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Seismic Strengthening of Existing Buildings

Seismic Committee Report

July 8, 1999

Executive Summary

The history of understanding the nature of earthquake dangers in Utah began shortly after the arrival of the Mormon pioneers in the mid 1850's. As surrounding areas experienced the destructive forces of earthquakes, both public and private sectors in Utah took note and sought a better understanding of the risks for the state. The Uniform Building Code has recognized the seismicity of Utah since 1935 and continues with improved understanding today. As our appreciation of seismic risk increases, it becomes necessary to look back on our existing building inventory and address the risks which are inherent in older designs and construction materials.

The Structural Engineers Association of Utah (SEAU) is a member organization of Engineers involved in the design and construction of buildings and other structures. Formed in 1980, it's goals include promoting legislation and codes relating to structural engineering and public safety.

The Utah Seismic Safety Commission (USSC) has requested that the Structural Engineers Association of Utah contribute to discussions regarding the need for evaluating and retrofitting existing buildings and other structures. SEAU welcomes this opportunity to lend its opinion regarding the technical issues of building rehabilitation and to comment on the need for attention to this class of buildings.

Building code regulations in the State of Utah are intended to provide a minimum acceptable level of building performance for both gravity (vertical) and lateral (earthquake) loading. The codes are continually updated to reflect new knowledge about behavior of materials, building systems and applied forces. Nowhere is this change more noticeable than in the design for seismic loading. The code has a long history of response to lessons learned from

past earthquakes. Each edition refines the knowledge available for building design and provides regulation of acceptable design methodologies. With earthquake design, the code blends both theoretical and observed behaviors and attempts to give practical design parameters for economical designs.

We can readily acknowledge the impact of present building code requirements for seismic design in new buildings, however applying regulation to our existing buildings is an area less well defined. Presently, there is a diverse list of existing code references which could be interpreted to require seismic upgrades of existing structures. Unfortunately, these references do not provide a clear path toward addressing the hazards of our existing buildings. It is apparent that the need to focus on this area of building safety is a priority for the protection of both property and life.

The building code establishes a degree of protection by compromising acceptable risk and the economics of construction. This underlying premise is often little understood or appreciated. A definition of risk which refers to an interval of time for the reoccurrence of an event (earthquakes) is significantly different than understanding it as the probability of damage to a building or structure with known deficiencies. With this latter realization, risk of building damage is highly probable when structures which have shown to be poor performers are allowed to remain without some measure of improvement. It is this concern which should fuel the effort to require some form of review and rehabilitation of existing buildings.

Today, engineers have many tools to assist in the evaluation and upgrading of existing buildings. These resources offer several appropriate means to help reduce existing hazards in buildings and significantly improve their performance in an earthquake. Ranging from partial reduction of lateral force requirements to performance and component based approaches, each offers a means to focus some measure of attention on the need for rehabilitation. SEAU believes that the minimum level of safety for all existing buildings should be for collapse prevention. This threshold addresses the most basic reason for any regulation concerning existing buildings, protection of life.

Consideration of any technical regulations regarding rehabilitation of existing buildings is tempered by the extent of the program desired. While it would be presumptive to assume a level of compliance at this time, it is the opinion of the Structural Engineers Association of Utah that many existing buildings pose some measure of liability in view of the progression of knowledge regarding building performance and seismic design. In this light, we recommend that a Task Force be established to focus the various interests and proceed with recommendations for specific program(s) regarding seismic strengthening of existing buildings

Introduction

Utah has been concerned about earthquake design due to the presence of active seismic faults. The state has been promoting earthquake safety for over two decades. The formation of the Seismic Safety Commission in 1994 culminated the efforts of several Councils and a Task Force with the publication of "[A Strategic Plan for Earthquake Safety in Utah](#)". In this 1995 publication, the

Commission included five objectives consistent with the plan, the third of which is to improve the seismic safety of buildings and infrastructure. The Structural Engineers Association of Utah concurs with this basic strategy and endorses the new strategy 3.14 included in “[A Progress Report on Activities for the Period July 1994 to June 1996](#)” prepared for the Commission in November 1996. This new strategy adds the need to reduce structural hazards in older private buildings.

