central segments of the Wasatch fault.

According to the University of Utah Seismograph Stations, the chance of the "big one" – a magnitude-6.5 or larger quake on the Salt Lake City segment of the Wasatch fault – is estimated between 3 percent and 11 percent in the next 50 years. The chance of such a quake somewhere on the Wasatch fault's five central segments (from Brigham City south to Nephi) is 12 percent to 15 percent in 50 years, while the odds of a big quake somewhere in the Wasatch Front region (on the Wasatch fault or other faults) is 25 percent in 50 years.

The death, injury, disruption and destruction expected from a major earthquake on the Wasatch fault has been estimated by the Federal Emergency Management Agency using computer simulation software known as HAZUS, or Hazards U.S. This scenario included nine counties inhabited by about 2 million people: Salt Lake, Utah, Davis, Weber, Tooele, Box Elder, Summit, Wasatch and Morgan.

A 2009 simulation estimated that a magnitude-7.0 earthquake on the Salt Lake City segment of the Wasatch fault would kill about 2,300 to 2,900 people, depending on the time of day. Another 8,300 to 10,800 people would be hospitalized, and yet another 22,800 to 31,400 people would require medical attention but not hospitalization.

The simulation estimated the quake would displace a total of 97,700 households, and that 62,328 people would seek temporary housing in public shelters.

The HAZUS scenario also estimated damage to Utah buildings, utilities, transportation and other economic losses at almost $37 billion. Buildings alone would account for $35.4 billion of the losses.

The region covered by the 2009 HAZUS simulation included 541,000 buildings with a replacement value of $115 billion. A magnitude-7 quake would moderately, extensively or completely damage more than 38 percent of those buildings. If slight damage is added, half of all buildings would sustain damage.

Among education buildings in the HAZUS scenario, 22 percent would be completely damaged, 11 percent extensively damaged, 12 percent moderately damaged, and 10 percent slightly damaged – in other words, more than half of the schools would sustain damage.

Unreinforced Masonry is a Hazard

Many Utah schools were built before seismic safety regulations were used or enforced in the state. The first widespread seismic regulations came in the 1973 Uniform Building Code and were not fully implemented and enforced until 1975 and later. Those seismic requirements were crude by current standards. Each subsequent version of seismic design requirements reflected better understanding of earthquakes' effects on buildings, particularly weaknesses observed during real quakes.

Masonry is the predominant type of school building structure in Utah. Unreinforced masonry – lacking rebar that gives strength to block walls – was used in Utah into the 1960s and 1970s and, after that, reinforced masonry.

Unreinforced brick, cinder block or other masonry is a dangerous building type because it is susceptible to damage and collapse in earthquakes, as has been shown during strong quakes throughout the world. Structural engineers and seismic safety advocates believe all unreinforced masonry buildings should be subject to a mandatory evaluation by licensed structural engineers to determine their life-safety rating.

Reinforced masonry building practices – those using rebar or other materials to reinforce the structure – were improved and considered acceptable after the 1997 building code was enforced, but most of the older reinforced masonry schools remain open to question in terms of whether they met minimum seismic design requirements.

Beginning with the 2000 International Building Code, school buildings were required to be designed for an elevated "importance" factor. This essentially increased the forces buildings must be designed to resist by 25 percent. All buildings constructed before this are deemed "under designed."

The risk is not limited to public schools. The growth of charter schools has accelerated in recent years. The Utah State Office of Education estimates that at least 22 of Utah's 76 charter schools – 29 percent – are located in older buildings that school districts held in surplus or that were converted from other uses. Charter school boards should be asking tough questions on the seismic risk posed by these buildings.

An informal Utah State Office of Education study in 2006 indicated that 58 percent of Utah schools were built before 1975, when seismic regulations began to be enforced through building codes – a statistic cited by the Utah Seismic Safety Commission and the Structural Engineers Association of Utah in January 2010 in support of legislation to assess all schools for seismic risks.

That study recommended the state undertake a seismic inventory of all Utah schools and begin a 10-year plan to rehabilitate deficient schools.

