PROCEEDINGS

MID-AMERICA EARTHQUAKE INSURANCE WORKSHOP

NEW RESEARCH NEEDS

Sponsored by:

MID-AMERICA EARTHQUAKE (MAE) CENTER
Headquartered at the University of Illinois
Urbana, Illinois

and

INSTITUTE FOR BUSINESS AND HOME SAFETY
Boston, Massachusetts

Edited by

James E. Beavers
University of Illinois at Urbana-Champaign
Department of Civil and Environmental Engineering
205 N. Mathews Avenue
Urbana, IL 61801

Technical Report MAE Center
NSF Master Contract Number CMS-97-017895 COOP

July, 1999

This workshop was conducted in Memphis, TN on July 28-29, 1999

MID-AMERICA EARTHQUAKE CENTER
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
NEWMARK LABORATORY, URBANA, IL 61801

TABLE OF CONTENTS

EXECUTIVE SUMMARY

On July 28-29, 1999, the Mid-America Earthquake (MAE) Center and the Institute for Business & Home Safety (IBHS) co-hosted their first insurance industry research needs workshop at the Peabody Hotel in Memphis, Tennessee. The title of the workshop was *Mid-America Earthquake Insurance Workshop – New Research Needs*. The workshop was by invitation only and addressed the research needs of insurers of personal lines, commercial lines and reinsurance. Invitations went to the top 50 insurance company groups writing the largest volume of earthquake insurance in Mid-America.

During the first day of the workshop the authors of commissioned papers made presentations and the attendees had an opportunity to comment and question any findings and issues presented. On the second day, the workshop attendees broke up into two working groups, those representing personal lines and those representing commercial lines and reinsurance. Based on the previous day's discussion and overall goal of the workshop, each group was to identify specific earthquake research needs and prioritize them. A facilitator and secretary was assigned to each working group.
10.

During the workshop numerous research needs and issues were identified. Although there was a long list of research needs identified, some very general and some very detailed, it appears the highest priority needs can be identified into two general categories, improved understanding of the seismic hazard and retrofit and performance of structures. In addition, to the general category of research needs, education of the consumer was also identified as a high priority.

In the case of research needs for understanding the seismic hazard, the MAE Center and its partners, like the United States Geological Survey, are devoting significant resources toward solving this problem, with special emphasis on reducing the uncertainty in defining the hazard. However, with respect to understanding the performance of structures there were specific research needs identified the MAE Center has not been addressing. That research includes the performance of residential construction and retrofit solutions. As a result and as discussed in the proceedings, the MAE Center has established and is funding a pilot project on residential construction with representatives of the insurance industry as advisors. It consists of the evaluation of the seismic performance and assessment of the vulnerability of a common class of light-frame construction (wood frame structures with brick veneer) using cyclic static tests of representative component subassemblies and dynamic tests of wall systems. In addition, the Center is in the process of developing a program on the seismic performance and vulnerability of residential construction consisting of unreinforced masonry basements and crawl spaces.

In addition to discussing potential projects for specific residential construction and retrofit solutions, during the personal lines breakout session of the workshop, two recommendations were made related to the formation of an insurance industry seismic research consortium to consider ongoing funding of focused research by the Center. The first was for the IBHS Research Advisory Committee (RAC) to act as a focal point for the insurance industry and the second for the MAE Center to prepare a proposal for the formation of such a consortium. While this was discussed in the closing session no formal recommendations were made at that time. However, the MAE Center and IBHS through the Collaboratory are pursuing the establishment of the consortium.

1. INTRODUCTION

1.1. GENERAL

On July 28-29, 1999, the Mid-America Earthquake (MAE) Center and the Institute for Business & Home Safety (IBHS) co-hosted their first insurance industry research needs workshop at the Peabody Hotel in Memphis, Tennessee. The title of the workshop was: *Mid-America Earthquake Insurance Workshop – New Research Needs*. The workshop was by invitation only and addressed the research needs of insurers of personal lines, commercial lines and reinsurance. Invitations went to the top 50 insurance company groups writing the largest volume of earthquake insurance in Mid-America. The invitees were chief executive officers and their chief loss prevention expert(s). State Insurance Commissioners representing those states where insurance companies were writing the largest volumes were also invited. Although a targeted limit of 50 attendees was originally established, the workshop was in such high demand 65 people actually attended. The workshop agenda is shown in Appendix A.

The workshop was also conducted in compliance with the federal antitrust laws that prohibit agreements that might unreasonably interfere with free and open competition. Thus, at the beginning of the workshop an antitrust announcement was made that all activities of the workshop would comply with the IBHS Antitrust Compliance Statement as shown in Appendix B.

1.2. PLANNING COMMITTEE

An Insurance Workshop Planning Committee (IPC) representing the insurance industry and the MAE Center organized the workshop. The IPC consisted of insurance industry representatives from personal lines, commercial lines and reinsurers. The IPC was co-chaired by James E. Beavers, Deputy Director of the MAE Center and Harvey Ryland, President of IBHS. The other eight members of the IPC were:

Peter Colket
Vice President
American Re-Insurance Company
Princeton, New Jersey

Dennis Fasking
Senior Actuary
Allstate Insurance Group
Northbrook, Illinois

Dale Lauer
Senior Vice President
SAFECO American States
Indianapolis, Indiana

Gary Patterson
Information Officer
Center for Earthquake Research Info
Memphis, Tennessee

Dan Polenda
Vice President
SAFECO American States
Indianapolis, Indiana

Anselm Smolka
Seismoligist
Munich Reinsurance Company
Muenchen, Germany

Teri Spalding
Manager Research
State Farm Fire & Casualty Co.
Bloomington, Illinois

Peggy Young
Administrative Assistant
Central United State
Earthquake Consortium
Memphis, Tennessee

1.3. WORKSHOP GOALS

The IPC met to evaluate the needs of the insurance industry and to determine the structure of the workshop. It was agreed that the purpose of this workshop should be to develop insurance industry research needs to better understand how to estimate future expected losses from earthquakes in Mid-America and to find ways to reduce those expected losses. Based on current understanding of the seismic hazard and expected losses, and the associated uncertainties, the IPC established the following fourteen goals for the workshop:

1. Establish a better understanding as to what really happened during the New Madrid earthquakes of 1811 and 1812;
2. Establish a better understanding of the seismic hazard as it is today;
3. Further evaluate the seismic uncertainty related to the recent Science article (A. Newman et al., Science **284**, 619 (1999)) and the implications to the insurance industry;
4. Summarize what the future holds for risk-based building codes and their implementation and effective enforcement;
5. Discuss cost effective retrofit strategies of existing structures to reduce losses;
6. Evaluate the need for accessing structural details on the built environment;
7. Present some cases studies of success in mitigation and reduction of losses;
8. Establish what role the insurance industry should play in the development of codes and standards for new design and retrofit of existing structures;
9. Evaluate measuring the reduction of existing loss exposure verses cost of mitigation;
10. Evaluate potential for losses from future earthquakes, both direct and indirect;
11. Identify key uncertainties in loss estimation and the difficulties determining sound probable maximum and average annual losses;
12. Establish what the insurance industry should do to help reduce losses;
13. Identify key education needs for the public and the insurance industry; and
14. Identify key research needs for reducing losses through mitigation in order to make earthquake insurance available, affordable and equitable to all parties.

2. BACKGROUND

2.1. MID-AMERICA EARTHQUAKE CENTER

The Mid-America Earthquake (MAE) Center was founded in 1997 by the National Science Foundation (NSF). It is a consortium of seven core institutions. These institutions are Georgia Institute of Technology (Georgia Tech), Massachusetts Institute of Technology (MIT), Saint Louis University, Texas A&M University, University of Illinois, University of Memphis and Washington University in St. Louis. The headquarters of the Center resides within the Department of Civil and Environmental Engineering at the University of Illinois.

As stated in its 1999 annual report to the NSF, the Center's vision is *Research combined with education can help to reduce significant economic losses that are expected with a future earthquake in Mid-America.* The mission of the Center is to *Develop and disseminate new information on the physical, technical, economic and social attributes of the earthquake problem that are unique to the central and eastern United States*. To accomplish the Center's vision and mission, research projects have been coordinated within three primary thrust areas: network vulnerability, facility retrofit, and hazard evaluation. These thrust areas conform to the strategy of the National Earthquake Hazards Reduction Program (NEHRP). NEHRP was initiated in 1977 by the U.S. Congress to help minimize the effects of earthquakes. An act passed in April of 1999 by the U.S. House of Representatives re-authorized the NEHRP for the next two fiscal years.

The Center is a cross- and multi-disciplinary center where seismologists, geophysicists and geologists at Saint Louis University and the University of Memphis combine their talents with geotechnical engineering researchers at Georgia Tech and the University of Illinois. Structural engineering researchers at Texas A&M University, Georgia Tech, Washington University, MIT and the University of Illinois research response and behavior of the built environment that is translated to the impact on communities and national networks in accordance with assistance of researchers in the social sciences, economics and urban planning at Texas A&M University, MIT, Georgia Tech, Washington University and the University of Illinois.

One of the Center's main functions is to establish and maintain an Industry/Users Collaboration, Outreach, and Technology Transfer (ICOTT) Program. The ICOTT Program has the following specific missions: (1) Complement and support the education thrust area by involving partners in all education activities of the Center; (2) Complement and support the research thrust areas by bringing partners to the research program for planning, project selection, participation and implementation; (3) Develop and foster intellectual ties with engineers and scientists from industry and government to facilitate a seamless two-way flow of ideas, knowledge and advances; and (4) Develop a sustainable funded ICOTT Program within the Center involving business, industry and government.

2.2. INSTITUTE FOR BUSINESS AND HOME SAFETY

The Institute for Business and Home Safety (IBHS) was founded by the property casualty insurance industry and only insurers and reinsurers can be members. Other disciplines contribute to the Institute's work as associate members. Each year natural disasters take a huge toll in deaths and injuries, property damage and economic loss. An even greater tragedy is the fact that much of this devastation can be reduced through existing mitigation techniques and greater public awareness of them. IBHS' vision is: *The planning and construction of the Nation's built environment will incorporate structural and nonstructural loss reduction initiatives, enabling the public and business communities to live and work in an atmosphere of personal safety, financial security and social stability*. The mission is to *reduce deaths, injuries, property damage, economic losses and human suffering caused by natural disasters*. The member insurance companies of IBHS envision a nation in which its citizens insist on building the safest and most damage resistant structures possible to protect themselves. To enable its vision to become a reality, IBHS' members have directed it to fulfill this critically important mission.

To implement the mission, IBHS is guided by its Strategic Plan that has the following key result areas: (1) public outreach, (2) community land use, (3) new building construction, (4) retrofit of existing structures and (5) information management. Public outreach will ensure that all stakeholders (policy and decision makers, the insurance industry, businesses, emergency managers, the media, planners, lenders, designers, builders, and the general public) are aware of natural hazards, understand the associated risks, know how to reduce these risks, and desire to reduce the level of risk to which they are exposed. Community land use will promote locating structures out of high risk areas that are subject to floods and wildland fires, and where feasible, earthquakes and windstorms. Construction of new buildings will ensure that all new structures will be designed, engineered and constructed using up-to-date techniques and materials that mitigate natural disaster risks. The Institute would also like to encourage research and development of effective mitigation materials and techniques that are more affordable to the owner than currently available. Measuring the vulnerability of existing structures will promote the strengthening of structures to mitigate natural disaster losses through a process called "retrofitting." Information management will provide for the collection, analysis, and dissemination of natural disaster loss and mitigation information.

2.3. A COLLABORATORY

Previous studies of the potential losses from a repeat of the 1811-1812 New Madrid earthquakes have shown that the total losses could be as high as $200 billion, exceeding the insurance industry's capacity to handle them. The probability of such an event occurring in the next 25 years is on the order of 2%. Thus, the residents of Mid-America live in an earthquake zone where very large earthquakes are infrequent but for which the consequences are very devastating. This is a decidedly different situation compared to those who live in more seismically active California. However, a more likely earthquake, the repeat of the Charleston, Missouri, earthquake of 1895 having a magnitude of 6.8 has about a 50% probability of occurring in the next 25 years. It has been shown by recent loss estimation studies that this earthquake could result in total losses between $4 and $10 billion, although one loss number projected has been as high as $60 billion (see commissioned paper No. 6). Thus, even in a moderate earthquake in Mid-America, the potential for large losses is significant. Finally, it is believed by many that a moderate earthquake is over due.

American Re[1] provided information on the insurance industry's portfolio of earthquake insurance premiums in the portion of Mid-America that surrounds the New Madrid Seismic Zone. The premium value is well over $100 million. In addition, research showed that depending on insurance company, state, personal verses commercial lines, percent deductible and seismic zone the premium rate may range from 0.01 percent to 0.2 percent of the insured liability. It was also found that the percentage of homeowners who have purchased earthquake insurance ranged from as low as 1 percent to as high as 90 percent, depending on seismic zone. Assuming the average premium rate for homeowners is 0.025 percent and half of the above premium is for homeowner insurance, the earthquake insured liability becomes $200 billion. Assuming the percentage of homeowners who have earthquake insurance is 15 percent, the potential earthquake insured liability market is $1.3 trillion. As the public becomes educated as to the risk of self-insurance, they will seek to transfer that risk to the insurance industry. Thus, the insurance industry portfolio will continue to grow and be at risk. As a result, it is also in the best interest of the insurance industry to take research steps to reduce future earthquake losses, including fire following earthquake.

The MAE Center and IBHS are both deeply interested in minimizing the future losses of earthquakes and have initiated a research collaboratory toward taking the steps required to reduce earthquake losses in Mid-America. The workshop and these proceedings represent the first products of this collaboration.

3. WORKSHOP ACTIVITIES

3.1. PROCESS

The process for conducting this workshop was set up to get the maximum input from the insurance industry on what are its unmet earthquake research needs by addressing the fourteen goals established by the IPC. To set the stage using the identified goals, thirteen discussion papers were commissioned as shown in Table 1. Seven of these papers were on the state of some of the research and knowledge of earthquakes and earthquake engineering prepared by members of the engineering and seismology community and primarily addressed issues related to the first seven goals. Six of the papers were on insurance issues prepared by members of the insurance community primarily related to the last seven goals. The commissioned papers were distributed to all attendees two weeks prior to the workshop and are included in their entirety in Appendix C. In addition to the commissioned papers, Mr. Bill Thomas, Senior Vice President and Chief Operations Officer at SAFECO and an IBHS Board Member, made the dinner presentation to the attendees that is also included in Appendix C.

[1] Communications with Peter K. Colket, Vice President, American Re, May 15, 1999.

During the first day of the workshop the authors of the commission papers made presentations on their papers and the attendees had an opportunity to comment and question any of the findings and issues presented. On the second day, the workshop attendees broke up into two working groups, those representing personal lines and those representing commercial lines and reinsurance. Based on the previous day's discussion and overall goal of the workshop, each group was to identify specific earthquake research needs and prioritize them. A facilitator and secretary was assigned to each working group.

Table 1.0 Insurance Workshop Commissioned Papers

1. The MAE Center Approach to Understanding Earthquakes in Mid-America, *Daniel P. Abrams, Mid-America Earthquake Center*
2. What Really Happened in 1811 and 1812 and Will It Happen Again?, *Arch Johnston, Center for Earthquake Research and Information*
3. Will New Maps Lower or Raise the Hazard?, Robert Herrmann, *A. Akinci and R. Ortega, Saint Louis University*
4. Seismic Design Requirements of the Future, *Gerald H. Jones, Multihazard Mitigation Council of the National Institute of Building Sciences*
5. Future Issues of Seismic Retrofit, *J.D. Dolan, Virginia Polytechnic Institute*
6. The Insurance Industry's Role in Building Codes and Loss Mitigation Advocacy, *David Unnewehr, American Insurance Association*
7. Building Code Effectiveness Grading Schedule for Seismic Design, *Ralph Dorio, Insurance Services Office*
8. The Need for Insurance Support of Seismic Retrofit, *Paul Devlin, Institute for Business and Home Safety*
9. What do the Uncertainties do to the Insurance Industry?, *Anselm Smolka, Munich Reinsurance Company*
10. Reducing Seismic Losses for a Large Commercial Line—The Anheuser-Busch Approach, *Michael Griffin and Alan Scott, EQE International*
11. The Need for Seismic Retrofit—Unreinforced Masonry Basements, *Stephen M. Marlin, USAA*
12. Mid-America at Risk: Insurance and Natural Disaster, *Walter W. Hays, American Society of Civil Engineers*

13. Earthquake Benefit/Cost Study – Can Mitigation as a Public Value Be Accomplished Without it?, *Dennis Fasking*, *Allstate Insurance*

Following the working group sessions the workshop closed with a plenary session with the two facilitators presenting the results of the respective working groups. As discussed earlier, the workshop agenda is shown in Appendix A. The participant list is shown in Appendix D.

3.2. SUMMARY OF COMMISSIONED PAPERS

3.2.1. Introduction. To provide the reader with the key points of each commissioned paper provided in Appendix C and to link the commissioned papers together the following sections represent an abridged summary of each paper, linking them as appropriate to each other and the fourteen goals.

3.2.2. The MAE Center Approach to Understanding Earthquakes in Mid-America. As discussed above, the MAE Center's vision statement is: *Research combined with education can help to reduce significant economic losses that are expected with a future earthquake in Mid-America*. Since its inception in October of 1997, the central focus of the Center has been to reduce earthquake losses through research and education. The better the public and the private sectors are informed on their earthquake risk in the eastern and central United States the more they can protect their investments in construction and business.

Academic research in the past has been typically done through individual investigator grants. Ties with industry were not necessarily strong because links with universities were through individual faculty members who each had to develop their own alliances. This interaction can be increased substantially through the coordinated structure of the MAE Center. The Center's research thrust areas of network vulnerability, facility retrofit and hazard evaluation are directed largely through extensive involvement of potential end users of the research. The consensus opinion that is formulated through these programs on future research directions and interpretations of research results is uncommon in a traditional academic setting. The focus of these programs on development of practical products that will reduce losses in future earthquakes is also unique and attractive to industry practitioners. This same analogy can be used successfully by the Center, IBHS and the insurance industry to reduce losses from future earthquakes. There is a need for the research community to understand that the personal lines portion of the insured portfolios of the larger insurance companies are comprised of large numbers of relatively homogeneous structures. The costs of data collection and analyses for such structures would need to be addressed since personal lines and small commercial insurers would not have the same ability to pass along those costs to the property owner as part of their insurance premium as is possible for large commercial risks.

Based on the Center's four programs areas, the three research thrust areas and the ICOTT Program area, and a fifth program, an Education Program, it is clear that the Center's work supports the achievement of all fourteen goals. However, the MAE Center's specific goal for this forum is to help refine the research interests of the insurance industry, define a common agenda for reducing the severe effects of earthquakes on Mid-America, and establish an action plan that will exploit these complementary interests in the most effective manner possible.

3.2.3. What Really Happened in 1811 and 1812 and Will It Happen Again? As noted above, one third of the MAE Center's research is on evaluating the hazard. The New Madrid Seismic Zone (NMSZ) is the most active seismic area east of the Rocky Mountains and in Mid-America. Scientist and engineers have been studying the NMSZ for the past 25 years, yet much is yet to be learned. However, to understand what is in store for the future, one must understand what has happened in the past. That is why this paper was commissioned for the workshop, i.e., to further enhance the achievement of Goals 1, 2 and 3.

As discussed in the paper, a sequence of powerful earthquakes struck the mid-Mississippi River Valley, central United States, in the winter of 1811 and 1812. The sequence included at least six (possibly nine) events of estimated moment magnitude $\mathbf{M} = 7$ and two of $\mathbf{M} \simeq 8$. The last two probably exceeded the size of any continental western U.S. earthquake, even the 1906 San Francisco earthquake. No fewer than 18 of these events were felt on the Atlantic seaboard or in Washington D.C., at least 1000 km east, which implies moment magnitude $\mathbf{M} \gtrsim 6.0\text{-}6.5$. Over time, this earthquake series took the name of the small riverboat town New Madrid, which lay at the heart of the epicentral zone and which in 1811 was the largest settlement on the river between the Ohio River and Natchez. The name has proven apt, for New Madrid by happenstance marks the intersection of three of the six fault segments currently illuminated by microseismicity and believed to be rupture planes of the principal 1811-1812 earthquakes.

The question today remains to be: Just how active is the NMSZ? At first glance, the Mississippi River and its surrounding expanse of nearly level flood plains would seem to be evidence of a region that is tectonically and seismically dead. However, seismological, geodetic, and most paleoseismological data suggest a surprisingly short recurrence interval for major earthquakes in the NMSZ, on the order of a thousand years or less, with deformation rates comparable to those at plate margins.

The simplest interpretation of paleoliquefaction results is that, in addition to the 1811-1812 events, there were at least two strong ground-shaking earthquakes in the past 2000 years. Evidence for one of these, which likely occurred between A.D. 800 and A.D. 1000, is clear at Reelfoot scarp and north of New Madrid. There is also evidence for liquefaction of this age near Marked Tree, Arkansas to the south, and at several sites near Blytheville, Arkansas. Evidence for a liquefaction-producing event between A.D. 1400 and A.D. 1600 is found in the Blytheville area and may be present in the Reelfoot area and at the northernmost sites. Moreover, there is evidence, presently inconclusive, of liquefaction ages both younger than (~ A.D. 1600) and older than (prior to A.D. 600) these two age ranges. Thus, 1811 was not the first time in the Holocene that the New Madrid region experienced strong ground shaking. The data all are consistent with as few as two and as many as four earthquakes in the 2,000 years prior to 1811. These data strongly suggest that the New Madrid Seismic Zone is not tectonically and seismically dead and the earthquakes are indeed in the future. It is just a matter of when.

Since the NMSZ is still seismically active from all of the smaller earthquake activity and because of what has happened in the past, today's seismic hazard maps must reflect this activity. This knowledge represents the foundation of the NEHRP Maps discussed below.

3.2.4. Will New Maps Lower or Raise the Hazard? The question that is always asked when a new generation of mapping occurs is will the new findings result in the hazard going up or will it be reduced? Since a portion of the MAE Center's Hazard Evaluation Program represents the development of enhanced mapping concepts, this question was posed for this workshop. The results of this paper and the associated work enhance Goals 1, 2 and 3, in particular, Goal 2.

The estimation of earthquake ground motion has advanced significantly since the inception of the NEHRP two decades ago. Better instrumentation, accumulated recordings of ground motion, better understanding of earthquake physics and the expected recurrence rates of earthquakes have permitted improved estimates of expected ground motion in terms of peak acceleration, velocity or response spectral ordinates. The confidence in these estimates permits detailed mathematical modeling of structural response and inference of damage thresholds. The improved estimates are also accompanied by an awareness of what is not known because of the lack of data.

Recently, the United States Geological Survey (USGS) developed the 1996 Seismic Hazard Maps. These maps represent state-of-the-art understanding of what the seismic hazard is on a national scale in the United States. Shortly thereafter, the 1996 maps were transformed to be used in building codes through Project 97and became known as the 1997 NEHRP Maps. Project 97 was a joint effort between the USGS and the Building Seismic Safety Council to establish just how the NEHRP Maps would be used in the building code process. The maps are probabilistic in nature and are now being used as the basis for the seismic hazard in the *International Building Code (IBC)* and the *NEHRP Guidelines for the Seismic Rehabilitation of Buildings, (FEMA 273)*. The IBC and FEMA 273 are discussed below in Section 3.2.5. Because of the differences between previous seismic hazard maps and the new 1997 NEHRP maps representing the central United States, the MAE Center is examining the assumptions that went into the current maps and are doing research to advance those maps.