This position paper serves to express the opinion of the Structural Engineers Association of Utah with regard to the need for seismic strengthening of existing buildings and to help clarify and refine the various regulations and information available.

History

In the state of Utah, the Uniform Building Code model code has been adopted. Additionally, the Utah Uniform Building Standards Rules are provided for amendments to the model code and has been the vehicle by which modifications and additions to the base code are promulgated.

Presently, the 1997 edition of the Uniform Building Code (UBC) has been enacted in the State of Utah. Chapter 34, titled “[Existing Structures](#)”, addresses maintenance, additions, alterations, repairs, moving and change of occupancy in existing buildings. Appendix Chapter 34 Division I titled “[Life-Safety Requirements for Existing Buildings Other than High-Rise Buildings](#)” which addresses occupant safety in existing buildings which do not conform to the minimum requirements of the code and Division III, “[Repairs to Buildings and Structures Damaged by the Occurrence of a Natural Disaster](#)” have not been adopted by the State of Utah. The Uniform Code for the Abatement of Dangerous Buildings is a companion document which addresses equitable remedies consistent with other laws for the repair, vacation, or demolition of dangerous buildings. Few jurisdictions in Utah have adopted this document at this time although some use it as a guideline.

The Utah Uniform Building Standards Rules addresses the need for strengthening of parapet walls, cornices, spires, towers, tanks, signs, statuary, and other appendages through an amendment to Chapter 34 with the addition of section 3403.2. The provision applies to buildings constructed prior to 1975 when said building is undergoing re-roofing, or alteration of or repair to said feature.

In 1983, the City of Ogden instituted a single-stage mandatory reduced force ordinance for all buildings constructed prior to June 1975, with an occupant load over 100 persons or an area greater than 3,000 square feet. There are exceptions for certain residential dwellings and multiunit residences. The triggers for the ordinance are structural alterations or repairs to structural elements and alterations or repairs totaling over 50% of replacement cost of the building. The upgrade level was set at 50% of the force level of the 1979 UBC (Zone 3).

During the early 1990’s the Uniform Building Code Commission of the state of Utah filed a code change submittal to change the UBC seismic zone along the Wasatch front from zone 3 to zone 4. The reasons stated at this time for the submittal were in recognition of larger peak ground accelerations

uncovered by research in the preceding ten years. The Lateral Design Committee of the International Conference of Building Officials eventually disapproved the submittal on the basis of insufficient data.

Some Building departments in Utah have recognized the need to address mitigation of seismic hazards in older buildings and selectively require the use of strengthening guidelines such as the Uniform Code for Building Conservation (UCBC). These are appropriate regulations for considering seismic retrofitting for older buildings however there is no uniform approach or enforcement except as deemed appropriate by the Building Official. Furthermore, the present conditions under which these provisions may be invoked are limited to changes in occupancy or proposed alterations and additions to an existing building. No provision would necessarily apply to existing buildings not undergoing improvements.

The Present Risk

Building design generally acknowledges that the life span of a structure extends into the future some number of years. It is to be expected that structures constructed under earlier building codes may at some point become “nonconforming” in relation to present codes due to the nature of the evolution of provisions. In particular, the design of buildings for seismic resistance has historically relied upon new information obtained by direct observation of post earthquake damage. Design force levels and building construction detailing are often more thoroughly addressed as this new understanding of building performance is introduced. This fact suggests that building construction techniques allowed during one period may, upon further review and experience, prove to be less desirable in later periods. Poor performance of certain classes of building construction have become evident to the structural engineering community and require special consideration.

Utah sits within an active seismic area. The deep lake bed and quick rising mountain range contain qualities which produce several seismic features conducive to amplification of earthquake forces. Research in the recent past confirms the growing concern for a potentially significant seismic event along the Wasatch fault. Coupled with this knowledge is the recognition that the present economy and future events within the state have produced a building boom of unprecedented proportion. Existing buildings are being considered for reuse as well as new structures and some means to mitigate known liabilities is required.