3. Methods: Rapid Visual Screening of Schools

The Utah Schools Rapid Visual Screening Pilot Project was funded by $69,000 in grants from the Federal Emergency Management Agency (FEMA). The project was intended to encourage serious consideration of the seismic vulnerability of Utah's school buildings and action to address the problem.

This study surveyed the seismic safety of 128 Utah school buildings to help project what might be found by a full inventory of the more than 1,000 schools statewide.

Seventeen licensed engineers organized by the Structural Engineers Association of Utah conducted the survey during Sept. 13-15, 2010 using methods established in FEMA Publication 154, "Rapid Visual Screening for Potential Seismic Hazards." Rapid visual screening allows structural engineers or other trained individuals to make quick "sidewalk surveys" or assessments to identify and rank buildings that may be vulnerable to earthquakes and thus require further evaluation and possible rehabilitation or replacement.

FEMA calls rapid visual screening "a nationally accepted standard procedure for rapid assessment so local communities can understand their vulnerabilities in their existing building stock."

FEMA says this "sidewalk survey" approach allows buildings to be classified into two categories: "Those acceptable as to risk to life safety, or those that may be seismically hazardous and should be evaluated in more detail by a design professional experienced in seismic design."

ROVER Data Entry Software for Smart Phones

As part of the survey of 128 Utah school buildings, the participating engineers tested ROVER (Rapid Observation of Vulnerability and Estimation of Risk), which is a software version of FEMA's rapid visual screening process. ROVER allows screeners to enter into smart phones the data they collect on buildings.

FEMA and the Applied Technology Council provided the data-entry software and trained the engineers how to use the software on smart phones purchased with FEMA funds.

When a building was screened, its address, year built, occupancy and some other data was loaded into the phone. The engineers also used their phones to photograph the buildings they screened and to log soil types and other hazard conditions.

Selection of Schools for the Survey

Of approximately 1,085 schools in Utah counted by the Utah State Office of Education, 128 school buildings were surveyed using rapid visual screening. The 128 buildings represented a somewhat smaller number of schools because at some schools, more than one building was screened.

High schools, junior highs, elementary and charter schools were included in the survey in proportion to their statewide numbers.

Of the school buildings surveyed, about 40 percent were from northern Utah (North Salt Lake northward), 50 percent from Salt Lake City south to Juab County, and 10 percent from Juab County southward.

In terms of age of schools, the survey placed greatest emphasis on those constructed before modern seismic building codes: 50 percent were built before 1975, when the first seismic building codes were enforced; 30 percent from 1975 through 1996; and 20 percent after the onset of even tougher seismic codes in 1997. This distribution of ages of the schools in the survey may not accurately reflect the actual proportions for the entire state. A 2006 informal study by the Utah State Office of Education found 58 percent of Utah schools were built before 1975.

Most of the schools in the study – like those statewide – were built prior to the implementation of newer building codes that now better protect the lives of building occupants during major seismic events.

Rapid Visual Assessment and Scoring of School Buildings

A rapid visual screening, or "sidewalk survey," takes 15 to 30 minutes, during which the engineer or other screener identifies the building's primary structural system for resisting "lateral loads" – sideways forces on the building from earthquake shaking – and other characteristics of the building that influence how well the building's structure will resist such shaking.

The screener fills out a data-collection form that includes the building's name, use, number of stories, year built, floor area, number of occupants, a sketch and a photograph of the building, soil type, unusual building configurations such as an irregular floor plan, and any nonstructural falling hazards such as chimneys, parapets and cladding.

The data forms include pre-determined basic seismic hazard scores for each of 15 different structure types, ranging from small wood-frame residential and commercial buildings, which are most quake-resistant, to unreinforced masonry buildings, which are least resistant.