The 1997 NEHRP maps define the seismic hazard throughout the central and eastern United States at what is called the B/C Boundary. The B/C Boundary is the boundary between rock and a very stiff soil. They do not represent the seismic hazard at the surface where the overburden soil has to be considered. The MAE Center probabilistic seismic hazard maps are meant to carefully evolve from the 1997 NEHRP maps and represent the seismic hazard at the surface. All steps will be documented so that deviations from the 1997 maps are justified. The efforts of the MAE Center are directed toward reducing uncertainty and to eliminate the use of soil factors currently used in defining the seismic hazard at the surface. In addition the MAE Center efforts complement the internal and external USGS research programs in the NMSZ. This task is not taken lightly, since the numbers resulting from these computations have economic significance. It is likely that in some locations better scientific understanding of the seismic hazard will cause it to go up and in other locations cause it to go down. The MAE Center is aware of the needs of the insurance community. Certainly cooperative efforts are required.

In addition to the MAE Center advancing the 1997 NEHRP maps, during 2000 the USGS has begun a national process of updating those maps. The results of the MAE Center's research will be folded into that process. Thus, future MAE Center seismic hazard maps will reflect the advances made during the development of the 2000 NEHRP Maps.

3.2.5. Seismic Design Requirements of the Future. As noted above, great progress has been, and is being, made in understanding the seismic hazard in Mid-America. It is also true that great progress has been made for the engineering and building industry toward better design of the built environment for earthquakes. In fact, in reference to the title of this commissioned paper, the future of seismic design requirements is here and the resulting discussion achieves Goal 4 of the workshop.

With the recent publication of the IBC this past January 2000, cities and other jurisdictions in the United States now have a single model building code available for adoption for the first time. In addition, the Federal Emergency Management Agency (FEMA) recently published the *NEHRP Guidelines for the Seismic Rehabilitation of Buildings, (FEMA 273)*. A selection for varying performance objectives for the rehabilitation of existing buildings is now possible. The *NEHRP Guidelines* offer the owner, designer and the public an informed choice for the extent of rehabilitation, recognizing that triggers in existing codes frequently do not require rehabilitation.

Design professionals have, for years, advocated greater use of "performance codes" in contrast to the more common "prescriptive codes". The new IBC still has many of the prescriptive requirements from the previous codes. However, to move the new code in the direction of a truly performance code, like the *NEHRP Guidelines*, the International Code Council (ICC) has created a Building Performance Code (BPC) Committee and a Fire Performance Code Committee to develop a "Performance Code" which can be used as an alternate to the IBC. The BPC Committee has published the Intent, Scope and Performance structure for developing performance provisions. They have developed structure and linkage between topics and objective standards and have accepted numerous objectives, functional statements, and performance requirements. These items have been published in the *Guidelines for Use of ICC Performance Code*. The BPC Committee is basing its proposed Seismic Provisions on *Vision 2000* developed by the Structural Engineers Association of California, and future designers will be expected to: (1) Specify Performance Requirements, (2) Define Earthquake Hazard Design Levels, (3) Define Performance Levels and (4) Define Seismic Hazard Exposure Group.

The principles of performance based codes have been recognized as very desirable for centuries, but the execution of such design and construction has been measured by prescriptive or "deemed to comply" regulations. However, today it is clear that performance codes are here to stay and will be used extensively in the future. The insurance industry is interested in matching the performance codes to the risk of loss in more of a risk-based performance code. It should take careful note of the potential consequences and work cooperatively to solve the problems that surely will be encountered as performance codes become norm rather than the exception.

3.2.6. Future Issues of Seismic Retrofit. Section 3.2.5 briefly mentions the *NEHRP Guidelines* but primarily discusses the future of the IBC. Indeed, while recent building codes (last 15 – 20 years) have been revised extensively in an effort to address performance problems associated with seismic resistance, they have primarily focused on new building construction rather than existing construction. However, the huge volume of existing construction also should be retrofitted when possible to improve the life-safety of the structure and reduce damage associated with seismic events. The cost of loss of life, repair and expenses associated with loss of use can be astronomical when compared to the cost associated with retrofitting buildings to improve performance. While it is politically unattainable to require the retrofit of all buildings with significant seismic risk, many buildings should be considered for retrofit from a pure economic standpoint, while others should be considered from a societal or safety concerns. Thus, this commissioned paper was chosen to address seismic retrofit and to provide some information related to Goals 5 and 6.

The *NEHRP Guidelines* are for the retrofit or rehabilitation of existing buildings. In addition FEMA has continued to publish the *Recommended Provisions for Seismic Regulations for New buildings and Other Structures (FEMA 302)*. While there are dissimilarities between FEMA 273 and FEMA 302, both documents provide guidance in designing buildings to resist earthquakes. The *Provisions* have continually updated since the mid 1980's and have begun to mature. The *Provisions* were used as the foundation for the seismic provisions of the IBC, while the *Guidelines* are still in their infancy. As mentioned above in Section 3.2.5, the future of seismic design is here. However, the adoption and enforcement of the IBC for new buildings and the use of the *Guidelines* for rehabilitation of, or retrofitting, existing buildings would be more widely applied if incentives rather than mandates were made for their use. Retrofitting buildings can reduce the risk of damage or collapse of buildings, and while quantifying the change in risk might be difficult, <u>insurance</u> is one of the potential motivation tools.

3.2.7. The Insurance Industry's Role in Building Codes and Loss Mitigation Advocacy. While it is stated above that *the future of seismic design is here*, the implementation of state-of-the-art seismic design in local codes is nonexistent in many parts of the United States. This paper was commissioned to discuss the insurance industry's role for the improvement of local building codes and it discusses many of the issues related to Goal 8.

Passage and rigorous enforcement of comprehensive statewide building codes has significant potential for reducing both catastrophe and more routine property losses. However, currently, only 23 states in the U.S. mandate a model code or state code to cover all buildings and occupancy classifications. Twenty states do not have state-mandated building codes covering the entire state, but generally have codes governing building activity in larger cities. An additional eight states mandate building codes for commercial and institutional property, but exempt one and two-family dwellings which are typically much more vulnerable to wind, hail, and other sources of loss. A number of states in hurricane-prone areas including Texas, Louisiana and several other Gulf coast states and earthquake-prone areas such as Missouri still have no widespread or statewide building code requirements. Missouri, in fact, has a legislative prohibition on the ability of all but its largest jurisdictions to enact and enforce a building code.

The American Insurance Association (AIA) supports enactment of statewide comprehensive building codes in all states. State-wide codes have the advantage of uniformity and clarity that help to promote training and better understanding of code provisions by developers, builders, sub-contractors, building materials manufacturers, and building officials.

These attributes ultimately will lead to better compliance and enforcement than currently exists. Comprehensive and uniform codes often help lower costs and increase efficiency for builders who can deal with one document rather than a confusing patchwork of regulations from one jurisdiction to the next.

In addition to building codes, AIA supports land use planning as an effective loss mitigation tool that can help people, insurers, local communities, and disaster agencies by limiting building in very hazardous areas subject to repeat losses, or ensuring that areas with higher risks are subject to higher standards of protection. AIA also supports a rate structure that encourages homeowners to undertake steps to mitigate losses. State insurance department should allow insurers to use higher deductibles for customers that do not take steps to mitigate losses. The insurance industry should also seek ways of involving the mortgage lending industry in strategies to encourage mitigation such as lower cost loans for homeowners who undertake retrofitting or those building or purchasing homes with superior construction with respect to life safety and property loss reduction.

AIA and industry coalitions should continue to look for opportunities for increasing the number of states with statewide risk-based building codes and for improving existing codes and enforcement.

3.2.8. Building Code Effectiveness Grading Schedule for Seismic Design. As discussed above in Section 3.2.7, there is a lack of enforcement and uniformity of building code adoption throughout the United States. Similar to the previous commissioned paper, this paper also discusses issues related to Goal 8.

Following Hurricane Andrew, the Insurance Services Office (ISO) developed the Building Code Effectiveness Grading Schedule (BCEGS) to rate the building codes in effect in a particular community as well as how the community supports and enforces those codes. It was based upon a program designed by IBHS's predecessor organization, the Insurance Institute for Property Loss Reduction, and turned over to ISO for implementation. The BCEGS program was developed in conjunction with the three national model code groups (now the members of the ICC), IBHS and information from 1,500 building code officials. Pilot testing was done in 154 communities. The result is a rating and underwriting tool based on a building code classification developed for each community. The BCEGS concept is similar to that used for public protection classification, which classifies municipal fire suppression capabilities and has been used by insurers for decades.

Under the ISO rating system the following credits are given to communities (the specific rating criteria can be found in the commissioned paper in Appendix C):

- buildings constructed under code-enforcement departments with classifications 1 through 3 (exemplary code enforcement) are eligible for the maximum credit in the approved schedule
- buildings constructed under code-enforcement departments with classifications 4 through 7 are eligible for an intermediate credit in the approved schedule
- buildings constructed under departments with classifications 8 and 9 are eligible for the minimum credit in the approved schedule

- buildings constructed under departments with a classification of 10 (minimal code enforcement) are not eligible for credits

ISO designates communities that fail to meet minimal BCEGS requirements, i.e., a classification of 10 as Class 99. A Class 99 community basically means the community has no codes or code enforcement.

The results of the grading system were compared between the Western Seismic States region and the New Madrid States region. In the Western Seismic States region, forty-one percent of the people live in Class 3 rated communities and zero percent live in Class 99 rated communities. However, in the New Madrid region, only 2 percent of the people live in Class 3 rated communities and a startling 34% of the people live in Class 99 communities. As an example, Missouri, a state that has the Missouri Seismic Safety Commission, actually forbids 93 of its 114 counties from enacting any building code for any reason, as briefly mentioned above in Section 3.2.8. This situation clearly demonstrates that the public is at a much higher risk in the central and eastern United States from potential building failures than in the west. As a result, all participants of this workshop must work together get adoption and enforcement of codes in all communities.

3.2.9. The Need for Insurance Support of Seismic Retrofit. This commissioned paper discusses issues of seismic retrofit related to Goals 5, 6, 8, 9 and 10. The NMSZ includes the states of Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri and Tennessee. As discussed in Section 3.2.8, 34% of the people in live in Class 99 communities. Three of these seven states do not require their communities to have any building code for any purpose. Two others have a statewide code but do not require it for houses. The following is a thumbnail status of statewide codes in these seven states:

Arkansas: a non-current (1991) statewide code covers all occupancies.

Illinois: no statewide code.

Indiana: a statewide code does not cover one and two-family dwellings.

Kentucky: a statewide code covers all occupancies.

Mississippi: no statewide code.

Missouri: no statewide code.

Tennessee: a statewide code does not cover one and two-family dwellings.

Of this group, only Kentucky has an up-to-date code covering all occupancies. Missouri is at the other extreme. As noted above, Missouri actually forbids 93 of its 114 counties from enacting any building code for any reason. And even where codes are in place, they are not always current.

When an earthquake hits, the property losses can be enormous. The Northridge earthquake (1994) erased over 25 years of earthquake insurance premiums in California. The common estimate of the insured losses from Northridge is $12.5 billion. The IBHS paid-loss database, which collects actual payments by insurers over time, indicates a total insured loss exceeding $15 billion. Even this figure pales in comparison to projected total losses from two other, more likely, events:

- Magnitude 6 in the New Madrid zone: about $60 billion
- Magnitude 7.8 in San Francisco: about $200 billion

In addition, it has been projected that the total losses from a repeat of one of the 1811-1812 New Madrid earthquakes of magnitude 8.0 would be on the order of $200 billion.

Retrofit is the only way to get at the massive inventory of vulnerable structures. Retrofitting a home or office for seismic resistance is fairly easy and inexpensive for nonstructural items like bookshelves, computers, water heaters and the like. But it is often expensive and complex for the structural features of a building. As a result, property owners are generally not inclined to undertake it. The only way to succeed is to reduce the cost and complexity of retrofitting, as IBHS has demonstrated with residential roof sheathing in wind-prone areas, and give property owners some incentive to act. This can be done by identify new potential cost-effective retrofit techniques and conduct the research to verify the benefits of these techniques.

3.2.10. What do the Uncertainties do to the Insurance Industry? This paper addresses issues related to Goals 10, 11 and 12. The question posed in the title can most easily shown by a graph shown in the paper (Appendix C). The graph presents the results of two loss-estimation models offered for the region by different modeling firms. The models differ to an acceptable degree in the low probability range of about 0.001 per annum. For more rare and more frequent events the difference becomes larger to such an extent that the average annual loss calculated by these models varies by a factor of three. This is hardly a satisfactory situation, but it clearly demonstrates the problems we are faced with in view of the uncertainties about earthquakes in the Mid-America.

The uncertainties are caused by at least two factors, hazard uncertainty and vulnerability uncertainty. Hazard uncertainties consist of understanding: (1) active earthquake sources and earthquake source zones, (2) maximum magnitude and seismicity rates, (3) attenuation of ground motion, (4) source depths, (5) stress drop, and (6) deep soil effects. Vulnerability uncertainties consist of understanding: (1) construction style, (2) building regulations, (3) loss experience, and (4) the role of lower intensities.

Enormous progress has been made in elucidating Mid-America seismicity and risk in recent years. However, open issues remain which introduce considerable uncertainties to risk assessment:

- Activity of sources other than the 1811/12 source
- Typical rupture modes (complex vs. simple events)
- GPS measurements against other observations
- The role of „deep“ events

- The role of stress drop
- The influence of deep soil deposits
- The frequency and degree of the damaging effect of low loss events and intensities.

There is a wide scope for the scientific community and a great demand from the insurance industry for future research aimed at clarifying these issues and at reducing the concomitant uncertainties.

3.2.11. Reducing Seismic Losses for a Large Commercial Line—The Anheuser-Busch Approach. This paper presents a case example of mitigation to reduce losses and achieves Goal 7 of the workshop. EQE International has summarized a number of success stories as a result of its work in retrofitting existing structures in California. The most notable was its work on the Anheuser-Busch Brewery in Van Nuys, California, approximately 25 km northwest of downtown Los Angeles in the general epicentral area of the January 17, 1994, Northridge Earthquake.

The Anheuser-Bush Brewery was originally constructed in 1954 with a major addition in 1981. The Brewery is a large industrial complex producing 12 million barrels of beer per annum. Some of the items that were of seismic resistance concern were the brewhouse, stockhouses, power plants, and fuel oil and firewater storage tanks. The estimated cost to replace the Brewery was $1.3 billion.

The retrofit project was conducted in three phases. The first phase involved EQE meeting with the client, reviewing structural and equipment drawings; obtaining seismology, geology, and soils information; performing on-site reviews of the facilities; and determining the earthquake risk to the brewery in terms of the probable maximum loss (PML) if the brewery were subjected to a future earthquake. The estimated PML on the brewhouse and stockhouses ranged from 30 to 50% and were designated as high to very high risk for collapse and business interruption. The PML on the power plants ranged from 25 to 35% and were designated as moderate to high risk for damage/safety and business interruption. The PML for the fuel oil and firewater storage tanks was at 50% considered very high risk for fire following earthquake.

The second phase of the project involved decision making by the client and EQE acting on those decisions. The client established a desired level of acceptable risk at 15% for damage with considerable importance placed on business interruption. As a result, EQE was asked to perform detailed engineering analyses of potential strengthening options, cost/benefit analysis of those options and resulting conclusions and recommendations.

The third phase of the project involved the actual project implementation of the most cost-effective strengthening option. Final design was performed, development of construction drawings and specifications as well as a construction schedule. Construction on the retrofit project began in 1989 and was completed in1993 at a cost of $17 million represent only 1.3% of the total facility replacement cost of the facility. The $17 million also included planned major facility process upgrades in addition to the seismic strengthening measures constructed.

Following the Northridge earthquake, the damage of the Brewery was evaluated as light ($35 million) with damage mainly to the nonretrofitted sections. The retrofit designs achieved better performance than anticipated and initial operations resumed in four days and full production of the Brewery occurred within seven days. Although the damage ($35 million) was twice the $17 million in retrofit costs, it was estimated that the retrofit resulted in a total avoided cost of over $750 million dollars in losses, or a 4200% payoff on investment in less than one year. As a result of this experience, Anheuser-Bush has also completed a similar seismic retrofit project at its St. Louis brewery.

3.2.12. The Need for Seismic Retrofit—Unreinforced Masonry Basements. It is important to note that the insurance industry in this country has limited experience with earthquakes. Most of the events in recent years have been on the West Coast, California, Oregon and Washington. When we compare the West Coast to the Midwest, we anticipate some significant differences in soil types, ground water tables and building designs. Typically, masonry construction does not perform well during an earthquake. Moreover, we have very little experience with basements as the foundation system. Most of our earthquake experience has been with slab on grade or pier and beam foundation systems, since basements are not typically used on the seismicly active West Coast. Thus, this commissioned paper actually discusses one issue related to Goal 6, i.e., what are the specific structural details required to mitigate damage to unreinforced masonry basements.

To date, the insurance industry has been unable to estimate the amount of existing building stock exhibiting unreinforced masonry basements. It is possible that there is a significant inventory, especially with older building stock throughout the New Madrid area. When a major event occurs, we anticipate these structures to suffer catastrophic failure. The failure of the foundation system will result in the failure of the building with extensive collapse of structures. These structural failures may well result in a higher frequency of injury and death to the occupants, particularly if the event occurs during evenings or weekends

The insurance industry believes there is a need for seismic retrofit for unreinforced masonry basements. Today, nothing exists to help a homeowner determine if the basement is unreinforced and, if it is, how the homeowner should retrofit the basement. Basement retrofit may be complex and is viewed today as probably being too costly for a homeowner to justify. What is needed is research and laboratory testing of designs to effectively retrofit unreinforced masonry basements. The retrofit needs to be cost-effective, yet efficient, in reducing the probability of catastrophic structural failure. Saying that “nothing exists” or that “it’s too complicated” is not the answer.

3.2.13. Mid-America at Risk: Insurance and Natural Disaster. Insurance against natural hazards is a business involving: accountants, actuaries, salespersons, brokers, claims adjusters, managers, and executives; other property casualty insurance companies; reinsurance companies; and state regulators. Insurance is a product providing value to the insured at the cost of a premium. In theory, insurers can offer protection to the insured against any risk that they can identify, as long as they can obtain reliable information about the frequency and magnitude of potential losses, and they have the freedom to set realistic premiums. Thus, this commissioned paper addresses all fourteen goals from a global perspective.

Every year, the Earth's atmospheric, geologic, and hydrologic systems generate 100,000 thunderstorms, 10,000 floods, thousands of landslides, over 100 earthquakes large enough to be damaging, hundreds of wildfires, scores of windstorms (hurricanes, cyclones, typhoons and tornadoes), and dozens of volcanic eruptions, tsunamis, and droughts. Fortunately, extreme events (e. g., 500-year floods, category 5 hurricanes, magnitude 8 or greater earthquakes, large-volume explosive volcanoes, large-volume landslides; tsunamis affecting the entire Pacific rim, wide spread, long-duration wildfires, and long duration droughts) and combinations of extreme events (e.g., earthquakes - tsunamis - landslides - floods -fires; or hurricanes - floods - landslides - coastal erosion) are rare occurrences.

The bad news of the 20th century is that insured losses and overall economic losses from natural hazards are increasing with time. Natural hazards do not respect geographic or political boundaries, seasons, schedules, time of day, a business' balance sheet, or a community's state-of-preparedness, losses are increasing due to rapid growth of population and the increasing vulnerability of cities and megacities having large concentrations of people living and working in disaster-prone regions and buildings surrounded by fragile infrastructure, neither of which were planned, located, designed, and constructed to be resilient to floods, severe storms, earthquakes, landslides, volcanoes, wildfires, tsunamis, and droughts.

Natural disasters represent policy failures. The financial sector, business, industry, governmental and non-governmental organizations, and the citizens and policy makers (i.e., mayors, city managers, city councils can work together as partners, as for example in the Central United States, to make natural disaster reduction a public value.

3.2.14. Earthquake Benefit/Cost Study-Can Mitigation as a Public Value Be Accomplished Without it? This commissioned paper gets down to specific discussion of benefit/cost studies and discusses issues primarily related to Goals 10, 12, 13 and 14.

Stakeholders such as insurance companies will most likely require that Benefit/Cost studies be completed in order to begin to provide a widespread offering of financial incentives to their customers. These studies could be accomplished if a process for collecting the necessary detailed structural information for specific structures could be devised. Then using this information along with the existing catastrophe models to do the analyses would enable stakeholders such as the insurance companies to gather the information they are likely to need to financially justify the offering of mitigation incentives.

The MAE Center could potentially improve the Benefit/Cost analyses that would serve to encourage insurance companies or other stakeholders to provide mitigation incentives as follows: 1.) by improving the models through focused research that reduces the uncertainty inherent in the catastrophe models in use today; and 2.) by promoting ways for gathering more construction information on each individual structure so that a more specific estimate of the expected losses for a specific structure could be determined instead of using default or average structural characteristics to do the estimating for the "as is built" condition and for certain "what-if?" mitigation alternatives. But if these actions by the MAE Center are not done, it will not necessarily preclude individual companies from completing their own Benefit/Cost analyses and then offer mitigation incentives based on analysis tools already available to them.

4. BREAKOUT SESSION RESULTS

4.1. INTRODUCTION

As discussed in Section 3.1, on the second day, the workshop attendees broke up into two working groups, those representing personal lines and those representing commercial lines and reinsurance. The purpose of each group was to identify specific earthquake research needs and prioritize them. Each working group was assigned a facilitator and secretary.

4.2. PERSONAL LINES

4.2.1. Key Discussion Points. Dennis Fasking from Allstate Insurance was assigned as the facilitator of the Personal Lines Group and Gary Patterson from the Center for Earthquake Research and Information was assigned as the secretary. Both were members of the Planning Committee. Dennis opened the Personal Lines Breakout Session (PLBS) with a summary of the IPC purpose and goals of the workshop. Following Dennis' opening remarks key discussion points captured by Gary Patterson during the breakout session are provided below. In addition, following each key discussion point, the MAE Center staff have responded (in italics) by identifying existing activities and, or, new initiatives that could close out the discussion point.

- The MAE Center has a strong presence's in the NMSZ; however, there is also a need for more research and emphasis on other seismic zones, for example, the Wabash Valley, East Tennessee and Charleston, South Carolina.

  The MAE Center long-range plan is to expand its Hazards Evaluation Program to these other areas. At the most recent review of the Hazards Evaluation Program, specific discussion occurred about which areas should the Center move into next.

- As presented in Section 3.2.12, the MAE Center should establish a research program on developing retrofit measures for unreinforced masonry basements.

  The MAE Center is in the process of developing a plan to begin conducting research on cost-effective retrofit measures for unreinforced masonry basements.

- Similar to what was discussed in Sections 3.2.5 and 3.2.6, means of retrofitting of residential structures, including unreinforced masonry basements is needed. Residential structures can be retrofitted structurally and nonstructurally. The insurance industry and the public need to know the cost effectiveness of retrofitting structurally to maintain life safety and to reduce losses. What can be done to establish cost-effective retrofit guidelines?

Retrofit guidelines have been developed for seismic areas of the West Coast. The MAE Center now has a project to take West Coast retrofit guidelines and modify them to be applicable to Mid-America. This project is being funded jointly by State Farm Insurance Companies and the USGS. In addition, the MAE Center has created a pilot project to study new cost-effective retrofit techniques with the members of the insurance industry as advisors.

- Although, not specifically identified as a goal of this workshop, the issue of how the MAE Center could assist the insurance industry in a post-earthquake response mode was discussed.

  The MAE Center has a project (SG-1) that will provide state of the art communications between seismic stations and emergency managers. This is a service that claims adjusters and insurance hazard coordinators could subscribe. Using elements of this project a forum was recently held (April 2000) on the kick-off of the Rapid Earthquake Information System (REIS) for the New Madrid Seismic Zone. The REIS is sponsored by the Center for Earthquake Research and Information at the University of Memphis and the MAE Center. The REIS is designed to provide information to scientists, government and private institutions, and the public within sufficient time to allow effective response to a damaging earthquake.

- There needs to be a consumer education/awareness program about earthquake hazards in Mid-America and earthquake insurance. As noted above in Section 2.3 there is at least a $20 billion portfolio insurance market in seven states. It is believed that many consumers do not know that their homeowner policy does not cover earthquake insurance.