The public perception of a need for seismic retrofit of our existing building stock is relatively weak in Utah. This is due in part to the infrequent nature of damaging seismic activity here as well as a lack of understanding of the significant differences between the present built environment and towns and cities of the past which were affected by earthquakes in Utah. A large percentage of the states population now resides close to the major earthquake fault in Utah. Protection of our community resources such as schools, houses, hospitals and emergency facilities before a devastating earthquake occurs is essential.

Specific earthquake hazards affect a range of building types and configurations. Ground shaking, surface fault rupture, and liquefaction generally have very adverse affects on unreinforced masonry buildings and older structures of irregular configuration and inadequate continuity. Landslides,

avalanches and seiches affect all building types both of new and older construction. There exists a need to evaluate these hazards in all buildings but most importantly to address known concerns with older building construction techniques. Presently, the UBC will not allow construction of certain existing building types in recognition of their poor overall performance. The opportunities to provide improvement to these properties are present in Utah at this time.

Existing Buildings Hazards Consideration

The Seismic Committee of SEAU believes that there is a significant need to address how we continue to use and reuse existing buildings. Utah is a major populated western state within seismic zone 3 which does not have an existing building ordinance or provide direction with regard to the reuse of existing buildings. Numerous model programs exist which emphasize the need to update our older building stock in ways appropriate to the particular jurisdiction. While it is not the purpose of this paper to make recommendation of a specific model program, it is apparent that many interested parties will become partners in this decision and the specific concerns of the structural engineering community will need to be stated.

Hazardous buildings are those which endanger the lives of its occupants or those nearby. Collapse of a portion or all of a building, nonstructural damage, and blockages of exit and rescue passageways all constitute reasons to consider rehabilitation of deficient buildings. Hazard mitigation programs evaluate existing building types as well as building configurations, age and quality of construction. By far, the most notable building class deserving of attention is unreinforced masonry structures. Performance of these types of buildings in past earthquakes has been reason for the disallowance of this kind of construction in modern building codes in regions of seismic activity. Other building types such as non-ductile concrete frames, steel or concrete frames with in-fill masonry, tilt-up, post-tensioned and precast concrete structures all present special design considerations under today's building codes due to lessons learned from building performance.

Other considerations in the reuse of existing buildings is the potential for an increase in building occupancy. Risks to greater numbers of persons is an issue which is clearly less desirable. Combined with this factor is the seismic performance variations of different building types. For example, residential buildings generally have better redundancy due to the presence of more interior partitions than commercial structures which tend to have open floor plans. While hazard priorities are largely weighted by life-safety factors, building structural types can play a significant role in overall evaluation.

The Need for Existing Building Regulations in Utah

The earthquake hazard in Utah is not disputable. The ground beneath us literally has determined our exposure to this danger. It is a fact with which we need to apply many ingredients to determine what is an acceptable risk. This has been the purpose of building code regulations from the beginning and presently we accept that new construction needs to follow a defined level of safety.

Older buildings presently fall outside of the envelop of performance expectations of structures constructed under today's building codes. This fact places existing buildings and other infrastructure in a category needful of attention and evaluation. Ignoring, or minimizing this exposure ill-serves the public and the State.

Presently, the many jurisdictions within the state may use a variety of means to address this hazard from existing buildings. Although the hazard is clearly regulated for new construction, the application of rehabilitation standards and guidelines for existing structures is inconsistent, vague and possibly filled with conflicting requirements. Most notably, the mechanisms with which existing buildings are "brought to light" with regard to their hazard is sorely lacking. It is the opinion of the Structural Engineers Association of Utah that regulations for existing buildings are required to define the minimum level of risk acceptable for this building class.

Rehabilitation programs for existing buildings places economic and social costs on a community. Building owners, occupants, and those involved in public safety have duties to help weigh the perceived risk and maintain a level of assurance acceptable to that community. Determining a proper course of action requires evaluation of the variety of impacts which result from studying the problem. Life safety, community resource protection, rehabilitation program impacts, levels of seismic performance, and social benefits are some of the factors used in deciding upon a feasible program for rehabilitation of existing buildings.