There are three different versions of the basic form: one each for low-, moderate- and high-seismicity regions. So, for example, in a moderate-seismicity region, a wood-frame home might have a basic score of 5.2 and an unreinforced masonry building might have a basic score of 3.4, but in high-seismicity regions the scores would be lower at 4.4 and 1.6, respectively, indicating greater building vulnerability due to higher seismicity. Most of Utah is classified as a high-seismicity area, and some of the state is characterized as moderate in seismicity.

On the data-collection form below the basic scores, points are added or subtracted if the building has features that add or detract from its basic seismic hazard score.

For example, an unreinforced masonry school in a high-seismicity area may have a basic seismic hazard score of only 1.6 – already low enough to warrant detailed evaluation for seismic safety. But the screener also noted the irregularity of the school's floor plan (such as jogs in the building's footprint, or a non-rectangular building), resulting in subtraction of 0.5 points, and the fact the school was constructed before building codes, worth another 0.2 off the total. And with another 0.4 deducted for soft soil, the building's final seismic hazard score was only 0.5.

In this study, however, a somewhat more complicated formula was used within the ROVER software so that no school received a negative final score – something that would imply a chance of collapse greater than 100 percent, which is not possible.

FEMA says the hazard score "reflects the estimated likelihood that building collapse will occur if the building is subjected to the maximum considered earthquake ground motions for the region."

FEMA recommends a cutoff score of 2.0, meaning that any building with a score of 2.0 or less should be evaluated in detail for seismic safety.

The scores are on a logarithmic scale. So a score of 2.0 means the chance of building collapse during a major quake is one in 10 to the 2nd power, or one in 100, and thus should be evaluated in detail, according to FEMA. Buildings in this category may or may not require rehabilitation or replacement once a more detailed study has been completed.

A score of 1 means the chance of collapse is one in 10 to the 1st power, or one in 10. And a score of zero means one in 10 to the zero power, which is a one-in-one chance, or near certainty of collapse.

4. Findings: 60 Percent of Schools May Be Vulnerable

The Federal Emergency Management Agency (FEMA) says that its rapid visual screening method "can be implemented relatively quickly and inexpensively to develop a list of potentially hazardous buildings without the high cost of a detailed seismic analysis of individual buildings." FEMA divides buildings into two groups based on their rapid visual screening scores:

- "If a building receives a high score above a specified cut-off score [2.0] … the building is considered to have adequate seismic resistance."
- "If a building receives a low score on the basis of this RVS [Rapid Visual Screening] procedure, it should be evaluated by a professional engineer having training or experience in seismic design. On the basis of this detailed inspection, engineering analyses, and other detailed procedures, a final determination of the seismic adequacy and need for rehabilitation can be made."

The Utah Schools Rapid Visual Screening Pilot Project of 128 Utah school buildings found the following:

- 40 percent of the Utah school buildings screened (51 of 128) were found to have adequate seismic resistance. All but a few of them were reinforced masonry buildings, the predominant alternative in Utah to seismically unsafe unreinforced masonry.
- 60 percent of the Utah school buildings screened (77 of 128) scored 2.0 or lower, indicating a one-in-100 or greater chance of collapse during the maximum earthquake considered likely, and thus requiring further evaluation of seismic safety. A one-in-100 chance of collapse may seen low, but is consistent with established national engineering standards for the prevention of building collapse.

Analysis of the 77 school buildings requiring further evaluation for seismic safety revealed other trends:

- <u>School type</u>: 45 are elementary schools, 15 are junior highs, 12 are high schools and four were other schools.
- <u>Collapse potential</u>: 46 (or more than a third of all 128 school buildings that were screened) had scores between 1.0 and 0.0, indicating a 10 percent to 100 percent potential chance of collapse during the maximum credible earthquake, according to FEMA guidelines. Thirty-nine of the 46 are unreinforced masonry. Ten of the 46 schools with scores of 1.0 or less had scores of 0.0 or 0.1, indicating a potential 100 percent collapse risk, according to FEMA. All 10 are unreinforced masonry buildings. Based on the total number of schools in Utah, this preliminary finding suggests some 650 schools statewide may have a greater

than a 1 percent chance of collapse. Of those, 390 may have a 10 percent to 100 percent chance of collapse, while, in turn, 85 of those may have a potential 100 percent risk of collapse.