  As noted above, the MAE Center is has an Education Program to educate the public on the seismic hazard in Mid-America; however, it only deals with the hazard and mitigation of the risk, i.e., retrofit techniques, both structural and non-structural. The MAE Center is willing to work with the insurance industry to educate the public on the issues of earthquake insurance, it availability and affordability.

- The insurance industry needs to have concrete mitigation solutions to specific housing types and soil conditions so it can properly educate the public. Thus, the insurance industry, as a whole, should fund research on residential-single family dwellings that is focused on specific mitigation measures. A consortium of insurers might be formed to fund such research.

  As discussed above, the MAE Center has created and funded a pilot project to study new cost-effective retrofit techniques with the members of the insurance industry as advisors. The advisors of this represent IBHS' Research Advisory Committee, State Farm Insurance Companies and Allstate Insurance. While this project is moving *forward, the MAE Center and IBHS are evaluating the establishment of a consortium of insurers that will fund research to develop cost-effective mitigation for single family dwellings.*

- Research on cost-effective mitigation techniques is needed for chimneys; unreinforced-masonry homes; soft structures, for example, homes with bedrooms above garages; connectivity between brick and stone veneer and wood framing, crawl spaces, conventional foundations and unreinforced basements. In addition, the insurance industry needs to understand the relative performance of homes of different types of construction and age.

  Again, the MAE Center has funded the pilot project mentioned above. However, this project can only address one small element of those listed above. The project is looking at the connectivity between brick veneer and wood framing. This project is funded by the Center at $60,000 and is a one-year project. However, this project is only a beginning. The MAE Center is now evaluating the establishment of a project on unreinforced basements.

4.2.2. Prioritization of Insurance Industry Needs. Following the breakout session discussion and the identification of the above "key discussion points," the group developed a listing of thirteen prioritized "general needs" that would be of significant benefit to the personal lines insurance industry. The needs are a mixture of research, planning and education. The prioritized list is as follows:

- Understanding the earthquake exposure in Southern Illinois.
- Understanding the earthquake exposure in Mid-America.
- Development of cost-effective retrofit techniques for residential structures to include unreinforced masonry basements, crawl spaces, chimneys, brick and stone veneer, garages, carports, etc.
- Enhance consumer awareness of the risk and the corresponding expectations of earthquake damage and how that damage can be mitigated through retrofit.
- Enhance consumer awareness on retrofit techniques, including which retrofit techniques are most cost-effective as a function of home construction, i.e., a prioritization of retrofit techniques.
- Planning for post event communication with the public.
- Understand and develop improved geotechnical database to reduce the uncertainty in seismic hazard, both pre- and post-event.
- Need to develop effective communication models to establish stronger outreach relationships to the public.
- Establish a rapid earthquake information system for post-earthquake response and recovery.
- Must establish a global sharing of information.
- Should establish a pilot city to study the issues of existing structures and the resulting needs.
- Should conduct research on the performance of structures and use that knowledge to identify retrofit needs.

- Should establish a broadbased consortium of the insurance industry, including loss estimation modelers.

Based on this list of prioritized needs, it appears that the top priority issue resulting from this breakout session is to better understand the seismic hazard. This is in direct line with the MAE Center research program in that one of the three research thrust areas is the Hazard Evaluation Program. The next area of research needs appears to be the development of cost-effective retrofit techniques of residential structures. The third area of needs appears to be the education of the consumer.

4.2.3. Recommendations. In concluding their breakout session, the personal lines group made two general recommendations. The first recommendation was that the Research and Advisory Committee of IBHS should serve as a focus group for future activities related to new research to support the insurance industry, including the formation of a broad based consortium identified as a key discussion point. The Response and Recovery Committee of IBHS could be a focus group for future activities related to data and communications during the response and recovery phase of future earthquake events with communications.

The second recommendation was that the MAE Center should put together a proposal with time frames and costs and identify deliverables to establish a consortium of insurance companies to fund earthquake research. It was suggested that IBHS should serve as the medium for the formation as noted in the first recommendation.

4.3. COMMERCIAL LINES AND REINSURANCE

Dale, Dan, Peter and Anselm during changes of computers my detail files on this session where lost. However, Dave Unnewehr and I have collaborated our hand written notes and memories as to what we did during this session. If you have anything else you would like to add please do so. Our recommendations section is not specific like the personal lines group, but my recollection is that this group wanted everything done at the same time. I remember asking the question, if we only have $40,000 what would you do first and the group really didn't want to make a choice. I remember Dan or Dale finally making a choice(which may have been research on tilt-up construction) although Dave and I do not remember the specific. However, after that choice was made, my recollection is that the group as a whole wanted it to go as I have discussed in the recommendation section (4.3.3) discussed below for the group.

4.3.1. Key Discussion Points. David Unnewehr from the American Insurance Association was assigned as the facilitator of the Commercial Lines and Reinsurance Group and Jim Beavers from the MAE Center was assigned as the secretary. Similar to the personal lines group, the commercial lines and reinsurance group also came up with some key discussion points, many the same or similar to the personal lines group. These discussion points are listed below with comment on related MAE Center activities.

- The reinsurance industry and the insurance industry as a whole needs to have a better understanding, alone with the scientific community, on the seismicity rates and event probabilities of earthquakes in Mid-America. In addition, a better understanding of the effects of an earthquake at distance from the epicenter is needed. Does the relationship change based on the size of earthquakes? What about focusing effects? These issues are all critical to pricing of insurance and Probable Maximum Loss considerations.

This issue is similar to one raised by the personal lines group. Again, one of the major research thrust areas of the MAE Center is the Hazards Evaluation Program. The issues mention here are part of the program.

- There is uncertainty in the loss estimation models used by modelers that result in significant spreads in the data for commercial exposure to losses, including fire following earthquake. The insurance industry needs to have a better understanding if the newer models are reducing this disparity.

  The MAE Center has been working with modelers and will continue to provide research results to the modelers so loss estimation models can be improved.

- What should business continuation and recovery plans include to mitigate the loss to business property, revenues and human life?

  The MAE Center's vision for its research products is that they will be implemented and as a result of that implementation, losses will be reduced in future earthquakes. If funded by the insurance industry, the Center could conduct research on the effectiveness of various elements of business plans to improve the reduction of losses from future earthquakes.

- The insurance industry needs to understand the current state of commercial construction in Mid-America, i.e., will structures built to today's codes reduce damage and injury compared to those structures built previously.

  It is generally believed that new construction, especially those jurisdictions using the latest seismic code requirements, will result in reduced damage and losses. This is one reason why the MAE Center has focused one of its research thrust areas on existing buildings. In future earthquakes, the losses will come from the existing built environment and without the development of cost-effective retrofit technologies, the risks will not be reduced.

- The insurance industry needs to better understand how tilt-up construction is being built and how much seismic resistance such construction has in Mid-America.

  The MAE Center is beginning to complete its research thrust area on Essential Facilities and move into the area of Industrial Facilities. The MAE Center may begin addressing this issue at that time. However, specific issues should be brought to the attention of the Center.

- The insurance industry should develop a Building Code Effectiveness Rating Schedule for earthquake design, similar to that for wind.

  The MAE Center is willing to work with the insurance industry to assist in the development of such a rating schedule.

- The insurance industry needs to better understand which businesses will be more impacted as a result of an earthquake, e.g., loss of life from employees and customers, and be able to tell those businesses what they can do to mitigate the risk.

  As noted above, the MAE Center will be creating a new thrust area on Industrial Facilities. While the field of Industrial Facilities does not capture all businesses, some of what is learned will be applicable to other business.

4.3.2. Prioritization of Research. The commercial lines and reinsurance group did not develop a prioritized list of activities. In fact, the group thought that many of their concerns needed to be addressed in parallel. However, they did list a similar set of research needs.

- Understanding of the seismic hazard in Mid-America needs significant improvement.
- Better definition of soil types throughout Mid-America needs to be developed and mapped.
- There needs to be an inventory of the building types housing commercial lines.
- There needs to be an inventory of commercial lines classifying them as to occupation by number of employees and members of the public. This is important from a life safety perspective.
- Research needs to be conducted on the performance of tilt-up construction in Mid-America during earthquakes.
- Research needs to be conducted on the performance of high-rise construction at great distances during a New Madrid type event.

4.3.3. Recommendations

The commercial lines and reinsurance group took more of a global approach to the Mid-America earthquake problem and seemed to feel that all of the issues addressed during the workshop were important and extremely intertwined. As a result, no specific recommendations were related to the research needs identified in Section 4.3.2. The overriding theme of the group seemed to place a high priority on research on all fronts and to let the MAE Center determine the priority and specific recommendations based on further study and future research funds.

4.4. OTHER AREAS OF DISCUSSION

In preparation for the workshop research and/or improved knowledge needs were identified by the insurance industry that were not fully captured in the notes of the breakout sessions. From a claims department perspective, the insurance industry needs to know what specific components in a structure are likely to be damaged or destroyed for a given size earthquake and what can be done to retrofit those components. This issue is actually covered by research on cost-effective retrofit technologies discussed above. As this research progresses for various type structures specific components and retrofit strategies will be identified.

Loss of power as it relates to food spoilage and fire ignitions following earthquakes were also identified as issues. Contents and how they respond to earthquakes was raised as an issue, although contents are usually considered as part of the non-structural inventory discussed above. Land use and the enforcement of building codes was also mention as an issue. The enforcement of building codes was a significant discussion during the workshop and at least four commissioned papers addressed the subject. However, very little was mentioned about land use planning and land use planning did not come up in the breakout sessions as a major item. Perhaps this is due to the completeness and effectiveness of work by IBHS's Land Use Planning Committee Land use planning will reduce losses in future earthquakes and could be an area of future research for the MAE Center.

Translating damage estimates into insured claims losses for physical repairs and replacement of structures, for loss of contents, and for an insured's coverage for additional living expenses were also addressed as issues and would need to be addressed in any measurement of the relative effectiveness of structural strengthening actions.

5. CONCLUSIONS

The *Mid-America Earthquake Insurance Workshop – New Research Needs* was a success. It represents the first time IBHS, the insurance industry and the MAE Center had sat down to discuss common issues and needs. It allowed IBHS and the insurance industry to better articulate their earthquake research needs and provided the MAE Center with potential direction for the future.

As discussed above in Section 4, numerous research needs and issues were identified. Although there is a long list, some very general and some very detailed, it appears the highest priority research needs can be identified into two general categories, improved understanding of the seismic hazard and retrofit and performance of structures. In addition, to the general category of research needs, education of the consumer was also identified as a high priority.

In the case of research needs for understanding the seismic hazard, the MAE Center and its partners, like the United States Geological Survey, are devoting significant resources toward solving this problem, with special emphasis on reducing the uncertainty. However, with respect to understanding the performance of structures, there were specific research needs identified that the MAE Center has not been addressing. That research being the performance and retrofit of residential construction. As a result and as noted above, the MAE Center has established and is funding a pilot project on residential construction with representatives of the insurance industry as advisors. The research project consists of the evaluation of the seismic performance and assessment of the vulnerability of a common class of light-frame construction (wood frame structures with brick veneer) using cyclic static tests of representative component subassemblies and dynamic tests of wall systems. In addition, the Center is in the process of developing a program on the seismic performance and vulnerability of residential construction consisting of unreinforced masonry basements and crawl spaces.

As discussed in the personal lines breakout session two recommendations were made related to the formation of an insurance industry seismic research consortium. The first was for the Research Advisory Committee of IBHS to act as a focal point of the insurance industry and the second for MAE Center to prepare a proposal for the formation of such a consortium. While this was discussed in the closing session no formal recommendations were made at that time. However, the MAE Center and IBHS through the Collaboratory are pursuing the establishment of the consortium.

APPENDIX A

WORKSHOP AGENDA

MID-AMERICA EARTHQUAKE INSURANCE WORKSHOP

NEW RESEARCH NEEDS

PEABODY HOTEL
MEMPHIS, TENNESSEE

JULY 28 AND 29, 1999

PROGRAM AGENDA

Tuesday, July 27

5:00- 7:00 pm Early Arrival Sign-In/Package Pick-Up (Forest Room)
6:00- 7:00 pm Hosted Reception (IBHS) (Forest Room)
7:00 pm Planning Committee Dinner (Brinkley Room)

Wednesday, July 28

7:00 am Sign-In/Package Pick-Up and Continental Breakfast (Foyer Venetian Room)

8:00 am Welcome, Introductions, Purpose - Jim Beavers/Harvey Ryland (Venetian Room)

8:10 am Anti-Trust Announcement - Anti-Trust Monitor

8:15 am **Mid-America Earthquake Center and Earthquake Insurance Issues** - Dan Abrams, Mid-America Earthquake Center, University of Illinois.

8:45 am **Panel 1**- Moderator, Harvey Ryland, IBHS
Seismic Design Requirements of the Future, Gerry Jones, Retired Building Code Official and Chairman, Multi-Hazard Mitigation Council, National Institute of Building Sciences.
The Insurance Industries Role in Building Codes, Dave Unnewehr, American Insurance Association
Building Code Effectiveness Grading Schedule for Seismic Design, Ralph Dorio, Insurance Services Office

10:15 am Break

10:40 am **Panel 2 -** Moderator, Dennis Fasking, Allstate Insurance
Future Issues of Seismic Retrofit, Dan Dolan, Virginia Tech
The Need for Insurance Industry Support of Seismic Retrofit, Paul Devlin, IBHS
Retrofit Experience with Personal Lines, Steve Marlin, USAA

12:10 pm Lunch (Forest Room)

1:30 pm **Panel 3 -** Moderator, Jim Beavers, Mid-America Earthquake Center, University of Illinois

What Really Happened in 1811 and 1812 and Will It Happen Again? Arch Johnston, Mid-America Earthquake Center Hazards Evaluation Program Coordinator and University of Memphis

Will New Maps Lower or Raise the Hazard? Bob Herrmann, Mid-America Earthquake Center and Saint Louis University

What Do the Uncertainties Do To the Insurance Industry? Anselm Smolka, Munich Reinsurance.

3:00 pm Break

3:30 pm **Reducing Seismic Losses for a Large Commercial Line -- The Anheuser-Busch Approach**, Michael Griffin, EQE International.

4:00 pm **Mid-America at Risk--What You and Insurance Can Do.** Walter Hays, American Society of Civil Engineers.

4:50 pm Breakout Session Instructions

5:00 pm Close

6:00 pm Hosted Reception (IBHS) (Forest Room)

7:00 pm Dinner (Forest Room)
Speaker: **Mr. Bill Thomas, Sr. VP, Personal Lines Underwriting, SAFECO**

Thursday, July 29

7:00 am Continental Breakfast (Foyer Venetian Room)

8:00 am **Earthquake Benefit/Cost Study -- Can Mitigation As A Public Value Be Achieved Without It?** Dennis Fasking, Allstate Insurance (Venetian Room)

8:30 am Breakout Sessions -- 1) Commercial Lines (Venetian Room) and 2) Personal Lines (Louis XVI Room)

10:30 am Break

11:00 am Plenary Session -- Prioritizing Insurance Research Needs (Venetian Room)

12:30 pm Close of Workshop

APPENDIX B

IBHS ANTITRUST COMPLIANCE STATEMENT

Antitrust Compliance Statement

The Institute for Business and Home Safety strives to conduct all its activities in compliance with the antitrust laws. The federal antitrust laws prohibit all agreements, which unreasonably interfere with free and open competition. The McCarran-Ferguson Act allows the insurance industry to operate under a limited federal antitrust exemption, subject to insurance regulation by the states. With the exception of acts of boycotts, coercion and intimidation, which are matters saved for federal antitrust enforcement, the states provide for the regulation of insurance and enforcement sanctions. State regulators are administering the insurance industry in areas such as rates, unfair trade practices, claims practices, solvency, as well as others.

The extent of the limited exemption is not well defined and antitrust concerns are serious matters, particularly in the area of pricing. Price fixing and conspiracies to set prices are, per se, violations of the federal antitrust laws. Other than that, application of the antitrust laws to a particular set of circumstances can be ambiguous. Therefore, this meeting will err on the side of caution to avoid any chance that you as participants may be subject to prison and/or treble damages. Most importantly, remember that discussions in violation of antitrust laws are no less punishable if they take place outside of this meeting room.

The following subjects will give rise to antitrust problems. We will not be discussing them as part of any joint activities.

- *Raising, lowering or stabilizing actual rates*
- *Restricting the availability of insurance*
- *Allocating markets, territories or insureds*
- *Boycotting in any form*
- *Actual or future prices*
- *Profit levels*
- *Credit terms*
- *Premium costs*
- *Quoting or not quoting certain classes or types of risks*

If any company participating in this meeting were to transact its business with respect to any one of the above topics in a manner similar to a participant who is a competitor, the discussion of that topic at this meeting may be offered as evidence of the existence of a conspiracy in violation of the antitrust laws.

APPENDIX C

COMMISSIONED PAPERS

The MAE Center Approach to Understanding Earthquakes in Mid-America

Daniel P. Abrams

Director, Mid-America Earthquake Center
University of Illinois at Urbana-Champaign

Abstract

This introductory paper provides an overview of the goals and programs of the Mid-America Earthquake Center and serves as a preface to this workshop on insuring against earthquake losses. A brief description of the vision, mission and goals of the Mid-America Earthquake Center is followed by a discussion on how the Center will reduce earthquake losses through research and education. Examples are given that demonstrate how the insurance industry can work with the Center in developing more accurate risk assessment tools through the sharing of researchers and facilities and by forming a cooperative research group.

Introduction

Since its inception in October of 1997, the central focus of the Mid-America Earthquake Center has been to reduce earthquake losses through research and education. The better the public and the private sectors are informed on their earthquake risk in the eastern and central United States the more they can protect their investments in construction and business.

Attention to the Mid-America earthquake problem is slowly developing among practicing engineers, architects, planners, developers, and industry and community leaders. The insurance industry has become aware of the significant loss potential of an infrequent, but high consequence event like the New Madrid earthquake (approximately $200 billion) and requires more precise estimates of the risk. Communities are concerned about their loss potential (the FEMA Project Impact program has designated disaster resistant communities in each state) and are starting to take measures to mitigate potential effects of multiple hazards including earthquakes. State and federal transportation departments acknowledge the vulnerability of national highway, waterway, railway and airway networks to an earthquake in the central United States. Though investments in seismic retrofit are not routine in Mid-America, benefit-cost studies have shown seismic rehabilitation to be prudent for system-wide communities or nation-wide networks when indirect business losses and public health and safety issues are considered.

If research of the MAE Center over a ten-year period can reduce losses from a repeat of the New Madrid earthquake by as little as 10%, the savings in expected losses will be approximately a thousand times the research investment. Moreover, mitigation practices based on large, but infrequent earthquakes can help to reduce losses for the more frequent, lesser ground motions that are quite likely to occur even over the short life of an engineering research center. A repeat of an event such as the 1898 Cairo-Charleston earthquake has over a 50% probability of occurrence in the next fifty years. The reduction in earthquake losses through research and education for even a moderate earthquake can exceed the investment by many times.

Reducing Losses through Research and Education

Vision, Mission and Goals of the MAE Center

The principal long-term goal for the Mid-America Earthquake Center is to reduce potential losses resulting from future earthquakes through improved evaluation of seismic hazards and development of cost-effective retrofit strategies. This vision for earthquake engineering practice will be obtained in part if the research, education and outreach programs of the MAE Center make a difference for the better in reducing economic losses and insuring the health and safety of the public. To accomplish this long-term goal, the research thrust areas of the Center incorporates the discovery process in a holistic and integrated fashion with emphasis on the systems aspects of earthquake hazard mitigation.

The mission of the MAE Center is to develop and disseminate new information on the physical, technical, economic and social attributes of the earthquake problem that are unique to the eastern and central United States. To accomplish this mission, research projects are coordinated within three primary thrust areas: network vulnerability, facility retrofit, and hazard evaluation. These coordinated research programs aim specifically at systematic seismic risk reduction plans. Programs and subsequent projects are organized in a complementary, cross- and multi-disciplinary, manner to identify and evaluate possible seismic hazards, and to develop loss reduction strategies for the built environment.

Nearly all of the engineering research of the MAE Center is focused on mitigating the effects of future earthquakes. However, other issues such as response, recovery and post-earthquake reconstruction are within the MAE Center's domain of interest, since the Center is viewed as the regional center for studies of earthquakes that occur east of the Rocky Mountains.

As adopted from the strategic plan of the National Earthquake Loss Reduction Program, the four major goals of the MAE Center are:

1. Improve engineering of the built environment.
2. Improve data for construction standards and codes.
3. Continue development of seismic hazards and risk assessment tools.
4. Develop an understanding of societal impacts and responses related to earthquake hazard mitigation.

Under each one of these goals, a series of targets and intended products are listed ranging from development of improved analytical techniques and seismic risk assessment methodologies to identification of social, economic and political factors that facilitate and hinder the adoption and implementation of seismic safety measures. A complete listing of these goals, targets and products can be found on the MAE Center website (http://mae.ce.uiuc.edu).

Thrust Area Research

Formulation of the Center strategic plan was founded on the creation of parallel engineering research programs, or thrust areas, on facilities and networks. The objective of the facilities programs is to develop cost-effective retrofit strategies for building structures across a community, whereas the objective of the networks programs is to reduce earthquake losses to national systems through selective retrofit of critical components. Two parallel programs were envisioned in the Center proposal so that a third program on hazard evaluation could feed into both programs. The overall schedule of these three programs is shown in Figure 1 for an anticipated ten-year life of the Center.

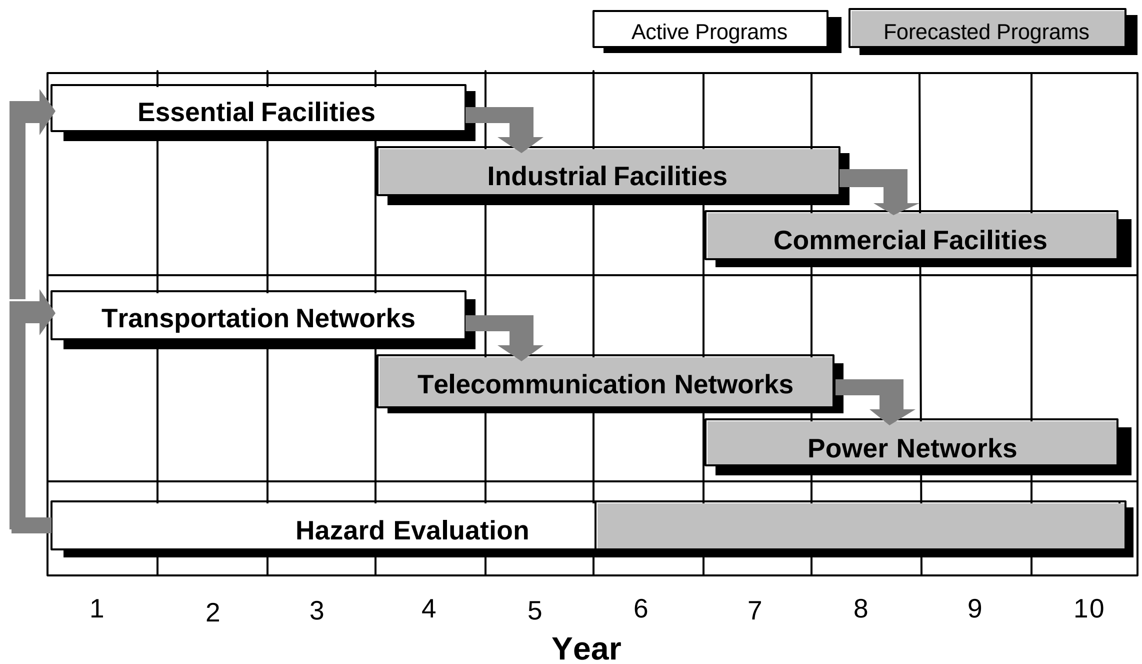


Figure 1 Thrust Area Research Programs

The first facilities program is directed at those building structures that must remain operable immediately following an earthquake to ensure public health and safety. Retrofit of these essential facilities are generally dependent on community-wide concerns for access in response and recovery operations rather than on simply recovering the repair costs for the amount of direct damage. These systems include firehouses, police stations, school buildings if used for emergency shelters, hospitals and clinics. The structural system is usually quite simple with a wall or frame structure of a few stories. Technology developed on how these building systems respond to earthquakes will be transferred to subsequent programs on industrial and commercial buildings. Retrofit strategies for these building types will be based more on economical concerns for building owners rather than on public health and safety across a community. Since the structural systems for industrial and commercial buildings may entail different materials and construction types than the low-rise essential facilities, progression of the facilities thrust area shall broaden to a variety of building types. The coordinator of the Essential Facilities Program is Professor Barry Goodno at Georgia Institute of Technology.