Types of Rehabilitation Programs

Communities at risk generally consider a range of programs addressing a variety of concerns including direct costs, indirect impacts and relative effectiveness. Types of programs are often categorized as minimum, voluntary, and mandatory efforts. Minimum programs establish a building inventory basis and provide for some notification and possible mitigation planning. Voluntary efforts continue this program with additional engineering studies which further define potential problems and create public information about such hazards. Mandatory strengthening programs can be prescriptive or analytical. Examples include minimum anchorage requirements, multiple-staged reduced force levels or full or special code compliance programs.

The structural engineering community has an interest in helping define the level of effort needed to address the concern regarding the liabilities of our older existing building stock. Model programs existing in California, Oregon and other western states provide a wealth of information and experience from which to draw. Recent advances in building seismic performance evaluation are available which provide useful tools which relate expected performance objectives with definable building weaknesses.

Consideration of any technical regulations regarding rehabilitation of existing buildings is tempered by the extent of the program desired. While it would be presumptive to assume a level of compliance at this time, it is the opinion of the Structural Engineers Association of Utah that many existing buildings pose some measure of liability in view of the progression of knowledge regarding

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References

1. *Establishing Programs and Priorities for the Seismic Rehabilitation of Buildings. A Handbook.* FEMA 174 / May 1989.
2. *Establishing Programs and Priorities for the Seismic Rehabilitation of Buildings. Supporting Report.* FEMA 173 / May 1989.
3. *Seismic Considerations for Communities at Risk.* FEMA 83 / September 1995.
4. *A Strategic Plan for Earthquake Safety in Utah.* Utah Seismic Safety Commission 1995.
5. *Earthquake Safety in Utah - A Progress Report on Activities for the Period July 1994 - June 1996.* Utah Seismic Safety Commission, Compiled by F. Bruce Funk for the Commission, November 1996.
6. *A Case Study of the Reestablishment of a Utah Seismic Safety Commission.* Elliot Mittler December 6, 1998.
7. *The Effects of Changing the Uniform Building Code Seismic Zone from Zone 3 to Zone 4 on the Wasatch Front of Utah (Brigham City to Nephi) Final Report.* VSP Associates Inc. January, 1993
8. *Incentives and Impediments to Improving the Seismic Performance of Buildings.* EERI Special Report June 1998
9. *Promoting the Adoption and Enforcement of Seismic Building Codes: A Guidebook for State Earthquake and Mitigation Managers.* FEMA 313 January 1998

References and Standards Used in the Evaluation, Risk Assessment and Seismic Retrofit of Existing Buildings.

- ✍ ***Uniform Code for Building Conservation (UCBC)***. Current edition is 1997. Establishes life-safety requirements for all existing buildings that undergo alteration or a change in use. Its provisions offer alternative methods of achieving safety so that the inventory of existing buildings can be preserved.
- ✍ ***Uniform Building Code (UBC)***. Current edition is 1997 although earlier editions provide reduced force levels and simplified assumptions for building seismic design. The most widely adopted model building code in the United States. Presently being combined with other national codes into the International Building Code (IBC) for year 2000.
- ✍ ***ATC 14 Evaluating the Seismic Resistance of Existing Buildings***. Applied Technology Council 1987. Early guideline efforts to provide seismic design methodology to guide engineers in evaluating existing buildings to determine potential earthquake hazards and identify buildings or building components that present unacceptable risk to human lives.
- ✍ ***FEMA 178 NEHRP Handbook for the Seismic Evaluation of Existing Buildings***. Building Seismic Safety Council, 1992. This is a continuation of work beginning in the ATC 14 document. Handbook to provide guidance to engineers involved in seismic evaluation of existing buildings. Deals with life-safety objectives, does not address other objectives of code compliance, damage control, or building performance under special conditions. Two tier analysis.
- ✍ ***FEMA 273 NEHRP Guidelines for the Seismic Rehabilitation of Buildings***. Building Seismic Safety Council, October 1997. The primary purpose of this document is to provide technically sound and nationally acceptable guidelines for the seismic rehabilitation of buildings. Relates seismic performance levels and rehabilitation objectives. Intended for use with voluntary risk reduction efforts as well as adoption into model codes and standards with due considerations.
- ✍ ***FEMA 274 NEHRP Commentary on the Guidelines for the Seismic Rehabilitation of Buildings***. BSSC companion document to FEMA 273 providing further background materials and commentary.
- ✍ ***FEMA 310 Handbook for the Seismic Evaluation of Buildings - A Prestandard***. ASCE January 1998. Springing from the FEMA 178, this document has been made consistent with the component-based approach introduced by FEMA 273. Provides a three tiered process for seismic evaluation of existing buildings.
- ✍ ***ATC40 Seismic Evaluation and Retrofit of Concrete Buildings***. Applied Technology Council, November 1996. Provides an analysis and design methodology and supporting commentary for the evaluation and retrofit of existing state and local government concrete buildings.
- ✍ ***IBC 2000***. International Code Council. The International Building Code is intended to replace the three model codes in the United States with a single uniform code. Pending adoption.