- Construction date: 61 of the 77 buildings were built before 1975, when seismic building codes were first enforced, while 16 were built from 1975 onward. Of the total sample of 128 school buildings, 50 percent were built before 1975, compared to 80 percent of those (61 of 77) requiring further evaluation.

- Building type: 45 of the 77 school buildings requiring further evaluation are unreinforced masonry (58 percent), 23 are reinforced masonry with flexible floor and roof diaphragms (30 percent), three are reinforced masonry with rigid (generally more dangerous) diaphragms, five are concrete frame with unreinforced masonry infill and one is concrete energy-resisting frame. None of the 51 seismically adequate school buildings are unreinforced masonry. Of those 51, 41 are reinforced masonry with flexible diaphragms and another six were reinforced masonry with rigid diaphragms.

Note on survey findings: The data collection forms for the 128 school buildings in this survey are not included with this report, nor are individual schools named. However, these public records may be obtained from the Utah Division of Homeland Security pursuant to provisions of the Utah Government Records Access and Management Act.

5. Conclusions: Legislation and Gradual Repairs

In July 2010, the Western States Seismic Policy Council issued a formal recommendation that stated: "Children have the right to be safe in school buildings during earthquakes. WSSPC recommends each state, province, territory and community adopt a program that would identify and rank the potential seismic vulnerability of schools in their communities in a timely manner. Furthermore, programs to reduce the seismic vulnerability of those schools at greatest risk should be developed."

The Federal Emergency Management Agency also recommends such an approach in its Publication 395, "Incremental Seismic Rehabilitation of School Buildings (K-12)," which calls for gradually strengthening school buildings as part of the regular program of maintenance and capital improvements.

Prior to this report, several attempts have failed in recent years to secure legislation to use rapid visual screening to create an inventory of all Utah schools and rate their potential vulnerability to earthquakes – a necessary first step toward setting priorities for repairs and/or reconstruction.

It is hoped this study will highlight the need for legislative action to authorize and fund such an inventory (at a cost of $500,000) and thus identify potential problems with the older stock of school buildings in our high seismic risk area.

In funding the Utah Schools Rapid Visual Screening Pilot Project, the Federal Emergency Management Agency stated that the project "is intended to lead the way for developing a complete inventory of vulnerable school buildings in the area."

FEMA's intent was clear, saying the effort "will enable Utah to identify which schools need further engineering evaluation and future seismic retrofitting to ensure the safety of staff and students should an earthquake occur. This would also set a model that Utah could employ towards a more comprehensive building assessment project that would include other state-owned critical facilities."

Legislation for Rapid Visual Screening of All Utah Schools

Many school construction programs are dealing with the problems of updating and replacing older buildings, or putting into place plans to rehabilitate or replace them, but there currently is no uniform system to evaluate the seismic safety of Utah's school buildings or to set priorities in retrofitting or replacing seismically vulnerable schools.

Yet engineers and earthquake specialists are in wide agreement that schools and other buildings erected prior to seismic regulations in building codes most likely will experience significant damage during a moderate to major earthquake.

The rapid visual screening method used in this study and developed by FEMA would provide a uniform way to identify Utah's most vulnerable school buildings as candidates for further evaluation and for possible rehabilitation or replacement.

During the 2011 Utah Legislature, legislation is being introduced in what will be the fourth formal attempt to authorize and fund rapid visual screening of schools statewide for potential seismic hazards.

During the 2010 legislative session, state Rep. Larry Wiley – a building inspector and contributor to this report – sponsored House Bill 72, the Utah School Seismic Hazard Inventory Act. For a cost of $500,000 the bill would have authorized and funded rapid visual screening of all 1,000-plus schools in Utah, with the money made available to school districts and charter schools.

By conducting rapid visual assessment of all Utah schools at a cost of $300 to $600 per school, "the schools most at risk can be identified and steps taken to lessen the danger," according to a summary of the legislation.