The networks track is starting with a coordinated research program on national transportation systems. This program is intentionally conceived with a high leverage potential by including the four basic types of transportation networks of Mid-America (highways, railways, waterways and airways). The nodes and links of transportation networks represent the coarsest mesh of networks and are thus the easiest to identify. These systems are studied initially also because of the interests in transportation engineering at the core institutions (Illinois, Georgia Tech, Washington University, MIT and Texas A&M) and the ongoing federal and state programs on infrastructure renewal of transportation structures. Subsequent networks programs are envisioned on telecommunication and power systems that will benefit from the network vulnerability models developed in the first phase on transportation. The coordinator of the

Transportation Networks Program is Professor Tim Stark at the University of Illinois at Urbana-Champaign.

The Hazard Evaluation Program is intended to provide basic information on expected ground motions to the other two programs. The nature of research in seismology and geophysics tends to be extended over a long period of time because of the monitoring of instrumentation networks over several years. Unlike engineering research where projects of a two or three year duration can be sequenced and phased, hazard evaluation projects tend to be more continuous and provide information intermittently as the ground is shifting. The coordinator of the Hazards Evaluation Program is Professor Arch Johnston at the University of Memphis.

A complete listing, and a two-page task statement, of all research projects in these three thrust areas can be found on the MAE Center website (http://mae.ce.uiuc.edu).

Products and Deliverables from MAE Center Research

One aspect of a center approach, unlike that of traditional single investigator projects, is that a strong emphasis can be placed on development of tangible implementation products. Categories of research projects grouped by discipline (seismology, geotechnical engineering, structural engineering and social-economic) are shown around the perimeter of the diagram shown in Figure 2. Projects in each of these categories comprise the coordinated research thrust areas described earlier.

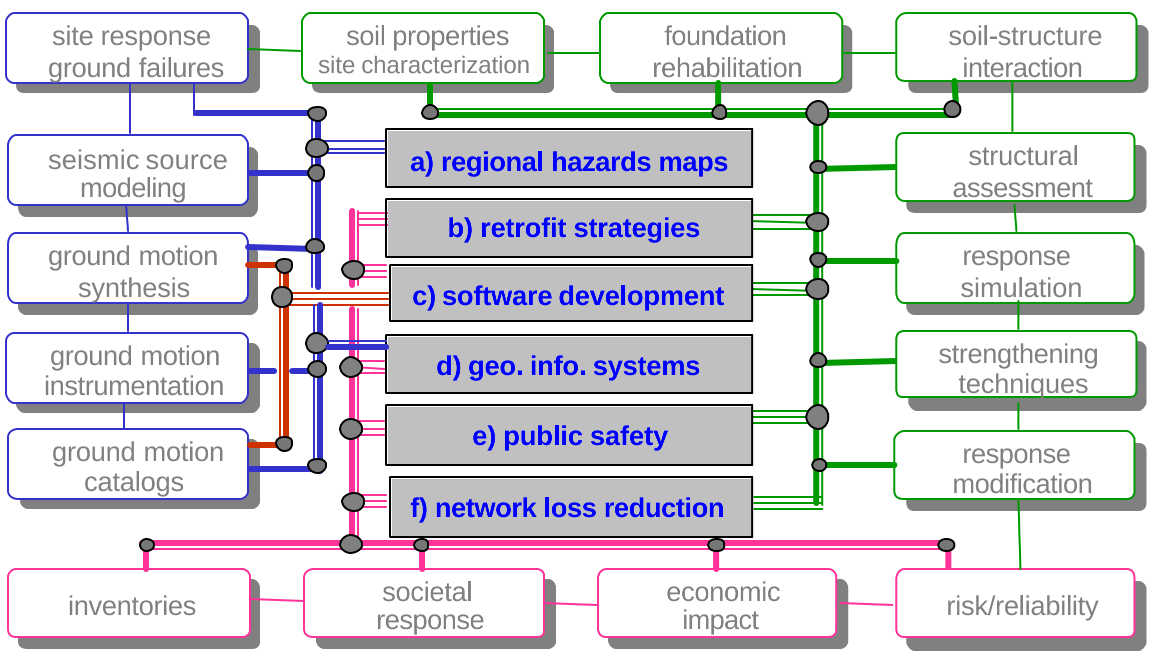


Figure 2 Flow of Research Outcomes to Systems-Level Implementation Products

Figure 2 depicts the flow of research outcomes to system-level products that can be implemented to achieve earthquake loss reduction. Each of these groups of implementation products will help achieve one or more of the four fundamental goals of the center. Regional hazard maps will transfer technology from seismological research to engineering practitioners. Retrofit strategies developed through engineering research will benefit communities as well as national transportation networks. Software developed within the MAE Center will encapsulate much of the fundamental research for easy retrieval by practitioners. Inventory data for construction across communities and national networks will be translated to practice in GIS formats for easy dissemination. The ultimate deliverable of the essential facilities program will be an enhanced level of public safety. The ultimate deliverable of the transportation networks program will be reduced economic losses across the national transportation system.

Education

Education programs are needed to transfer knowledge developed through Center research and thus reduce losses through more effective engineering practices. However, educating only engineers on only Center research is an overly narrow approach. Educational programs can play a much more direct role by instructing people of all ages and occupations to the possible earthquake hazard in Mid-America and mitigation methods. This broader focus on education will indeed make a much larger impact on reducing losses in future earthquakes than just appealing to the engineering community with products that the MAE Center has produced.

The education program of the MAE Center consists of a series of projects that serve as vehicles to deliver knowledge and information to the end user. The recipients of the MAE Center education projects are inclusive of all age groups, technical backgrounds and occupations and range from students in primary and secondary schools to undergraduates and graduates, practitioners and the general public. The mission of the Center's education program is to transfer knowledge gained from new discoveries, existing technology and collateral associations to these recipient groups. Mechanisms for transfer of knowledge to the recipients are the projects that are conceived and funded through the Center's education program. These mechanisms, or vehicles for knowledge flow, can be grouped in four basic categories: (a) innovative educational technologies, (b) teaching modules, (c) cross-disciplinary forums, and (d) instructional materials. Education projects are distributed across the core institutions and are coordinated by Professor Phil Gould at Washington University. Descriptions of each education project are available on the website as well.

How the MAE Center can Interact with the Insurance Industry

In the past, nearly all academic research was done through individual investigator grants. Ties with industry were not necessarily strong because links with universities were through individual faculty members who each had to develop their own alliances with industry. This interaction can be increased substantially through the coordinated structure of a research center. The MAE

Center research thrust areas are directed largely through extensive involvement of potential end users of the research. The consensus opinion that is formulated through these programs on future research directions and interpretations of research results is uncommon in a traditional academic setting. The focus of these programs on development of practical products that will reduce losses in future earthquakes is also unique and attractive to industry practitioners. The few examples, which follow, help to demonstrate these concepts relative to the interests of the insurance industry.

Assessing Earthquake Risk

As described earlier, the three coordinated research thrust areas of the MAE Center provide the research integration to help improve on the accuracy of evaluating future earthquake hazards and on the effectiveness of prescribing retrofit strategies. A few definable products of these programs will be a new set of hazard maps for Mid America, new methods for retrofitting existing buildings and bridges, improved loss assessment methodologies for communities and national transportation networks, and mitigation action plans for community leaders to follow.

The technology and skills developed by these research teams will be transferable to address the needs of a specific group such as the insurance industry. For example, with the existing Center expertise and staffing, associated projects can be envisioned that will provide modeling tools for specifying earthquake risk at a particular location. Not only can this technology improve on probability estimates for earthquakes of a particular intensity at a specific site, estimates can also be given as to the level of damage for a particular type of construction in its existing and retrofitted state. With future development of risk modeling tools, damage probabilities for buildings, bridges and other structures can be obtained by specifying their location coordinates. Data generated from these models can then be used to assess the risk and assign premium and deductible rates. Data can also be used to evaluate reduction in rates for retrofitted structures which can serve to motivate building owners to take precautionary measures.

Access to Center Research Facilities

The research facilities of the MAE Center core institutions are linked for convenient access by industry. Existing structural engineering laboratories at the University of Illinois, Georgia Tech, Washington University, and Texas A&M have facilities for the static and dynamic testing of structural components and assemblages. Large-scale replicas of buildings as tall as thirty-five feet can be tested at the new Georgia Tech structures laboratory. Reduced-scale models of civil engineering structures can be tested dynamically on the University of Illinois earthquake simulator.

With the cooperation provided by core institutions at the University of Memphis and Saint Louis University, a network of instrumentation is in place monitoring ground motions in the New Madrid seismic zone. In addition, GIS stations are in place to monitor movements across the New Madrid fault.

The MAE Center has access to shared testing facilities at the US Army Construction Engineering Research Laboratory (CERL) in Champaign, Illinois, and the US Army Waterways Experiment Station (WES) in Jackson, Mississippi. The Building and Fire Research Laboratory at the National Institute of Standards in Gaithersburg, Maryland has also offered the use of its testing facilities for MAE Center experiments. Each of these government laboratories will provide access to their facilities on a cost-reimbursable basis for equipment rental and testing services.

The triaxial earthquake and shock simulator at CERL has recently been upgraded for testing of structures with six simultaneous components of earthquake ground motions. This earthquake simulator is located on University of Illinois property and is one of the best in the country. The largest geotechnical centrifuge in the United States is located at WES and is presently being used for a MAE Center research project.

Cooperative Research Programs

One model for multi-corporation research involvement used by the NSF Engineering Research Centers program is to assemble a group of related industries to solve common problems through cooperative research. This concept has worked well for industries involved in manufacturing and product development because research expenses can be shared by a number of corporations. A similar analog can exist with the insurance industry where several firms or corporations are interested in improving the accuracy of risk assessment models. Through cooperative funding, a substantial research base can be established that can be directed at those problems of most interest to the insurance industry.

Cooperative research between the insurance industry and the MAE Center can be done to: (a) better understand the seismology of Mid-America and thus increase the accuracy of re-occurrence probabilities for a particular level of seismic intensity, (b) examine vulnerability of existing forms of construction and thus help to further refine seismic risk and set premiums, and (c) investigate cost-effective retrofit methods for reducing damage to particular types of construction and thus help to reduce claims. One of the purposes of this workshop is to explore how the insurance industry and the Mid-America Earthquake Center can work together for their mutual benefit. The concept of developing a cooperative research program is a good candidate for discussion.

Conclusions

Because the Mid-America Earthquake Center is still fairly young, much of its future is yet to be determined. Workshops such as this provide an excellent means for determining how industry can develop long-standing ties with the MAE Center, and in so doing, help define the Center's future endeavors and resulting success.

The three research thrust areas of the Center as well as its education and outreach activities are complementary to interests of the insurance industry. The goal of this forum is to help refine interests of the insurance industry, define a common agenda for reducing the severe effects of earthquakes on Mid-America, and establish an action plan that will exploit these complementary interests in the most effective manner possible.

Acknowledgments

The Mid-America Earthquake Center is funded by the National Science Foundation through the Division of Engineering Education and Centers under the Engineering Directorate. Opinions expressed in this paper are those of the author and may not necessarily reflect those of every researcher in the Center.

What Really Happened in 1811-12 and Could it Happen Again?

Arch C. Johnston

Mid-America Earthquake Center *and*
Center for Earthquake Research and Information (CERI)
The University of Memphis
Memphis, Tennessee 38152

ABSTRACT

Continental North America's greatest earthquake sequence struck on the western frontier of the United States. The frontier was not California but the valley of the continent's greatest river, the Mississippi, and the sequence was the New Madrid earthquakes of the winter of 1811-1812. Their described impacts on the land and the river were so dramatic as to produce widespread modern disbelief. However, geological, geophysical, and historical research, carried out mostly in the past two decades, has verified much in the historical accounts. The sequence included at least six (possibly nine) events of estimated moment magnitude **M** = 7 and two of **M** $\simeq$ 8. The earthquakes occurred on preexisting faults of the Reelfoot rift, beneath the saturated alluvium of the river valley, and their violent shaking resulted in massive and extensive liquefaction. The largest earthquakes ruptured at least six (and possibly more than seven) intersecting fault segments, one of which broke the surface as a thrust fault that disrupted the bed of the Mississippi in at least 2 (and possibly four) places.

Introduction

A sequence of powerful earthquakes struck the mid-Mississippi River Valley, central United States, in the winter of 1811 and 1812. The two largest probably exceeded the size of any continental western U.S. earthquake. No fewer than 18 of these events were felt on the Atlantic seaboard or in Washington D.C. (Nuttli 1987), at least 1000 km east, which implies moment magnitude **M** $\gtrsim$ 6.0-6.5 (Table 1). Over time, this earthquake series has taken the name of the small riverboat town New Madrid, which lay at the heart of the epicentral zone and which in 1811 was the largest settlement on the river between the Ohio River and Natchez. The name has proven apt, for New Madrid by happenstance marks the intersection of three of the six fault segments currently illuminated by microseismicity and believed to be rupture planes of the principal 1811-1812 earthquakes.

A comprehensive scientific assessment of the effects of the New Madrid earthquakes was not made until a century after their occurrence. Myron Fuller (1912), provides a thorough account of the geomorphic changes on the upper Mississippi Valley wrought by the earthquakes and a summary of the principal historical accounts. Placement of the earthquakes in the modern scientific framework of plate tectonics and seismic magnitude was achieved in the seminal papers by Burke & Dewey (1973), Ervin & McGinnis (1975) and Nuttli (1973). These papers initiated a 20-year period of concentrated research on the New Madrid seismic zone (Johnston & Shedlock 1992) that was spurred by the development of nuclear power generation in particular and seismic hazard concerns in general. Much of this work concerned the crustal structure in the vicinity of the 1811-1812 earthquakes, but there has been little additional study of the events themselves, probably because of the dearth of quantitative information.

Constraints on the faulting that took place during the 1811-1812 earthquakes comes primarily from three sources: (a) historical accounts, including far-field intensity data and eyewitness reports from the epicentral zone (Figures 1 & 2); (b) seismological effects remaining from the earthquakes, such as preserved liquefaction features and present-day seismicity in the rupture zone (Figure 4); and (c) the physical structure of the faults and crust of the 1811-1812 fault zone.

Table 1. The New Madrid Earthquakes, 1811-1812

Event Designator	Date	Time (local) (± 30 min.)	m_{Lg}[a]	estimated moment magnitude **M** from m_{Lg}[b]	estimated moment magnitude **M** from isoseismal areas[c]	M_o release[e] (units of 10^{27} dyne cm)	(% total)
D1	16 Dec 1811	02:15	7.2-7.3	7.9	$8.1^c \pm 0.3$	15.85	(44 %)
D2	same	~03:00	6.2	6.2	$6.6^d \pm 0.4$ (Aɪv radius)		
D3	same	07:15	5.5-6.0	5.8	$5.9^d \pm 0.55$ (*felt* radius)		
D4	same	08:15	7.0	7.4	$7.2^c \pm 0.3$		
D5	same	10:00	~6.0	6.0	$6.2^d \pm 0.55$ (*felt* radius)		
D6	17 Dec 1811	12:00	6.6-6.8	7.0	$7.1^d \pm 0.4$ (Aɪv, Av radius)		
D7	16 Jan 1812	23:00	5.5-6.0	5.8	$5.6^d \pm 0.55$ (*felt* radius)		
		Total D1 sequence ($m_{Lg} \geq 5.0$, $\mathbf{M} \geq 4.7$): 63 events				~18.0	(~50 %)
J1	23 Jan 1812	09:00	7.1	7.6	$7.8^c \pm 0.3$	5.62	(16 %)
J2	same	23:00	—	—	$5.5^d \pm 0.55$ (*felt* radius)		
J3	27 Jan 1812	09:00	5.5-6.0	5.8	$6.3^d \pm 0.55$ (*felt* radius)		
J4	04 Feb 1812	17:00	5.5-6.0	5.8	$6.2^d \pm 0.55$ (*felt* radius)		
		Total J1 sequence ($m_{Lg} \geq 5.0$, $\mathbf{M} \geq 4.7$): 31 events				~5.7	(~16 %)
F1	07 Feb 1812	03:45	7.3-7.4	8.0	$8.0^c \pm 0.3$	11.22	(31 %)
F2	same	20:00	5.5-6.0	5.8	$6.3^d \pm 0.55$ (*felt* radius)		
F3	same	22:40	6.6-6.8	7.0	$7.0^d \pm 0.55$ (*felt* radius)		
F4	10 Feb 1812	16:00	6.2	6.2	$6.5^d \pm 0.55$ (*felt* radius)		
F5	11 Feb 1812	06:00	6.2	6.2	$6.5^d \pm 0.55$ (*felt* radius)		
		Total F1 sequence ($m_{Lg} \geq 5.0$, $\mathbf{M} \geq 4.7$): 113 events				~12.1	(~34 %)
	Total 1811-1812 sequence:	>200 events, $m_{Lg} \geq 5.0$, $\mathbf{M} \geq 4.7$:				~35.8 (**M** 8.3)	(100%)

[a] m_{Lg} estimated by intensity attenuation with distance by Nuttli (1973), Nuttli et al (1979), Street (1982) and Street & Nuttli (1984)
[b] from the $\log(M_o)$–m_{Lg} regression (period ~1 s) of Johnston (1996a)
[c] from Johnston (1996c)
[d] from $\log(M_o)$ regressions on isoseismal areas (Johnston 1996b); higher uncertainty results from using radii for equivalent areas
[e] using $\mathbf{M} = (2/3)\log(M_o) - 10.7$ (Hanks & Kanamori 1979)

Historical Setting

For the researcher trying to gain a modern understanding of the earthquakes, the timing and location of the New Madrid sequence is both fortuitous and frustrating. European settlement of the North American interior was well underway, and by 1811 the Mississippi River was already fairly heavily traveled. All river traffic was by unpowered flatboat, barge, or keelboat, but the first steamboat on the Mississippi River completed its maiden voyage from the Ohio River to

New Orleans between the first principal earthquake on 16 December 1811 and the second on 23 January 1812. Settlements west of the Mississippi were so few that virtually all our information is limited to the river or points east (Figure 1). Had the New Madrid earthquakes occurred a century or so earlier they would have been included in the realm of paleoseismology; had they occurred a century or more later, millions of people would have been at risk, and abundant instrumental and macroseismic data would be available. However, they occurred in the transition, the crease in history, when the Mississippi River was for a brief period the western frontier of a new nation. Data useful for assessing the earthquakes in modern terms are available but fragmentary, and as a result legends and myths and scientific disbelief have proliferated concerning these events.

A historical perspective is important for assessing both the near- and far-field effects of the New Madrid earthquakes. Figure 1 shows that the epicentral region was on the forward edge of European settlement. Kentucky and Tennessee became states in 1792 and 1796 respectively; they were the only two states of the Union with territory in the meisoseismal zone, which lay primarily in what would become the states of Missouri (1821) and Arkansas (1836). The restricted population distribution (contoured in Figure 1) is a major problem in estimating the earthquakes' sizes from far-field isoseismal data.

Total population of settlements on the Mississippi River in the main disrupted zone—roughly from the mouth of the Ohio River to present-day Memphis, Tennessee—was less than 4000 with perhaps one-half living in or near New Madrid (Penick 1981). (The number of Native Americans, although greater, is unknown). Other estimates place New Madrid's population at only several hundred. Communications between the populous East and the river frontier were slow and unreliable. Not until months after the earthquakes did it become clear that they all originated in the New Madrid area.

The earthquakes began with what was probably the largest shock of the entire series at 02:15 on 16 December 1811. (All times are local with probable ±30 minute uncertainty.) There were no known foreshocks. The mainshock isoseismals are shown in Figure 1. Note that no felt limit is included; given the early morning origin time and the limited population distribution, it has to date proven impossible to determine. Table 1 lists the major earthquakes of the ensuing sequence. The three principal shocks of 16 December 1811 (02:15), 23 January 1812 (09:00), and 07 February 1812 (03:45) are designated D1, J1, and F1. Major aftershocks are numbered sequentially after their mainshock. As Table 1 shows, a number of aftershocks were major earthquakes in their own right and thus cannot be neglected in fault rupture scenarios.

The main sequence duration spanned eight weeks, although the epicentral zone has remained active to the present and produced two additional large earthquakes in 1843 (**M**~6.4) and 1895 (**M**~6.8). Most authors (Nuttli 1973, 1983; Nuttli et al 1979; Street 1982; Street & Nuttli 1984) designate the third principal event F1 as the largest, in contrast with Johnston (1996c) and this review. It should be noted, however, that the magnitudes of the three principal events D1, J1, and F1 each lie within the uncertainty bounds of the other two, making their sizes all statistically equivalent, clustered about **M**8.0 (Johnston 1996c). In addition to differences in size, variation in faulting mechanism and epicentral location can account for the reported differences in severity among D1, J1 and F1.

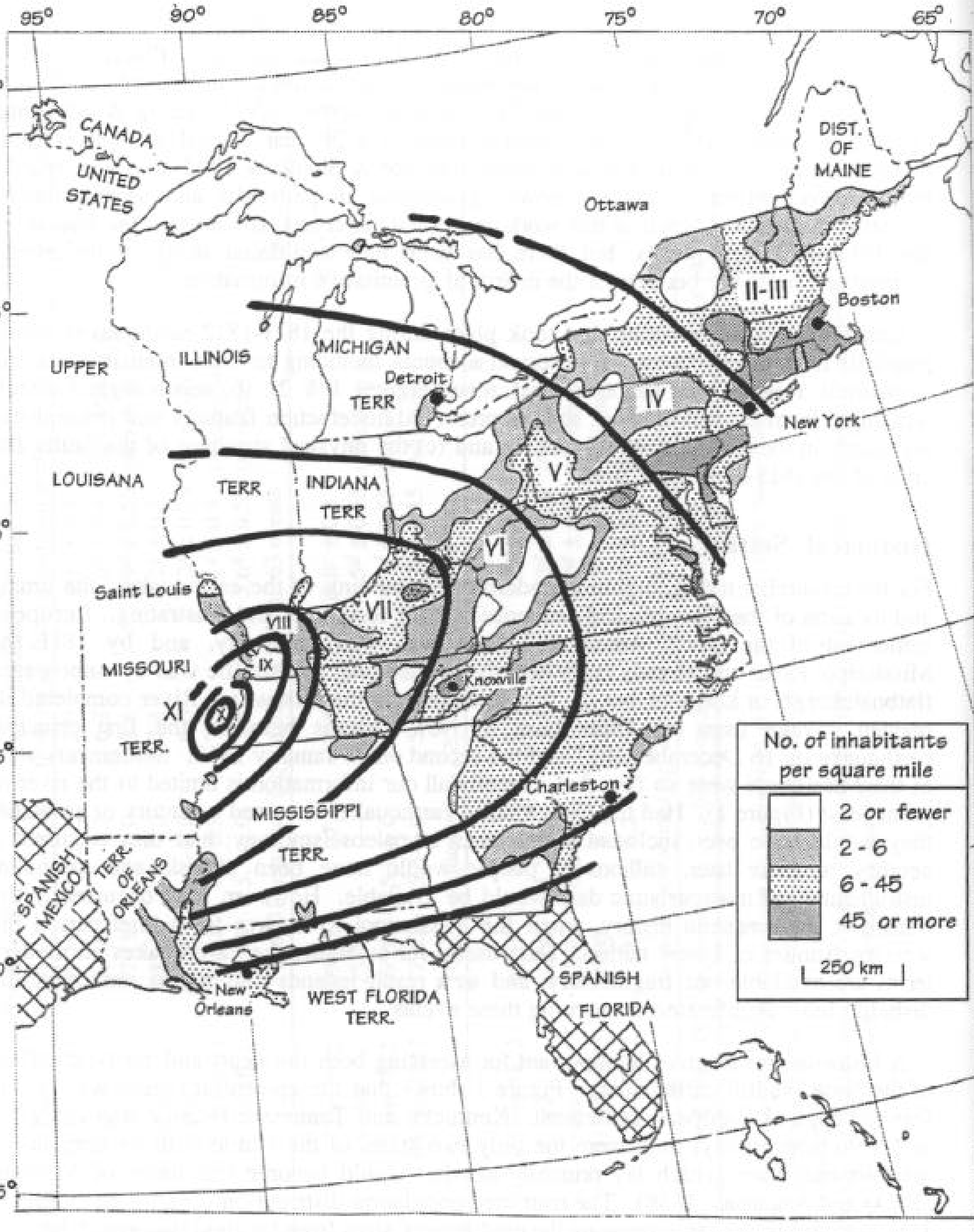


Figure 1 Historical setting in 1811-1812. States of the Union have continuous borders, territory and district borders have dash-dot orders, and Spanish possessions are cross-hatched. Modified Mercalli isoseismals of the 16 December 1811 mainshock (D1) are from Stover and Coffman (1993), modified from Nuttli (1973). Population density for the U.S. is for 1810 (Garrett 1988); in Canada, only principal settlements (dots) and trading posts (squares) are identified.