Terms and Definitions

<i>Acceleration</i>	Rate of change of velocity with time
<i>Amplification</i>	A relative increase in ground motion between one type of soil and another or an increase in building response as a result of resonance.
<i>Component</i>	Part of an architectural, structural, electrical or mechanical system.
<i>Configuration</i>	The size, shape, and geometrical proportions of a building.
<i>Connection</i>	A method by which different materials or components are joined together.
<i>Ductility</i>	Property of some materials to distort when subjected to forces while still retaining considerable strength.
<i>Exceedance Probability</i>	The probability that a specified level of ground motion or specified social or economic consequences of earthquakes will be exceeded at a site or in a region during a specified exposure time.
<i>Exposure</i>	The potential economic loss to all or certain subsets of the built environment as a result of one or more earthquakes in an area; this term usually refers to the insured value of structures carried by one or more insurers.
<i>Force</i>	Agency or influence that tries to deform an object or overcome it's resistance to motion.
<i>Frame, Braced</i>	Diagonal members connecting together components of a structural frame in such a way as to resist lateral forces.
<i>Frame System, Building</i>	A structural system with an essentially complete space frame providing support for vertical loads; seismic forces are resisted by shear walls or braced frames.
<i>Frame System, Moment</i>	A space frame in which members and joints are capable of resisting lateral forces by bending as well as along the axis of the members.

<i>Frame, Space</i>	A structural system composed of interconnected members, other than bearing walls, that is capable of supporting vertical loads and that also may provide resistance to seismic forces.
<i>Intensity</i>	The apparent effect that an earthquake produces at a given location.
<i>Irregular</i>	Deviation of a building configuration from a simple symmetrical shape.
<i>Joint</i>	Location of connections between structural or nonstructural members or components.
<i>Liquefaction</i>	The conversion of a solid into a liquid by heat, pressure, or violent motion; sometimes occurs to the ground in earthquakes.
<i>Loss</i>	Any adverse economic or social consequence caused by earthquakes.
<i>Return Period</i>	The time period in years in which the probability is 63 percent that an earthquake of a certain magnitude will occur.
<i>Risk</i>	The possibility of exposure to loss or damage.
<i>Seismic</i>	Of, subject to, or caused by an earthquake or an earth vibration.
<i>Seismic Event</i>	The abrupt release of energy in the earth's lithosphere causing an earth vibration; an earthquake.
<i>Seismic Forces</i>	The actual forces created by earthquake motion; assumed forces prescribed in various provisions that are used in the seismic design of a building and its components.
<i>Seismic Hazard</i>	Any physical phenomenon such as ground shaking or ground failure associated with an earthquake that may produce adverse effects on the built environment and human activities; also the probability of earthquakes of defined magnitude or intensity affecting a given location.
<i>Seismic Risk</i>	The probability that the social or economic consequences of an earthquake will equal or exceed specified values at a site during a specified exposure time; in general, seismic risk is vulnerability multiplied by the seismic hazard.
<i>Seismic Zone</i>	Generally, areas defined on a map within which seismic design requirements are constant.

Vulnerability The degree of loss to a given element at risk, or a set of such elements, resulting from an earthquake of a given intensity or magnitude; expressed in a scale ranging from no damage to total loss; a measure of the probability of damage to a structure or a number of structures.

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