Costs and Other Objections

Past efforts to pass this legislation have encountered objections, such as the high cost of repairing or replacing hazardous schools, potential disclosure of such schools' seismic status to the public, and the possibility of obligating the state to remedy dangerous buildings – although the 2010 bill was amended to address that issue. And because the Legislature has been reluctant to view schools as part of Utah's critical infrastructure, school administrators and teachers have voiced concern that money to assess schools' earthquake safety may come at the expense of the overall school budget.

Rep. Wiley's 2010 bill summary stated that "a plan for addressing the seismic vulnerability of Utah's schools can be integrated into the facilities maintenance operations through incremental seismic rehabilitation methods. This process interjects seismic rehabilitation components into the regular maintenance and improvement plans for structures and is a proven cost-effective means of addressing seismic safety."

The Western States Seismic Policy Council also has addressed some of the concerns in its 2010 policy recommending rapid visual screening, which said: "Protecting children from preventable injury during a seismic event is of the highest priority."

“Public safety is a distinct presumption and should be considered outside the realm of education spending,” WSSPC said. “Further, the costs of seismic retrofitting can often be segregated into discrete projects that can be incrementally achieved through the existing maintenance and upkeep programs already a part of most school building programs.”

Strengthening older masonry schools to make them better withstand earthquakes can range in cost from $14 to $32 per square foot, according to 1994-95 FEMA national estimates that have not been adjusted for inflation or location. Many school districts use this process rather than replacing facilities.

WSSPC acknowledged that the cost of reducing school buildings’ seismic vulnerability “can be challenging and needs to be fully justified in order to be properly assessed and ranked within the budgeting process. Therefore, it is necessary to put sufficient energy and resources into quantifying the extent of the problem. … The first step toward seismic safety of schools should be to demonstrate the magnitude of the problem; then the community can prepare to take the necessary preventive measures.”

The group recommended rapid visual screening of all schools to determine which should be further investigated for seismic vulnerability, followed by ranking of the inventoried schools – with those prone to collapse ranked high – and development of a program to reduce the seismic vulnerability of schools, ranging from gradual strengthening of some schools to retrofitting or phasing out the most dangerous buildings.

A Time to Act for School Children

In recent decades, major earthquakes around the world have provided important lessons about the necessity of adopting and enforcing modern building codes. They also have shown that unreinforced masonry buildings can pose a major liability problem and may be highly vulnerable to collapse during powerful earthquakes.

Many older school buildings in Utah were built of unreinforced brick or other masonry. The results of this pilot study indicate a critical need to check all of Utah’s schools for seismic safety by conducting rapid visual screening on all of them. School buildings are occupied by large numbers of children and adults, and many Utah communities consider using schools for emergency purposes such as shelters and command centers. Making sure that these school buildings are available for use after a major earthquake can provide shelter to displaced residents and help society get back to normal.

A number of states, notably Oregon and California, are ahead of the curve on this issue, not only screening all schools, but in some districts such as Portland, undertaking major seismic rehabilitation of a number of schools. In Utah, the Salt Lake City School District has followed a similar practice, replacing or strengthening many older facilities. The district could afford it because voters approved bonds and because low enrollment growth meant the money didn't have to go to new schools for more students.

It is hoped that this pilot survey of 128 Utah school buildings leads to rapid visual screening of all Utah schools for seismic safety, and ultimately to a broader goal of establishing a program that will start improving the earthquake safety of Utah's large number of older, seismically unsafe schools and other buildings.

Nevertheless, the proposed legislation to fund statewide rapid visual screening of all schools costs only $500,000, does not impose any requirements for rehabilitating school buildings, and merely will alert school districts and charter schools of the need for more thorough review of the buildings deemed by screening to be potentially hazardous.

Utah may have time to prepare and make its schools stronger before the next large earthquake, but research suggests that such a quake is likely sooner rather than later. So the danger to schools should be addressed with urgency but not alarm.

One must ask: Do we start improving the seismic safety of our schools now, or do we wait until the big quake collapses school buildings?

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