The most important of the near-field historical accounts are geographically located in Figure 2 Nearly all are first-hand accounts taken largely from the compilations of Nuttli (1973), Street (1982, 1984), and Street & Nuttli (1984). Many of the second-hand, summary accounts are cumulative for all the shocks and make it impossible to discriminate among D1, J1, and F1 effects, a problem that also frustrated Penick (1981).

The remarkably few extant first-hand accounts from people who were caught in the 1811-1812 earthquakes are an irreplaceable resource. In this brief review, we cannot present the descriptions in detail but can only touch on highlights. For the D1 sequence the accounts from the small flotilla of flatboats, keelboats, and barges tied up for the night along the Mississippi River (north to south: La Roche 1927, Bedinger 1812, Pierce 1812, Davis 1812, and Bradbury 1817) make it clear that the most severe vibration and liquefaction was in the Little Prairie vicinity and that it was more intense for the D1 aftershocks (Table 1) than for D1 itself. For example, only Pierce and Bedinger recount large waterspouts on the river or explosive cratering. A large wave (and perhaps a temporary retrograde current) was noted only upriver of Little Prairie (Bedinger, Bryan (1848), and La Roche) and was followed by a rapidly rising river level and swifter current downstream from approximately Bedinger's location (Bedinger, Davis, Pierce, Bradbury). These latter events are consistent with the large volume of ground water that must have been expelled by liquefaction. Tremendous noise, fissuring, splintering and toppled trees, and extensive caving of river banks were reported by all.

We shall apply these historical observations and others as constraints on plausible faulting scenarios for the D1, J1 and F1 sequences. However, other constraints come from the seismological and geophysical setting of the faulting and the size of the earthquakes, and we must therefore first examine the current scientific understanding of these aspects.

Size of the Principal Events

On the basis of the extensive macroseismic effects including massive liquefaction, fissuring, subsidence or uplift of landforms, violent disturbance of the river, and destruction of extensive tracts of forests, both Davison (1936) and Richter (1958) considered the principal New Madrid events to be 'great' earthquakes. In Richter's case, this presumably means a Richter magnitude M_R = 8, although he never explicitly assigned a magnitude value. In Davison's case, this put New Madrid in the class of the famous 1755 Lisbon, 1897 Assam, 1906 San Francisco, and 1891 Nobi earthquakes, among others. Both authors' estimates were based on the work of Fuller (1912) and consisted more of informed judgment than quantitative analysis.

All useful analysis of the New Madrid earthquakes—from their recurrence intervals to dynamic fault-rupture modeling to present-day seismic hazard assessment—hinges on their size. In modern seismology 'size' equates to the scalar seismic moment M_o, which defines moment magnitude $\mathbf{M} = (2/3)\log(M_o) - 10.7$ (Hanks & Kanamori 1979). [The symbol **M** conforms to the usage in the formal Hanks & Kanamori definition; for average stress drop, **M** is equivalent to the seismic energy magnitude M_w of Kanamori (1977).] Previous magnitude estimates for the 1811-1812 events (Nuttli 1973, 1983; Nuttli et al 1979, Street 1982, Street & Nuttli 1984) were in terms of the short-period magnitudes m_b or m_{bLg}, not easily related to scalar moment or moment magnitude.

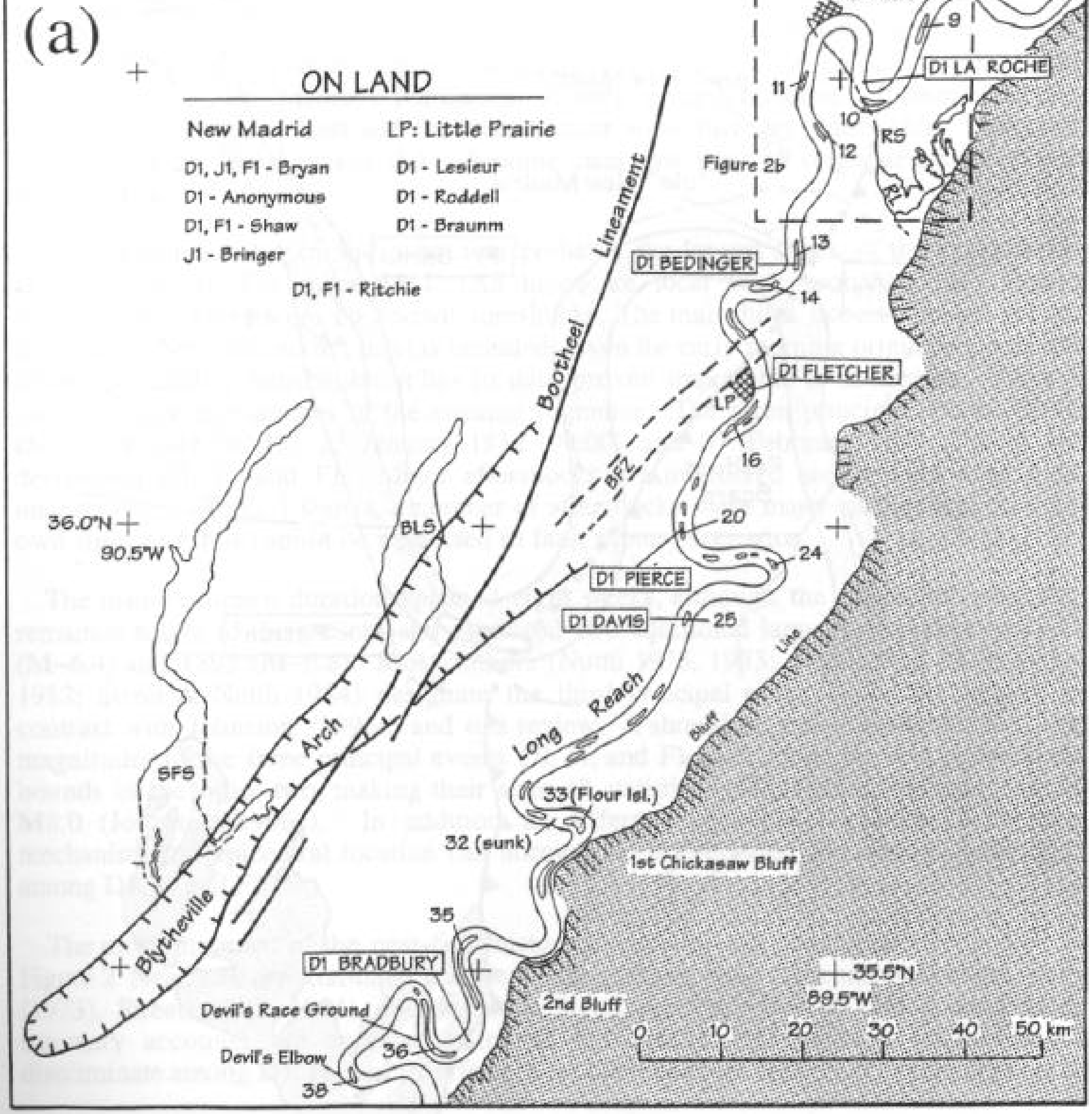


Figure 2 The Mississippi River in 1811-12. The river's precise course in 1811-12 is uncertain; this figure is based on maps from Cramer (1814), Wheeler & Rhea (1994), Odum et al (1995), and U.S. Geological Survey quadrangle maps. Island locations and numbers follow Cramer. See Table 2 for eyewitness references. *(a)* River locations of principal eyewitnesses to the D1 earthquake. River width is exaggerated for clarity. Included for reference from Figures 3 & 4 are the seismogenic structures of the D1 sequence. RS, Reelfoot scarp (dashed where inferred); RL, Reelfoot Lake; LP, Little Prairie; BFZ, Blytheville fault zone; BLS, Big Lake sunklands; SFS, St. Francis sunklands. Shaded area is eastern (non-floodplain) upland.

There are a wide variety of analytical techniques to directly recover M_O from instrumental seismic-wave data. For non-instrumental, historical events like New Madrid, a direct estimate of M_O is possible only if the rupture is well expressed at the surface. But the scalar moment's physical definition ($M_O = ?\ \bar{d}\ A$, where ? is the rigidity, $\bar{d}$ is the average rupture displacement, and A is the fault area) is dependent on both average slip and rupture dimensions. The New Madrid ruptures evidently were well masked or at least not preserved by the thick alluvial sediments of the Mississippi River Valley, except for the relatively short Reelfoot fault segment.

Because of this lack of instrumental or surface-rupture data, the seismic moments of the New Madrid earthquakes must be estimated indirectly from historical accounts. Notwithstanding a sensitivity to source and path effects, the best type of data for this estimate is seismic intensities, which in North America are mostly standardized to the modified Mercalli (MMI) scale. Extent and severity of liquefaction (Youd et al 1989) and landsliding (Keefer, 1984) can also provide useful constraints. All these effects were employed by Johnston (1996b,c) to obtain seismic moments with specified uncertainty bounds for the principal events D1, J1 and F1 and the largest aftershock D4 of the New Madrid sequence. This effort followed on the pioneering work of Nuttli (1973) with subsequent refinements (Nuttli et al 1979, Nuttli 1983, Street & Nuttli 1984) using intensity data to obtain the sizes of these events in terms of the short-period regional magnitude m_{bLg} (see Table 1). However, because m_{bLg} has no direct relation to fault rupture parameters, size measured by M_O or **M** is more useful for our purposes here.

Johnston (1996c) relied on a set of regressions of instrumental M_O on isoseismal area (felt through VIII) developed for stable continental region earthquakes (Johnston 1996b, Johnston et al 1994). These regressions are summarized in Figure 3. To these basic relations, corrections were applied for North America's extremely low anelastic attenuation to the northeast of New Madrid and for the considerably higher attenuation to the west (Singh & Herrmann 1983). The isoseismal areas of event D1, calibrated in this manner, are added to Figure 3. With data weighting, the outer isoseismals have the lowest uncertainty and dominate the best weighted average, $\mathbf{M}_{best}$. Hence the low A_{IV} value more than compensates for the high A_V and A_{VII} values, yielding $\mathbf{M}_{best}$ = 8.1. The one-standard-deviation uncertainty is ~±0.3 **M** units. At this uncertainty level **M**8 earthquakes can be clearly discriminated from **M**7 or **M**9 events if isoseismal data are adequate; discrimination from **M**7.5 or 8.5 is marginal. Similar **M**-estimates (Table 1) were made for the J1, F1 and D4 events using the isoseismal data of Street (1982) and Street & Nuttli (1984).

Several aspects of the size analysis in Figure 3 and results in Table 1 deserve further comment. Beyond an isoseismal area radius of ~100-150 km (shaded band, Figure 3), the anelastic attenuation of the continental Lg wave controls seismic ground motions; within ~100-150 km, geometrical spreading is the dominant control parameter (Hanks & Johnston 1992, Frankel 1994). The New Madrid D1 isoseismal areas are huge—among the largest known in the world—and even the outer radius for the onset of structural damage (MMI VIII) is in the regime of Lg attenuation, not geometrical spreading. This means that for very large earthquakes ($\mathbf{M} \gtrsim 7.5$) such as event D1, damage areas in eastern North America may well be significantly larger than those in the West. Conversely, this may not be the case for earthquakes smaller than **M**7.0-7.5 (but for a counterview see Bollinger et al 1993).

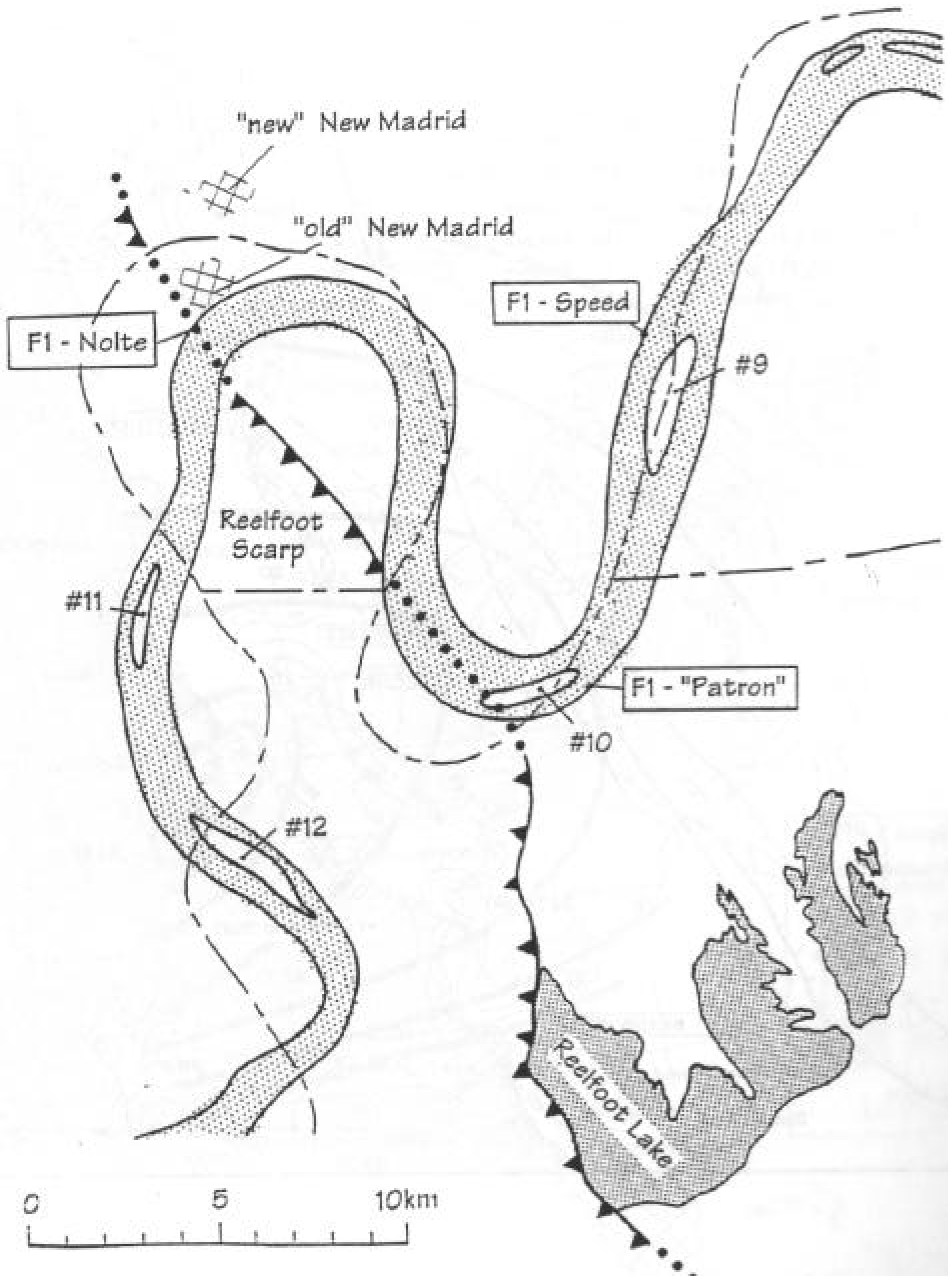


Figure 2(b) The Kentucky (or New Madrid) bend of the Mississippi River in 1812, showing river locations of the principal eyewitnesses to the F1 earthquake (all were in the Kentucky bend area). Present-day Reelfoot Lake is shown for reference (it was probably larger after the F1 earthquake). Dash-dot line shows the 1995 rivercourse (approximate centerline). Reelfoot scarp (from Van Arsdale et al 1995) has barbs on the hanging wall block and is dotted where inferred. Note that present-day New Madrid is ~2 km north of its 1812 location. Locations C-C' are profile endpoints for Figure 6.

Second, there are insuffecent data to determine a reliable felt area (MMI I-III) for the New Madrid sequence principal shocks. From Figure 1 it is evident that a felt area determination would require a comprehensive examination of historical records from French and British Canada, Spanish Mexico (Texas) and Florida, and the unsettled but explored American West. Such a study has not been undertaken. Well-constrained felt limits could significantly reduce the uncertainties in the sizes of the principal 1811-1812 earthquakes.

Finally, from Table 1, the total seismic moment release of the 1811-1812 sequence is an estimated M_O(total) = 3.6x10^{28} dyne-cm, equivalent to a single great **M**8.3 earthquake. How such a large moment release could occur on fault segments of the dimensions defined by current seismicity and the Bootheel lineament becomes a question of primary importance. For example, if coseismic slip is limited to = 10 m and occurs at depths of = 20 km (depth maximum of current NMSZ hypocenters), a total minimum fault length exceeding 500 km is required for normal upper crustal rigidity. The total fault length of the 7 fault segments that we believe participated in the 1811-1812 ruptures is ~350 km. This ~150 km discrepancy can be resolved in at least four ways. 1. Reduce the estimated seismic moments of the D1, J1, and F1 earthquakes (e.g. Gomberg 1992). 2. Allow unprecedentedly large coseismic fault displacements ($\bar{d} \gtrsim$ 15 m). 3. Allow rupture to depths significantly greater than the hypocentral depths of current seismicity. 4. Allow rupture on fault segments not identified by crustal structure studies or current seismicity.

A significant reduction in size of the 1811-1812 principal events leads to irresolvable difficulties in accounting for both the severe and extensive near-field effects and the great distances of far-field effects. Johnston (1996c) expressed the belief that the estimated seismic moments of events D1, D4, J1, and F1 (used in Table 1) were more likely to be in error by underestimating rather than overestimating size. The large displacement hypothesis also has numerous difficulties. Aside from exceeding known average displacements for all earthquakes except **M** > 9 subduction-zone ruptures, it implies very high static stress and strain drops, which in turn imply relatively short rupture duration times. Multiple independent historical accounts in the near field indicate durations approaching one minute to several minutes, not seconds. Moreover, the abundant historical and physical evidence of massive liquefaction, which needs many vibrational cycles to develop fully, would argue for longer, not shorter, source time functions. The fourth, the unidentified coseismic fault segment(s) hypothesis, is a possibility that cannot be dismissed, but it amounts to special pleading with no supporting theory or data, and therefore we do not consider it further.

Johnston (1995c) has presented the case for the third possibility, that of deep coseismic rupture. The argument applies to thick, 'average' cratonic crust with abundant quartz and feldspar minerals. Earthquake nucleation is limited to crust cooler than the quartz brittle-plastic transition (bpt) temperature, ~300-350°C. However, fully plastic behavior does not occur until the feldspar bpt is reached, at ~450°C. Earthquakes cannot nucleate in the brittle-plastic transition zone between the quartz and feldspar bpts, but coseismic fault rupture can propagate there, driven by strain energy release at shallower depths in the seismogenic zone. For plausible New Madrid crustal temperatures, this could be at depths exceeding 30 km and could explain the large 1811-1812 seismic moments without the need to appeal to unknown active fault segments of the NNSZ.

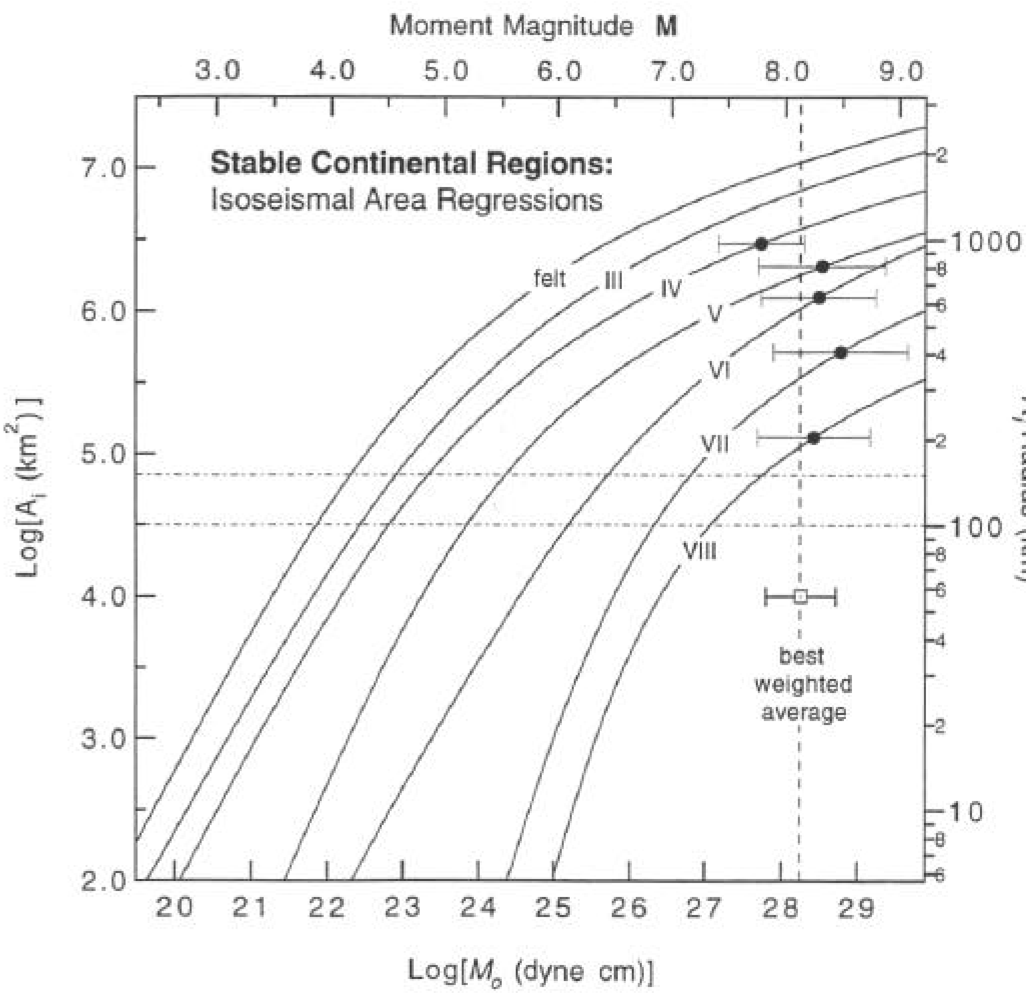


Figure 3 The regressions of seismic moment (moment magnitude) on modified Mercalli felt through VIII isoseismal areas for stable continental regions (modified from Johnston, 1996b). Large dots are the isoseismal areas for the D1 New Madrid event (see Figure 1), reduced according to Johnston 1996c. Formal one-standard-deviation uncertainties in predicted $\log(M_O)$ values are indicated as well as the best weighted average, **M** 8.1. Horizontal shaded band at a radius of 100-150 km separates domains in which intensities (seismic-wave amplitudes) are controlled by the geometrical spreading of body waves and by anelastic attenuation of surface (L_g) waves. For very large earthquakes such as D1, all isoseismals through MMI VIII are in the L_g domain.

Liquefaction Earthquakes before 1811-1812

Was the New Madrid earthquake sequence of 1811-1812 a fluke of geological history, a one time event? Or have large earthquakes occurred repeatedly in the NMSZ in the recent geological past? This question is important, not only for assessing the earthquake hazard of the New Madrid region, but also for understanding the long-term process of tectonic strain accumulation and release. At first glance, the Mississippi River and its surrounding expanse of nearly level flood plains would seem to be evidence of a region that is tectonically and seismically dead. However, seismological, geodetic, and most paleoseismological data suggest a surprisingly short recurrence interval for major earthquakes in the NMSZ, on the order of a thousand years or less, with deformation rates comparable to those at plate margins. If the largest of the 1811-1812 events each produced 8 to 10 meters of slip (Johnston 1996c), then repeated earthquakes of such a magnitude would clearly result in major disruption of fluvial systems, as well as the landscape in general. Yet, other data, particularly the low regional relief, indicate that the rapid rates of crustal strain implied by such magnitudes and repeat times cannot have been maintained for geologically long periods of time Schweig & VanArsdale (1996).

The most extensive and dramatic present-day evidence that survives from the 1811-1812 ruptures is not the current seismicity but the sandblow and fissure liquefaction features preserved in the alluvial soils of the upper Mississippi embayment. A comprehensive mapping of these features was carried out originally by Fuller (1912) and then in much more detail by Obermeier (1988, 1989). Obermeier's zone, depicted in simplified form in Figure 4, encompasses only the areas of most intense liquefaction where 1% to >25% of land surface is covered. Reports of significant outlying liquefaction episodes far removed from this zone include White County, Illinois and a region near St. Louis, ~250-300 km north of the NMSZ (Berry 1908, Obermeier 1988), to the south to below the mouth of the Arkansas River (La Roche 1927), about 250 km from the NMSZ.

The area of Obermeier's severe liquefaction zone exceeds 10,000 km^2 and Fuller's zone encompassing all types of ground failures, as modified by Street & Nuttli (1984), covers ~48,000 km^2. These rank among the largest earthquake liquefaction and ground deformation fields ever documented, perhaps surpassed only by those produced by great Himalayan front earthquakes in the Ganges alluvial plain of India (Richter 1958). Moreover, the New Madrid liquefaction zone obviously was restricted by loess-mantled upland areas of low-to-negligible liquefaction potential to the west (Crowleys Ridge) and to the east (the river's eastern bluffs). The New Madrid liquefaction zone encompasses all the linear epicentral segments of the NMSZ (except the eastern extreme of its central segment that extends beneath the loess bluffs), strongly suggesting that both the seismicity and the liquefaction are linked to the same set of source faults.

Figures 4 and 5 summarize the published results of paleoseismology studies in the fault zone area of the 1811-12 earthquakes. Not included is recent preliminary work indicating paleoearthquake liquefaction to the north and west of the seismic zone. The diagram shows the allowable ranges of earthquake events, and the ranges preferred by the individual investigators. The simplest interpretation of these results is that, in addition to the 1811-1812 events, there were at least two strong ground-shaking earthquakes in the past 2000 years. Evidence for one of

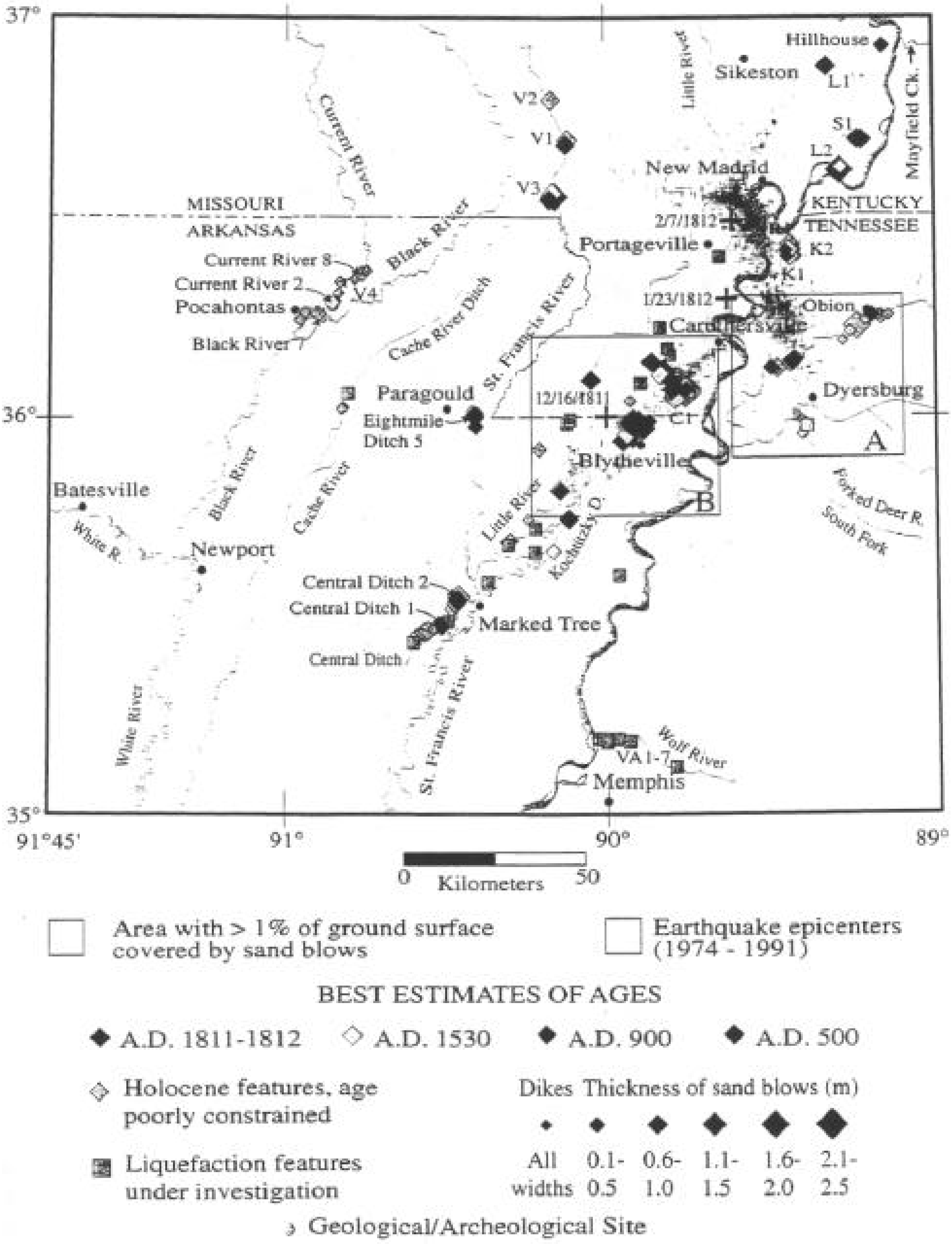


Figure 4. Seismological and liquefaction setting of the New Madrid seismic zone. Distribution of intense sandblow and fissuring liquefaction (light shading) from Obermeier (1989) spans the region SW-NE from approximately Central Ditch to Hillhouse and east-west from Dyersburg to Eight Mile Ditch. Trace of Bootheel lineament from Schweig and Marple (1991); Lake County uplift (LCU) from Russ (1982). Diamond symbols are sites of pre-1811 paleoliquefaction features; individual site names are used in Fig. 5.

these, which likely occurred between A.D. 800 and A.D. 1000, is clear at Reelfoot scarp and north of New Madrid. There is also evidence for liquefaction of this age near Marked Tree, Arkansas to the south, and at several sites near Blytheville, Arkansas. Evidence for a liquefaction-producing event between A.D. 1400 and A.D. 1600 is found in the Blytheville area and may be present in the Reelfoot area and at the northernmost sites. Moreover, there is evidence, presently inconclusive, of liquefaction ages both younger than (~ A.D. 1600) and older than (prior to A.D. 600) these two age ranges.

Thus 1811 was not the first time in the Holocene that the New Madrid region experienced strong ground shaking. The data all are consistent with as few as two and as many as four earthquakes in the 2,000 years prior to 1811. What were the magnitudes of the causative earthquakes? The only known post-1812 earthquake in the New Madrid region large enough to have caused liquefaction is the **M**6.8 1895 Charleston, Missouri, earthquake, which caused liquefaction over an area 16 km across (Obermeier 1988). Schweig & Ellis (1994) estimated that, when the severity of liquefaction is taken into account (Youd et al 1989), an **M**~8 earthquake would be required for an event to have caused the liquefaction at the northern sites and the southern Blytheville sites, separated by about 100 km. And since the distribution of A.D. 900 earthquake is represented at the northernmost and southernmost sites exceeding 250 km separation, a multiple event scenario similar to the 1811-12 sequence may be required.

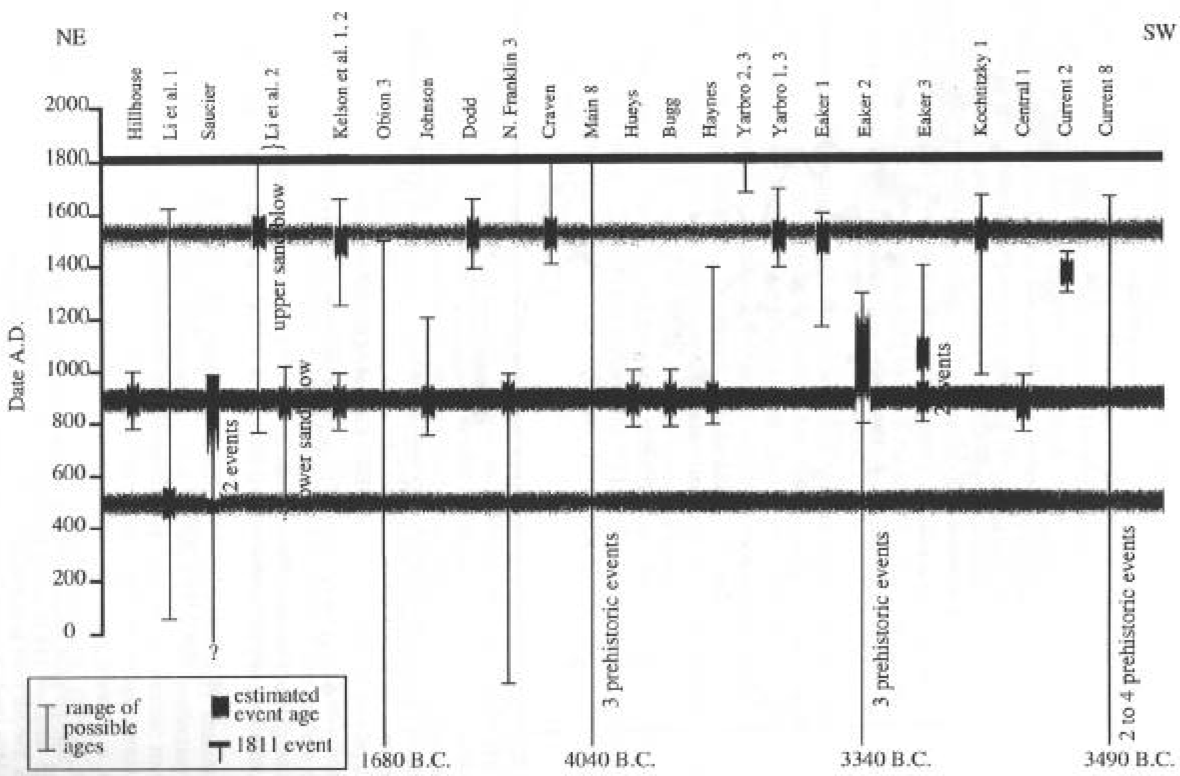


Figure 5. Summary of paleoearthquake investigations in the New Madrid seismic zone. Vertical bars and lines show results from individual sites or studies, generally arranged from north on left to south on right (see Figure 4 for site locations). Thick horizontal line at top represents the 1811-12 sequence. Horizontal shaded bands represent likely age ranges of earthquakes in the past 2,000 years, with darker shading representing the more likely dates (figure courtesy of E. Schweig).

Fault Rupture Scenarios

As if the earthquake triplet of 1811-1812 was not sufficiently complex, Street (1982) and Street & Nuttli (1984) demonstrated that some aftershocks of D1 and F1 were major (**M** = 7) events in their own right (see Table 1), requiring the accommodation of nonnegligible fault areas. These authors, in fact, considered event D4 to be a fourth principal shock. Moreover, the Bootheel lineament investigations, beginning with Schweig & Marple (1991), have raised the strong probability that fault segments not illuminated by present-day seismicity ruptured in the 1811-1812 sequence. The upshot of both these bodies of research is that a fault-rupture scenario for 1811-1812 must incorporate a minimum of seven fault segments (Figure 6) and six **M** $\gtrsim$ 7 earthquakes (Table 1).

Our faulting scenario begins with the moment magnitudes of the 1811-1812 sequence listed in Table 1. These yield a cumulative moment M_O(equival.) = 3.6 x 10^{28} dyne-cm (**M**=8.3). Whatever coseismic ruptures are adopted must sum to this cumulative M_O. Previously we considered but rejected alternatives to this requirement; its adoption here means that ruptures extend into the crustal depth zone between the quartz and feldspar brittle-plastic transition temperatures (possibly 30 km or more). If then coseismic displacements are limited to $\lesssim$ 10 m to keep stress and strain drops reasonable, the fault lengths of the D1, J1, and F1 principal events must be on the order of 110-150 km, 40-70 km, and 60-90 km, respectively.

Other general constraints are that coseismic ruptures must largely be contained within the intense liquefaction region described by Obermeier (1989) (Figure 4) and must include all the fault segments illuminated by current seismicity. We do not adopt the more severe constraint that coseismic ruptures must be limited to these illuminated segments; hence the Bootheel lineament is not excluded from the rupture scenarios.

Figure 6 summarizes three possible fault-rupture scenarios for the 1811-1812 New Madrid sequence. Others are certainly possible; the ones highlighted here, however, mostly meet other constraints from the historical accounts and structural data previously examined. In rough priority of their importance and strength of evidence to support them, the historical constraints are:

1. The F1 rupture must include the Reelfoot fault (RF) segment.
2. The D1 rupture must include the Blytheville arch (BA) segment.
3. The D1 aftershocks were stronger than the D1 mainshock at Little Prairie.
4. Both the D1 and F1 principal events were larger than event J1.
5. The D1 and F1 aftershocks were major events, requiring tens of kilometers of fault length.

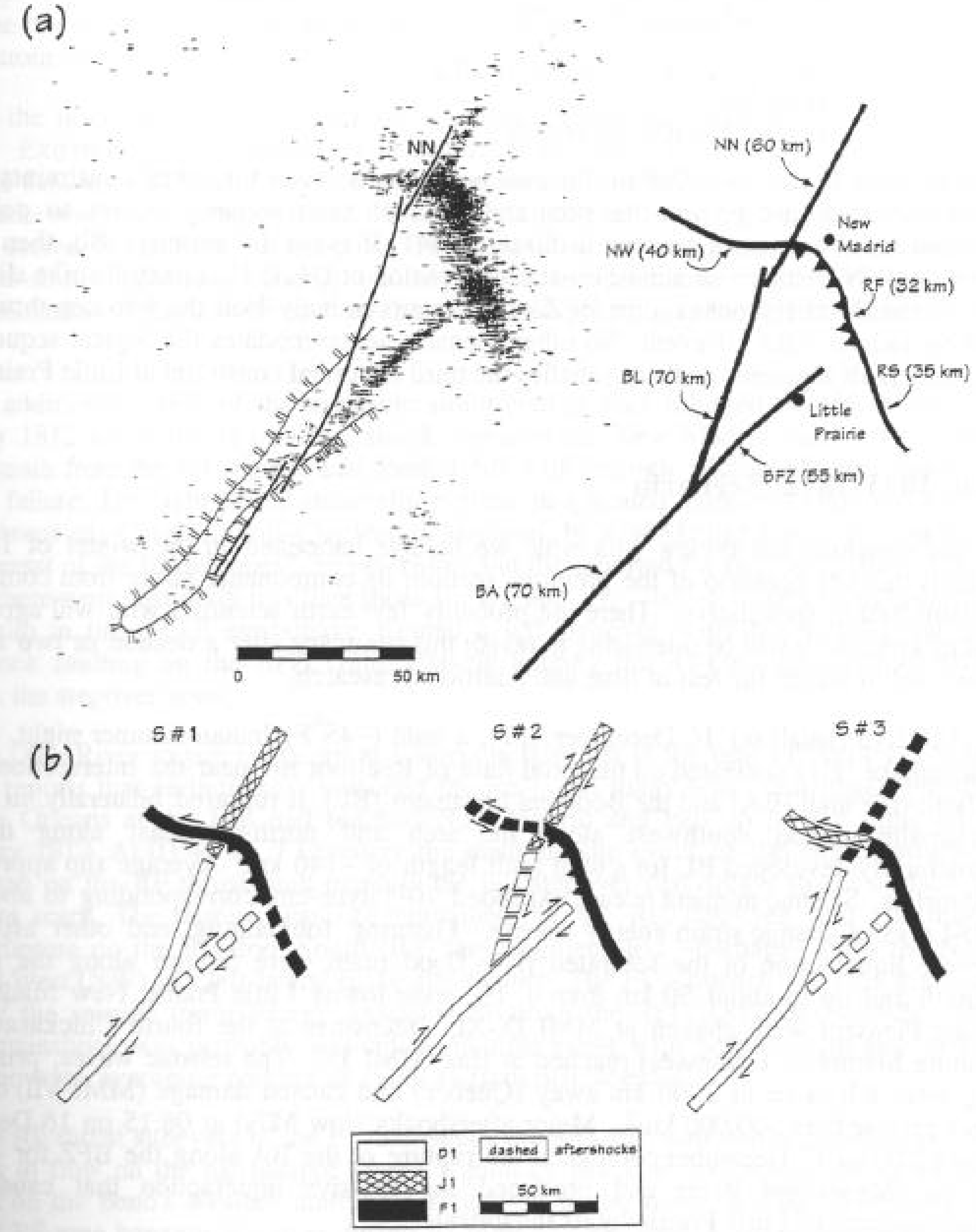


Figure 6. *(a)* Fault segmentation of the NMSZ. Seismicity of the NMSZ, the Blytheville arch, and the Bootheel lineament/NN fault (left) yield the seven segments (right) identified as: BA, Blytheville arch; BFZ, Blytheville fault zone; BL, Bootheel lineament; NW, New Madrid west; NN, New Madrid north; RF, Reelfoot fault; RS, Reelfoot south. Segments NW and RS are defined solely from seismicity. *(b)* Possible fault rupture scenarios (*S#1*, *S#2*, *S#3*) for the 1811-12 D1, J1, and F1 earthquake sequences, using the seven fault segments of *(a)*. Based on historical and physical constraints (see text), the D1 principal event must rupture BA, and the F1 principal event must rupture RF in all scenarios. S#1 is the favored scenario for reasons discussed in the text.

The candidate fault segments and their lengths are (Figure 9):

1. BA—Blytheville arch segment, axial fault, ~70 km
2. BFZ—Blytheville fault zone segment, axial fault, ~55 km
3. BL—northern Bootheel lineament, ~70 km
4. NN—New Madrid north fault + seismicity continuation, ~60 km
5. NW—New Madrid west seismicity trend, ~40 km
6. RF—Reelfoot Fault, ~32 km; and
7. RS—Reelfoot south seismicity trend, ~35 km.

Of the seven segment candidates, only one (RF) has structural expression at the surface. One other (BL) has secondary surface evidence in the form of aligned fissures and liquefaction features. Two segments, NW (strike slip) and RS (dip slip) are defined only by seismicity concentrations. At least five segments (BA, BFZ, BL, RF, NN) can be identified in the subsurface on seismic-reflection profiles, but their subsurface characteristics differ greatly. Some segments (RF, RS, BA) appear to lie wholly or partially within magmatic crustal intrusions. Two segments (NW, NN) are outside the Reelfoot graben, although probably within its northwest margin zone.

Given the faulting constraints and candidate fault segments listed above, numerous faulting scenarios for 1811-12 may be envisioned. We restrict our considerations to three (Figure 6), all of which satisfy the rupture size–fault length general constraint and all of the historical constraints (except that S#2 violates constraint number three). In outline form for **M** = 7, the scenarios are:

S#1: D1 on BA + BL. D4, D6 on BFZ
J1 on NN
F1 on RF + NW. F3 on RS;

S#2: D1 on BA + BFZ. D4, D6 on BL (?)
J1 on NN
F1 on RF + RS. F3 on NW; or

S#3: D1 on BA + BL. D4, D6 on BFZ
J1 on NW
F1 on RF + RS. F3 on NN.

Because we intend S#1–S#3 to illustrate possibilities given the initial constraints of this section, we do not go into the pros and cons of each scenario except to point out several fault-mechanics reasons in favor of S#1. If event D1 ruptures BL, then the J1 event on NN becomes an almost on-strike extension of D1. If J1 is dextral strike slip, then it and the D1 aftershocks on the BFZ would compressively load the left-step thrust fault RF for failure in the F1 event. No other scenario accommodates the logical sequence of loading fault segments and still satisfies the third historical constraint at Little Prairie.

An 1811-1812 Scenario

We conclude this review with what we believe happened in the winter of 1811-12. This is the S#1 scenario of the previous section; it's components range from confidently established to speculative. There are probably few earth scientists who will agree with all its aspects. It will be interesting to revisit this summary after a decade or two and see how well it stands the test of time and additional research.

At 02:15 (local) on 16 December 1811, a mild (~45°F) Indian-summer night, a great earthquake (D1) nucleated on the axial fault of Reelfoot rift, near the intersection of the Blytheville arch (BA) and the Bootheel lineament (BL). It ruptured bilaterally, in dextral strike-slip motion, southwest along the arch and north-northeast along the less structurally developed BL for a total fault length of ~140 km. Average slip approached 10 meters. Seismic moment release exceeded 10^{28} dyne-cm, corresponding to about 8 x 10^{23} ergs of seismic strain energy release. Fissuring, fountaining, and other aspects of severe liquefaction of the saturated river flood plain were intense along the rupture length and up to about 50 km from it. The river towns Little Prairie, New Madrid and Point Pleasant were shaken at MMI IX-XI. Intensities at the fourth Chickasaw bluff (future Memphis, Tennessee) reached at least MMI IX. The seismic waves, principally *Lg*, were felt as far as 2000 km away (Quebec) and caused damage (MMI VII) over an area greater than 500,000 km^2. Major aftershocks (low **M**7s) at 08:15 on 16 December and 12:00 on 17 December completed the rupture of the BA along the BFZ for ~60 km to the Mississippi River and produced the massive liquefaction that caused the abandonment of Little Prairie by its inhabitants.

The Mississippi River was strongly affected by these earthquakes (but not to the degree of the impending F1 event). A large river tsunami or seiche was produced upriver in the Kentucky bend area, whereas downriver of Little Prairie, tremendous volumes of groundwater squeezed out by liquefaction drained into the river and caused a rapid rise in level and a much swifter current than normal. Certain reaches of the river from Little Prairie to the fourth bluffs were clogged with tree trunks, branches and roots, some uprooted by vibration, liquefaction, and failing river banks and others brought from the riverbed to the surface by the intense, prolonged shaking or liquefaction of the riverbottom sediments.

For the next five weeks a vigorous aftershock sequence continued to shake the region. Extremely cold weather set in and froze the Ohio River so that by the third week of January 1812 there were few if any travelers on the Mississippi River. The D1 earthquake was very large but it and its aftershocks released only ~50% of elastic strain energy stored in the Reelfoot rift crust. The mainshock rupture stopped not because it depleted all available strain energy but because structural barriers halted it—probably the termination of Blytheville arch to the south and possibly igneous intrusions to the north.

An additional ~16% of the available strain energy was released at ~09:00 on 23 January 1812 when the J1 principal shock ruptured the New Madrid north (NN) fault. Static strain from the D1 rupture had loaded NN with enough additional shear stress to induce failure. The right-lateral strike-slip rupture propagated northeastward on NN to near present-day Cario, Illinois-Charleston, Missouri. In New Madrid it was "as violent as the severest of the former ones" (Bryan 1848), but the reported far-field intensities nearly everywhere were distinctly less than those for D1 and F1. The ~8 meters of right-lateral strike slip in this **M**7.8 earthquake formed a left stepover with the right-lateral D1 aftershock faulting on the BFZ, compressively loading the 32-km-long Reelfoot fault (RF) in the stepover zone.

The Ohio River icejam broke up at Louisville falls just at the time of event J1 [Nolte (1854) reports that earthquakes "loosened the ice"], and many boats that began the trip to New Orleans at the falls had reached New Madrid and tied up for the night of 6 February 1812. At 03:45 on 7 February the main dip-slip event of the entire sequence nucleated on the RF thrust fault plane in the left stepover that splays to the surface as Reelfoot scarp. The rupture was not contained by the RF, however, and continued thrust rupture on the Reelfoot South (RS) fault segment and—perhaps—onto the New Madrid West (NW) as a left-lateral strike-slip rupture. The F1 sequence released the final third of the seismic strain energy available to drive the 1811-1812 earthquakes. The **M**8.0 mainshock was probably a complex multiple event with both dip-slip and strike-slip subevents, averaging perhaps as much as 10 m displacement.

The RF thrust subevent of the F1 mainshock created one waterfall or rapids and two barriers to flow on the Mississippi River's Kentucky bend; an additional falls may have formed on the bend's western limb by deformation in the hanging wall. The hanging wall of RF rose beneath the river during F1 from ~12 km to ~17 km upstream of New Madrid. This created an uplift that obstructed flow near island #10 and a downdrop falls or rapids downstream of the island. This combination was the most severe river disruption; it generated the great upstream wave and retrograde current so graphically described by Speed (1812) and the "patron," (Shaler 1815) but both travelers' flatboats would survive being swept over the falls. The second intersection of RF with the river was immediately downstream of the town New Madrid (within 1 km). It uplifted the riverbed by one-to-several meters, accounting for the large wave and retrograde current at New Madrid, independently described by Bryan (1848) and Nolte (1854).

The riverbed from New Madrid to island #10 and the lakebed of to-be-formed Reelfoot Lake were on the footwall of a great thrust earthquake. Elastic rebound then accounts for their permanent subsidence by several meters relative to their pre-earthquake levels. Similarly, Reelfoot scarp's hanging wall was permanently uplifted. This combination of subsidence and uplift accelerated the town's takeover by the river and created the new lake.

The F1 principal event, with its coseismic faulting of the Mississippi riverbed on RF and large aftershocks on RS, was the culminating episode of the 1811-12 New Madrid sequence. Evidently the huge reservoir of elastic strain energy was finally depleted. Just how and why and at what rate the tectonic strain accumulation took place—and is taking place—is currently unknown. Understanding this process will be the research frontier of the coming decade with global-position-system measurements and improved knowledge of crustal composition, structure and rheology the principal tools.

We have presented a faulting scenario for the 1811-1812 New Madrid earthquakes that is consistent with the available historical, geological and seismological evidence. This evidence—compiled primarily within the past two decades—to a large measure confirms the past anecdotal reports of the dramatic effects of the earthquakes on the land and the river of the central Mississippi Valley. The seismic moment release of this earthquake series probably equals or exceeds one total of the continental western United States in historic times. How this can be when the New Madrid seismic zone lies deep within the stable midplate crust of North America remains an enigma.

Addendum. The above faulting scenario in not consistent with the recent results of Newman *et al*. (1999) "Slow Deformation and Lower Seismic Hazard at the New Madrid Seismic Zone" [*Science*, vol. 284, p. 619-621, 23 April 1999] who used six years of Global Positioning System (GPS) measurements to infer lower magnitudes and/or longer recurrence times—hence lower hazard—than estimated here. Their data's uncertainties, however, were too large to resolve the true deformation rate in the NMSZ. Moreover, they model the NMSZ as an infinitely long plate boundary, which would distribute and dilute the expected strain concentration within the NMSZ. Until the uncertainties are reduced significantly, GPS studies such as Newman *et al*. provide little useful constraint regarding 'What Really Happened in 1811-1812 and Could It Happen Again?'.

Acknowledgments
This paper is abridged and updated from A. Johnston and E. S. Schweig, "The Enigma of the New Madrid Earthquakes of 1811-1812," *Annual Reviews of Earth and Planetary Sciences*, V. 24, p. 339-384, 1996. I thank Buddy Schweig for the updated paleoliquefaction results.

References

Bedinger D. 1812. Journal excerpts. In National Intelligencer, 14 March 1812 issue, Washington DC; also Farmer's Repository, 28 Feb. 1812 issue (different account)

Berry D. 1908. The Illinois earthquake of 1811 and 1812. Trans. Ill. State Hist. Soc. 12:74-78

Bollinger GA, Chapman M, Sibol M. 1993. A comparison of earthquake damage areas as a function of magnitude across the United States. Bull. Seismol. Soc. Am. 83:1064-80

Bradbury J. 1817. Travels in the Interior of North America in the Years 1809, 1810 and 1811. Sherwood, Neely and Jones, London; reprinted 1966 in March of America Facsimile Series Ann Arbor, MI: Univ. Microfilms, Inc.

Braunm M. 1896. Narrative. In History of Dunklin County, Mo. 1845-1895, Smyth-Davis MF, pp. 15-18. St. Louis: Nixon-Jones

Bringier L. 1821. Notices of the geology, mineralogy, topography, production, and aboriginal inhabitants of the regions around the Mississippi and its confluent waters. Am. J. Sci. 3:15-46

Bryan E. 1848. Letter written in 1816. In The History of Cosmopolite; or, the Four Volumes of Lorenzo Dow's Journal. Wheeling, VA: Joshua Martin

Burke K, Dewey, JF. 1973. Plume-generated triple junctions: Key indicators in applying plate tectonics to old rocks. J. Geol. 81:406-433

Cramer Z. 1814. The Navigator. Pittsburgh, PA: Cramer, Spear and Eichbaum, 215 pp. 8th ed.

Davis, J. 1812. Letter. In Otsego Herald [New York]. 28 Mar. 1812 issue

Davison 1936. Great Earthquakes. London: Thomas Murby. 286 pp.

Ervin CP, McGinnis LD. 1975. Reelfoot rift: Reactivated precursor to the Mississippi embayment. Geol. Soc. Am. Bull. 86:1287-95

Fletcher J. 1812. Narrative dated Jan. 21, 1811. In Pittsburg Gazette, Feb. 14, 1812 issue

Frankel A. 1994. Implication of felt area-magnitude relations for earthquake scaling and the average frequency of perceptible ground motion. Bull. Seismol. Soc. Am. 84: 462-65

Fuller ML. 1912. The New Madrid Earthquakes. U.S. Geol. Surv. Bull. 494. 119 pp.

Garrett WE, ed. 1988. Historical Atlas of the United States. Washington DC: Natl. Geogr. Soc.

Gomberg J. 1992. Tectonic deformation in the New Madrid seismic zone: Inferences from boundary-element modeling. Seism. Res. Lett. 63:407-26

Hanks TC, Johnston AC. 1992. Common features of the excitation and propagation of strong ground motion for North American earthquakes. Bull. Seismol. Soc. Am. 82:1-23

Hanks TC, Kanamori K. 1979. A moment magnitude scale. J. Geophys. Res. 84:2348-50

Johnston AC. 1996a. Seismic moment assessment of earthquakes in stable continental regions—I. Instrumental seismicity. Geophys. J. Int. 124: 381-414

Johnston AC. 1996b. Seismic moment assessment of earthquakes in stable continental regions—II. Historical seismicity. Geophys. J. Int. 125: 639-78

Johnston AC. 1996c. Seismic moment assessment of earthquakes in stable continental regions—III. 1811-1812 New Madrid, 1886 Charleston, and 1755 Lisbon. Geophys. J. Int. 126: 314-44

Johnston AC, Coppersmith KJ, Kanter LR, Cornell CA. 1994. The Earthquakes of Stable Continental Regions: Assessment of Large Earthquake Potential. EPRI Rep. TR-102261, ed. JF Schneider. Palo Alto, CA: Elect. Power Res. Inst., 309 pp.

Johnston AC, Shedlock KM. 1992. Overview of research in the New Madrid seismic zone. Seismol. Res. Lett. 63:193-208

Kanamori H. 1977. The energy release in great earthquakes. J. Geophys. Res. 82:2981-87

Keefer DK. 1984. Landslides caused by earthquakes. Geol. Soc. Am. Bull. 95:406-21

La Roche F. 1927. letter dated Feb. 20, 1812. In A Sailor's record of the New Madrid earthquake. Missouri Hist. Rev. 22:268-70

Lesieur G. 1874. Letter dated 1871 to A D Hagar, former State Geologist of Missouri. In Campbell's Gazetteer of Missouri, p. 394. St. Louis: RA Campbell

Lexington Reporter. 1812. Extracts from a letter to a gentleman in Lexington, from his friend at N. Madrid (U. L.) dated 16th Dec. 1811. Lexington KY, Feb. 1, 1812 issue

Nolte V. 1854. Fifty Years in Both Hemispheres or, Reminiscences of the Life of a Former Merchant. London: Trubner

Nuttli OW. 1973. The Mississippi Valley earthquakes of 1811 and 1812; intensities, ground motion, and magnitudes. Bull. Seismol. Soc. Am. 63:227-48

Nuttli OW. 1983. Average seismic source-parameter relations for mid-plate earthquakes. Bull. Seismol. Soc. Am. 73:519-35

Nuttli OW, 1987. The effects of earthquakes in the central United States. Report for Central U.S. Earthquake Consortium, Memphis TN, Fed. Emer. Mgmt. Agency. 33 pp.

Nuttli OW, Bollinger GA, Griffiths DW. 1979. On the relation between modified Mercalli intensity and body-wave magnitude. Bull. Seismol. Soc. Am. 69:893-909

Obermeier SF. 1988. Liquefaction potential in the central Mississippi valley: U.S. Geol. Surv. Bull. 1832 21 pp.

Obermeier, SF. 1989. The New Madrid earthquakes: an engineering-geologic interpretation of relict liquefaction features. U.S. Geol. Surv. Prof. Paper 1336-B, 11 plates, 114 pp.

Odum JK, Stephenson WJ, Shedlock KM, Pratt TL 1998. The February 7, 1812, New Madrid, Missouri, earthquake: A structural model, derived from geomorphic and seismic data, for surficial deformation within a stepover zone. Geol. Soc. Am. Bull. 110: 149-62

Penick JL. 1981. The New Madrid Earthquakes. revised edit., Univ. Missouri Press, Columbia, Missouri, 176 pp.

Pierce WL. 1812. Letter dated Dec. 25, 1811. In New York Evening Post, 11 Feb. 1812 issue

Richter CF. 1958. Elementary Seismology. San Francisco: Freeman. 768 pp.

Ritchie, J. 1859. Narrative of an eye-witness. In The Earthquake of 1811 at New Madrid, Missouri. Ann. Rpt. of the Board of Regents of the Smithsonian Institution, T. Dudley, correspondent, pp. 421-24, Washington DC: WA Harris

Roddell G. 1812. narrative statement. See Lexington Reporter,1812

Russ DP. 1982. Style and significance of surface deformation in the vicinity of New Madrid, Missouri. In Investigations of the New Madrid, Missouri, Earthquake Region, U.S. Geol. Surv. Prof. Pap. 1236-H, ed. FA McKeown, LC Pakiser, pp. 95-114.

Schweig ES, Ellis MA. 1994. Reconciling short recurrence intervals with minor deformation in the New Madrid seismic zone. Science 264: 1308-11

Schweig ES III, Marple RT. 1991. The Bootheel lineament: a possible coseismic fault of the great New Madrid earthquakes. Geology 19: 1025-28

Schweig ES, Van Arsdale RB, 1996. Neotectonics of the upper Mississisppi embayment. Engr. Geol. 45: 185-203

Shaler W. 1815. letter dated March 23, 1812. See Mitchell 1815, pp. 300-02

Shaw J. 1912. New Madrid earthquake. Account of Col. John Shaw. Missouri Hist. Rev. 6:91-92

Singh S, Herrmann RB. 1983. Regionalization of crustal coda Q in the continental United States. J Geophys. Res. 88:527-38

Speed M. 1812. letter dated March 3, 1812. in Pennsylvania Gazette. March 18, 1812 issue

Stover CW, Coffman JL. 1993. Seismicity of the United States, 1568-1989 (revised). U.S. Geol. Surv. Prof. Paper 1527. 418 pp.

Street R, 1982. A contribution to the documentation of the 1811-1812 Mississippi valley earthquake sequence. Earthq. Notes 53(2):39-52

Street R, 1984. The Historical Seismicity of the Central United States: 1811-1928. Final report, contract 14-08-0001-21251, U. S. Geol. Surv., Append. A. 316 pp.

Street R., Nuttli O. 1984. The central Mississippi Valley earthquakes of 1811-1812. in Proceedings Symposium on "The New Madrid Seismic Zone." U. S. Geol Surv. Open-File Rpt. 84-770, pp. 33-63

Van Arsdale RB, Kelson KI, Lumsden CH. 1995. Northern extension of the Tennessee Reelfoot scarp into Kentucky and Missouri. Seismol. Res. Lett. 66: 57-62

Wheeler R, Rhea S. 1994. Map showing surficial and hydrologic features in the vicinity of New Madrid, Missouri. U. S. Geol. Surv. Misc. Field Studies Map MF-2264-E

Youd TL, Perkins DM, Turner WG. 1989. Liquefaction severity index attenuation for the eastern United States. In Proceedings from the Second U.S.-Japan workshop on liquefaction, large ground deformation and their effects on lifelines, ed. TD O'Rourke, M Hamada, 438-52. Buffalo, New York: National Center for Earthquake Engineering Research Tech. Rep. NCEER-89-0032

Will New Hazard Maps Lower or Raise the Hazard?

R. B. Herrmann, A. Akinci and R. Ortega
Department of Earth and Atmospheric Sciences
Saint Louis University
3507 Laclede Avenue
St. Louis, MO 63103
Email: rbh@eas.slu.edu

Summary

Yes!

Introduction

Earthquake loss estimation is hardly an exact science! The reason is simple - the lack of experience.

The state-of-the-art for earthquake loss estimation maps expected ground shaking into loss through an inventory of affected structures. This simple statement of the process glosses over the lack of knowledge inherent in the procedure.

The estimation of earthquake ground motion has advanced significantly since the inception of the NEHRP program 2 decades ago. Better instrumentation, accumulated recordings of ground motion, better understanding of earthquake physics and the expected recurrence rates of earthquakes have permitted improved estimates of expected ground motion in terms of peak acceleration, velocity or response spectral ordinates. The confidence in these estimates permits detailed mathematical modeling of structural response and inference of damage thresholds. The improved estimates are also accompanied by an awareness of what is not known because of the lack of data.

The mapping of ground motion into damage is imprecise. One current approach is to map quantitative ground motion expectations into the qualitative intensity value. This is appealing since the intensity measure describes damage. The Modified Mercalli Intensity (MMI) scale from I-XII is used in the United States, with an intensity VI indicating the threshold of structural damage and VIII indicating significant damage. The vagaries of earthquake ground motion is that many levels of ground motion may be associated with a given intensity level (Wald et al , 1999) because of local site perturbations of ground motion, physics of elastic wave generation at the source and its propagation over long distances to the site, and of course the specifics of the structure affected. Bollinger (1977), for example, observed that there is no simple relation between observed intensities as a function of distance from the source - the observations as a function of distance form a distribution with a mean and a variance. This observation is important if regional historical intensity data are used in a loss estimation model - use of published isoseismals (contours of intensity limits) may be biased toward overestimating the effect of shaking.

The last aspect of the process is that of inventory. This may be the most sophisticated component of current loss estimation. GIS techniques can easily incorporate local site conditions, building inventory, and permit rapid computation of loss given the estimate of shaking and mapping that shaking into damage. However, the numbers arising from the procedure are a function of these caveats. In addition the use of overlays for estimating local site effects is a non-linear process that may not be valid.

Earthquake loss estimation is not an exact science!

1996 NEHRP Maps

Work by Frankel *.et al.* (1996) are the basis of current recommended NEHRP provisions for seismic design (FEMA, 1997). The probabilistic seismic hazard maps are a synthesis of current knowledge on ground motion scaling with distance and earthquake size and expectations of earthquake locations and repeat times. The products so developed are readily available from

http://geohazards.cr.usgs.gov/eq/

The maps and tabular data made available by the U.S. Geological Survey are to be used with FEMA-273 (FEMA, 1997) to define response spectral shapes for evaluation of structures. Procedures are given to adjust the map values for local geological site conditions. Because these are a national level mapping effort, regional variations in seismic hazard can be focussed upon for further study.

Because of the differences between previous maps and the current 1996 maps in the central United States, the Mid-America Earthquake (MAE) Center is examining the assumptions that went into the current maps.

Sensitivity Studies

The 1996 NEHRP estimates of expected ground motion in the central United States makes critical assumptions about the earthquake process and ground motion propagation. The issues affecting expected motions are as follow, in order of approximately decreasing importance:

- Deep soil effects
- Maximum magnitude earthquake for New Madrid
- Repeat times of large earthquakes
- Spectral scaling of earthquakes
- Regional seismic wave propagation
- Completion of earthquake catalog

Deep soil effects:

Deep soil deposits are not unique in the United States, but the relatively flatness of the deposits in this region have only a few analogs inthe nation. Figure 1 indicates the thickness of deep fluvial deposits in the region. The effect of the deep soils is a result of two competing features: low material strength will increase the surface motion but the greater thickness of the soil column absorbs more energy. FEMA-273 (FEMA, 1997) has correction factors to be applied to the 1996 NEHRP maps, but cautions for site specific studies for very deep soil sites.

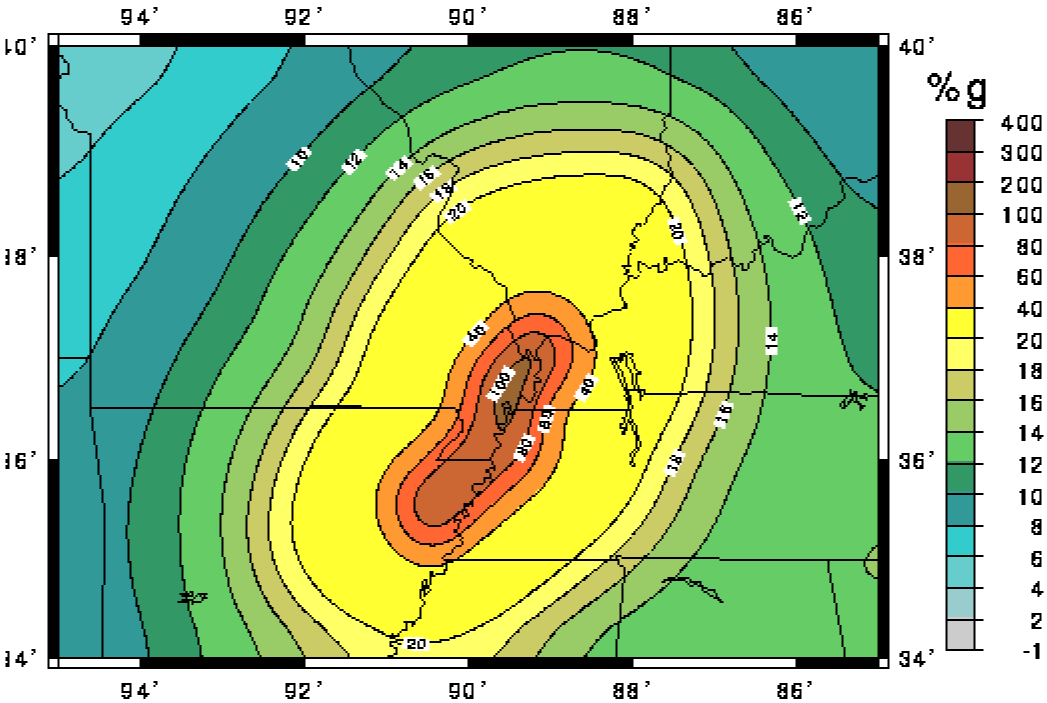


Fig. 1. Prototype deep soil thickness map for the Mississippi Embayment. Thickness in meters.

Figures 2 - 5 illustrate these tradeoffs. Figure 2 gives the 1996 NEHRP peak ground acceleration values with a 2% in 50 year expectation of being exceeded while Figure 3 gives the motions for the prototype deep soil model. The slight differences outside of the Mississippi Embayment are due to the fact that the 1996 NEHRP map as a uniform soil and Figure 3 has hard rock. At a site within the Embayment, such as Memphis, the deep soils reduce the peak acceleration. In addition, the pattern of iso-acceleration is no longer as symmetric.

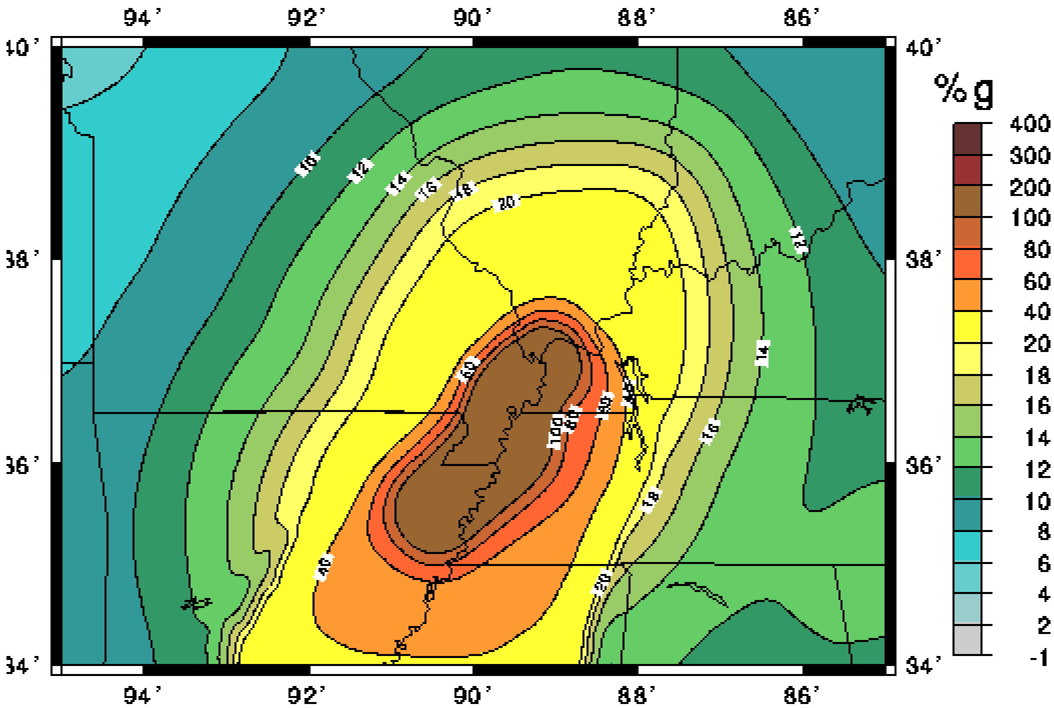


Fig. 2. 1996 NEHRP Peak acceleration map for 2% in 50 year exceedence.

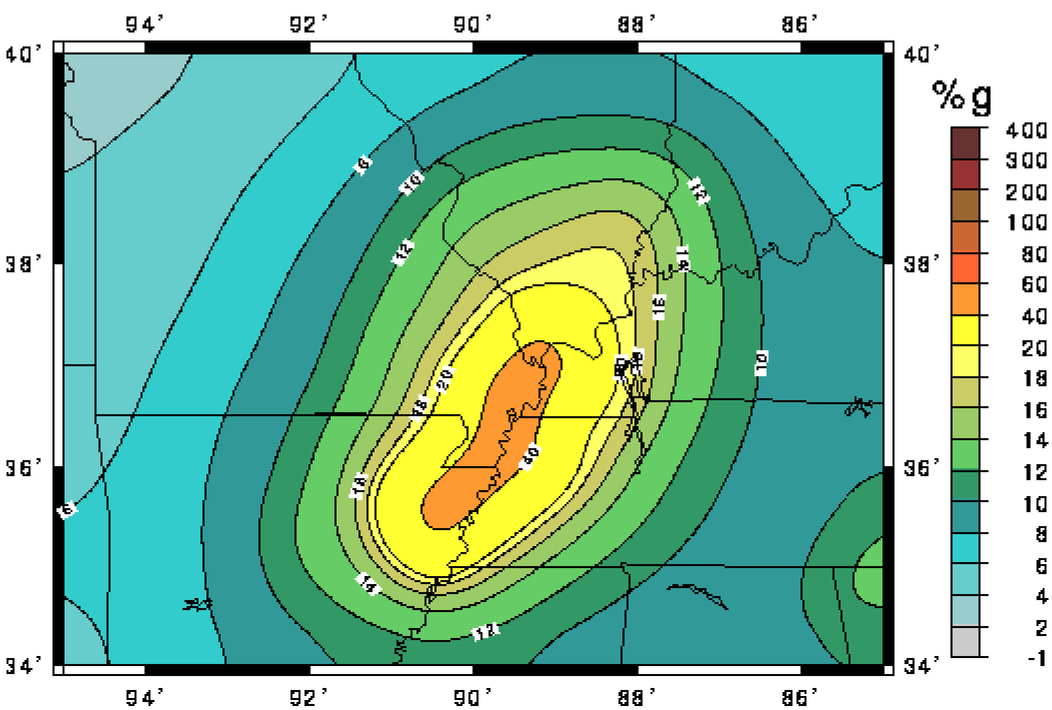


Fig. 3. Prototype Peak acceleration map for 2% in 50 year exceedence.

Figure 4 gives the 1Hz pseudo-acceleration spectra values for the 1996 NEHRP maps while Figure 5 gives the corresponding values for the deep soil model. In this case the deep soil column amplifies low frequencies more.

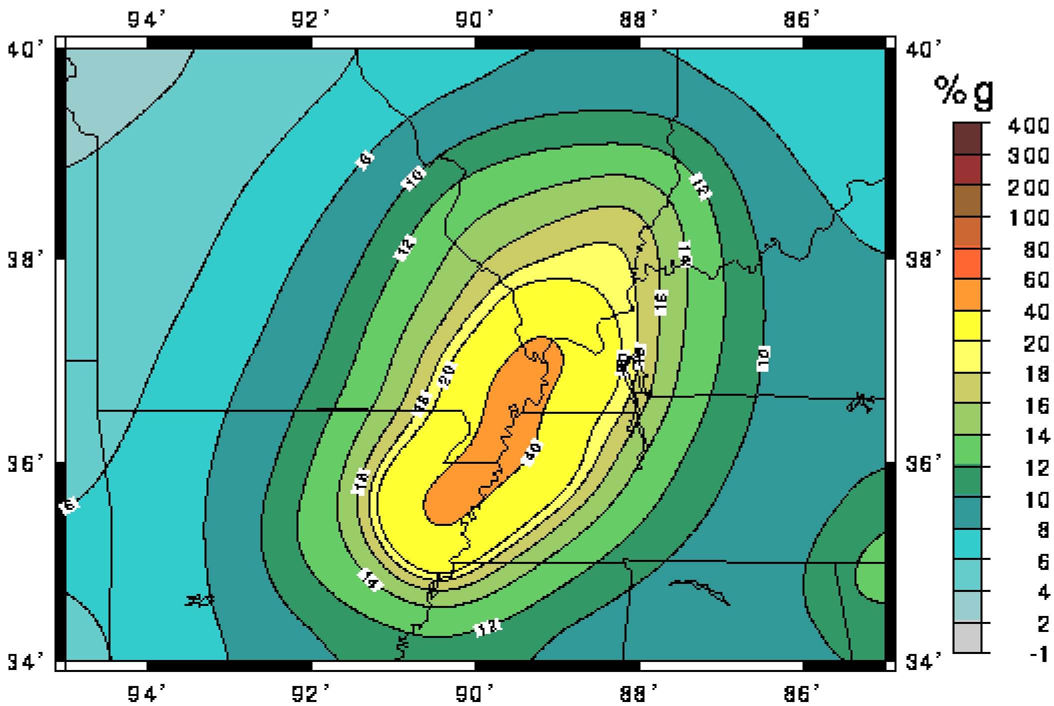


Fig. 4. 1996 NEHRP 1.0 Hz Pseudo-acceleration for 2% in 50 year exceedence.

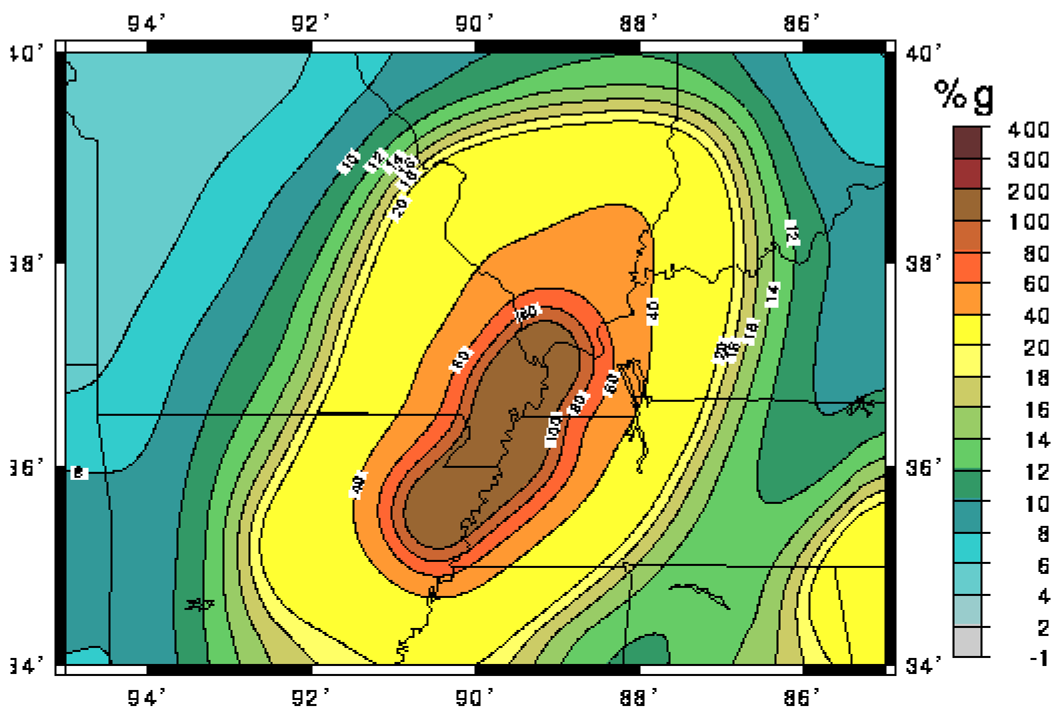


Fig. 5. Prototype 1.0 Hz Pseudo-acceleration for 2% in 50 year exceedence.

Maximum magnitude

The sizes of the 1811-1812 earthquakes is controversial because they are indirect estimates from the intensities or from liquefaction effects. The sizes of the large earthquake matter because they control the expected motion for annual probabilities on on the order of the repeat times of these large earthquakes. Thus the effect will be seen strongly on the 2% in 50 year maps. The current 1996 NEHRP maps assume a M_{max} = 8.0 for the repeat time of the characteristic 1811-1812 New Madrid earthquakes. To illustrate this effect, Figures 6 and 7 present the results of using the 1996 NEHRP parameters, changing only the value of M_{max} = 8.0 for the characteristic New Madrid earthquake to the low value of 7.0.

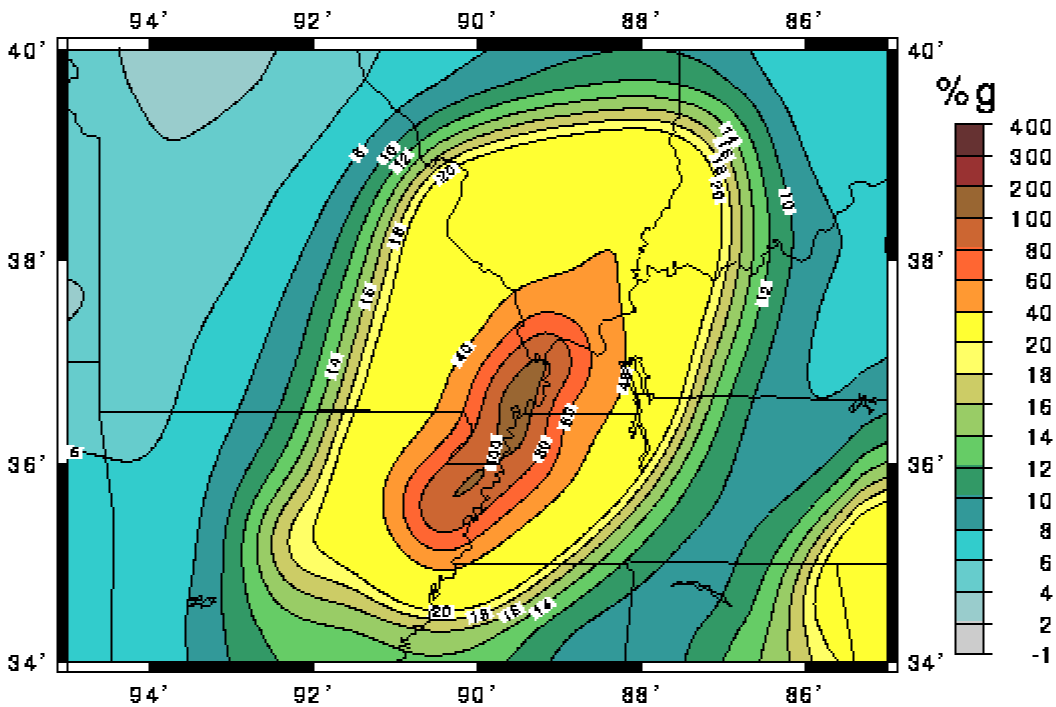


Fig. 6. 1996 NEHRP PGA for 2% in 50 year exceedence and M_{max}=7.0.

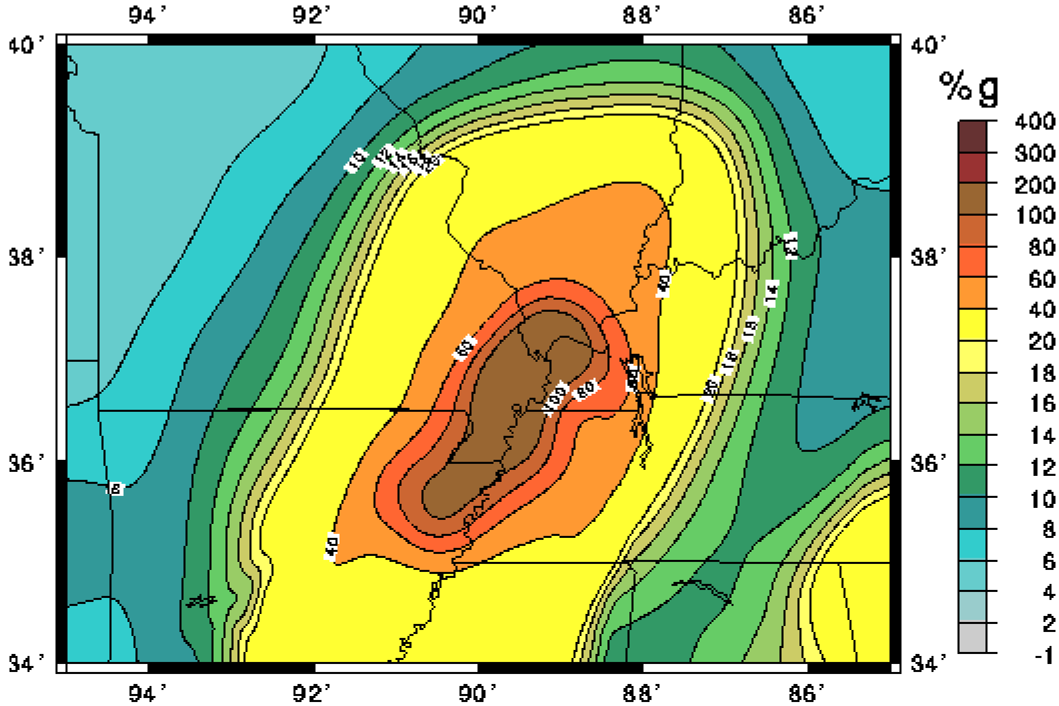


Fig. 7. 1996 NEHRP 1.0 Hz Pseudo-acceleration for 2% in 50 year exceedence and M_{max}=7.0.

Comparing Figure 6 to Figure 2, we see that the effect of drastically decreasing the size of the maximum New Madrid earthquake is to reduce the peak acceleration at Memphis by about a factor of 1.5. The level of motion is still high enough to cause damage. On the other hand, for locations a large distance from New Madrid, such St. Louis, there is no change. This is because the peak acceleration is typically controlled by nearby earthquake sources.

For the 1.0 Hz spectral acceleration, the motions at Memphis are reduced, as are those at St. Louis, by a factor of about 1.5.(comparing Figures 4 and 7). At this hazard level, the size of the New Madrid earthquake affects the entire region.

Other factors

The repeat times of major earthquakes, scaling of earthquake ground motion with earthquake size, differences between propagation to large distances between that assumed in the the NEHRP maps and the completeness of the earthquake catalog are other factors that affect the hazard maps. The MAE Center has projects addressing these issues and will work with USGS researchers in refining these parameters.

Relevance

The MAE Center probabilistic seismic hazard maps are meant to carefully evolve from the 1996 NEHRP maps. All steps will be documented so that deviations from the 1996 maps are justified.

The efforts of the MAE Center are directed toward reducing uncertainty. In addition the MAE Center efforts complement the internal and external USGS research programs in the New Madrid

Seismic Zone. This task is not taken lightly, since the numbers resulting from these computations have economic significance.

The MAE Center is aware of the needs of the insurance community. Certainly cooperative efforts are required. Additional work is required to address the weak points in loss estimation - the relation between ground shaking and damage, especially for the midwest. Within the lifetime of this Center, a significant earthquake will occur in the region whose effects should be extensively documented.

References

Bollinger, G. A. (1977). Reinterpretation of the intensity data for the 1886 Charleston, South Carolina, earthquake, in *Studies Related to the Charleston, South Carolina, Earthquake of 1886 - A Preliminary Report*, *U. U. G. S. Professional Paper 1028,* pp 17-31.

FEMA (1997). *NEHRP Guidelines for the Seismic Rehabilitation of Buildings*, *FEMA-273*, Washington, DC.

Frankel, A., C. Mueller, T. Barnhard, D. Perkins, E. V. Leyendecker, N. Dickman, S. Hanson and M. Hopper (1996). National Seismic-Hazard Maps: Documentation June 1996, *USGS Open-File Report 96-532*

Wald, D. J., V. Quitoriano, T. H. Heaton and H. Kanamori (1999). Relationships between peak ground acceleration, peak ground velocity and Modified Mercalli Intensity in California, *Earthquake Spectra*, in press.

Seismic Design Requirements of the Future

Gerald H. Jones, P.E.

Chairman
Multihazard Mitigation Council of the National Institute of Building Sciences

Abstract

With the anticipated publication of the International Building Code (IBC) in January, 2000, cities and other jurisdictions in the United States will have a single model building code available for adoption for the first time. An historic meeting of the memberships of the three building code organizations will take place in St. Louis from September 12th through September 18th, at when the International Building Code is to be approved for publication. The existing three building codes, the National Building Code (NBC) published by the Building Officials and Code Administrators (BOCA), the Standard Building Code (SBC) published by the Southern Building Code Congress (SBCC) and the Uniform Building Code (UBC) published by the International Conference of Building Officials (ICBO), will no longer be updated or promulgated.

The seismic design provisions of the existing three existing codes are also divergent, with the UBC based on the "Blue Book" published by the Structural Engineers Association of California (SEAOC), and the NBC and SBC based on earlier versions of the National Earthquake Hazard Reduction Program (NEHRP) Design Provisions published for the Federal Emergency Management Agency (FEMA) by the Building Seismic Safety Council (BSSC).

With the publication of the IBC-2000, seismic design provisions will be based on the latest edition of the NEHRP Provisions adapted for regulatory use.

These design provisions represent the "state of the art" and incorporate new calculation methods and design maps. "Soil factors" have a major impact on the new designs, and the first new seismic maps in 25 years are a critical element in the use of the code.

Communities such as St. Louis and Memphis with potential for significant ground motion and having large areas of poor soils will be required to improve construction practices, while large portions of the United States with relatively good soils and low seismicity will have lesser requirements.

Introduction

The enforcement of a code requires that it be adopted as a legal document setting forth the minimum legal requirements for construction to satisfy the health, safety and general welfare of the public. It is therefore desirable to briefly review some of the historical background of code development and a few of the forces that have influenced code development in the past and will probably continue to do so. This paper will also look at the use of performance based experience in other portions of the building codes and learn from the successes and failures. Since administration and enforcement of codes depends very heavily on accountability and responsibility of the project participants, there is a need to take a look at the responsibilities of the participants in the total building process from inception to long range maintenance of the constructed project.

History

The use of codes dates back to about 1700 BC, when the Code of King Hammurabi in Babylonian stated performance in an extremely simple and blunt manner -- build a house strong enough to avoid killing its owner, or die!

Noah was instructed to build the ark in a very prescriptive manner. Gopher wood was specified as the basic material, while the dimensions, exits; light and ventilation were clearly prescribed.

The collapse of a wooden amphitheater in Rome in about 27 AD, resulted in the banishment of the designer from Rome and all of Italy. New regulations were adopted for places of assembly.

Thatched roof fires and highly combustible construction in London in 1189, inspired Lord Fitz-Elyne to enact strict prescriptive roof covering and firewall requirements. Lack of enforcement allowed the "great fire" of 1666 to destroy the city.

Following a fire in Boston in 1630 that ignited neighboring homes, the Governor issued an order prohibiting the construction of chimneys made of wood and of thatched roofs.

Theater fires in New Orleans and Chicago resulted in prescriptive requirements for curtains and for periodic fire inspections.

The Triangle Shirt Waist fire brought specific exiting and panic hardware rules.

The Coconut Grove nightclub fire demonstrated the need for flame spread restrictions as well as enforcement of exit regulations.

Simply passing a law seldom makes anything change! Regulations must be accompanied by responsible enforcement!

Code Development

The International Building Code was developed by several sub-committees consisting of equal membership or the three existing code organizations. Each sub-committee was responsible for specific topics as follows:

General Subcommittee – Administration, Interior Environment, Electrical, Mechanical, Plumbing, Elevators, Special Construction and reference Standards
Fire Safety Subcommittee- Fire resistance of materials, fire protection, Plastics
Means of Egress Subcommittee – Egress and Accessibility
Occupancies Subcommittee – Use and Occupancy, Special Uses and Height and Areas
Structural Subcommittee – Structural design, Loads and Properties of Materials of Construction

Development Process

Each Subcommittee developed a draft document based primarily on existing code text in one or more of the existing codes. Where text conflicted, the committee resolved the conflicts, usually by majority vote. In selected cases, drafts were submitted, by invitation, by either material interests or by coalitions of design experts.

The draft seismic provisions were, by invitation, developed by the Code Resource Development Committee (CRDC) of the Building Seismic Safety Council with funding from the Federal Emergency Management Agency. The CRDC was created from representatives of the development team that published the 1997 edition of the National Earthquake Hazard Reduction Program (NEHRP) Design Provisions, building officials from the three existing code groups, the Structural Engineers Association of California and the American Society of Civil Engineers.

The draft code provisions were submitted to several public hearings, where the various Subcommittees heard testimony, made revisions to the draft for subsequent hearings. The last hearings were held March 15 to 26, 1999 in Costa Mesa, CA. The final reports of the committees were published in April 1999 with a deadline for public comments of June 18, 1999.

The final consideration for the 2000 edition of the code will be conducted in St. Louis on September 12 to 17, 1999.

The code is expected to be published and ready for adoption in early 2000.

Adoption

The adoption of a code is a political process. The typical citizen gives little or no thought to the details of construction of the structures, in which he and his family live and work. The presumption is that everything must be safe, or it would not be allowed to be built. Only after failures do the citizens become conscious of building safety and demand to know who "let this happen". That awareness diminishes in proportion with time following an event. A subdivision constructed on poor soil in Anchorage, Alaska was devastated by an earthquake thirty years ago. Memories are short and the subdivision is now being rebuilt in the same location.

Elected officials respond to public reaction to disasters by passing stringent laws so that "it will never happen again". Often, regulations hastily enacted in time of stress are not sufficiently researched and are unreasonably restrictive. Since these reactions are driven initially by the loss of life and property, they tend to focus on fixing the problems at hand. Some examples are banning the use of a specific material such as unreinforced masonry in high risk seismic zones, or mandating the installation of certain safety devices such as fire sprinklers in high rise buildings.

The published model code is simply a book until it is legally adopted by a jurisdiction. The jurisdiction may be any unit of government from an entire state to a small village or fire protection district.

The process usually requires the jurisdiction to prepare an adoption ordinance which enumerates the specific model document to be adopted, specific design loads selected from the model maps or tables appropriate to the geographical location, any administrative amendments appropriate to local or state law, and if deemed necessary by the local community, amendments to technical provisions.

Public hearings are conducted and the legislative body enacts the required ordinance to adopt the model code.

Some local amendments are necessary and beneficial, such as communities located where the national maps designate a "Special Hazard area" due to local conditions such as heavy snow, canyon winds and wild fire hazards.

Other local amendments are due to pressures from material suppliers such as a brick factory, a cement plant or other source of local employment. Some communities are subject to pressures from developers, unions or other politically powerful interests.

Such local amendments are the source of frustration to design professionals who work nationally or across jurisdictional boundaries.

My observation after 25 years as a local building official is that few citizens respond to notices of the public hearings and that the vested interests frequently are successful in influencing the adoption process. Insurance interests – either as individual citizens or as an industry –are missing an opportunity to influence the quality of construction (and the extent of risk) in each community.

Performance Based Codes

Design professionals have for years advocated greater use of "performance codes" in contrast to the more common "prescriptive codes".

The International Code Council has created a Building Performance Code Committee and a Fire Performance Code Committee to develop a "Performance Code" which can be used as an alternate to the International Building Code. They have published the Intent, Scope and Performance structure for developing performance provisions. They have developed structure and linkage between topics and objective standards. They have accepted numerous objectives, functional statements, and performance requirements have published "Guidelines for Use of ICC Performance Code.

The committee is basing their proposed Seismic Provisions on "Vision 2000" developed by the Structural Engineers Association of California, and the designer will be expected to:

Specify Performance Requirements
Define Earthquake Hazard Design Levels
Define Performance levels
Define Seismic Hazard Exposure Group

The committee continues to meet about every 60 days and intends to hold Update and Comment Sessions on the Performance Code in mid November 1999

Previous experience with performance based regulations

Many efforts that began with a goal of implementing performance based requirements stumbled over the ability to measure performance and to know when the goal had been achieved. For example the performance goal of keeping "smoke controlled" in the new covered mall shopping centers in 1975 soon became measured in prescriptive numbers of air changes. Control of "flame spread" became measured by the use of tested components with restrictions on the classes of flammability allowed in various areas in the building. The predicted building performance in a fire is assumed from the use of many tested and listed components and assemblies. The construction of each of those "assemblies" is very carefully prescribed from the results of detailed and extensive testing. The use of "heavy timber" construction is prescriptive in detail since experience has shown that the structural frame of such buildings retains a safety margin of strength while it is slowly being consumed. Thus, while it is not "one hour rated" construction, it is permitted to be used in most instances where one hour ratings are required, entirely due to its proven performance.

Existing authority to use alternate methods and materials.

All of the current model building codes have provisions for acceptance of alternate methods of construction or approval of engineered systems which follow very specific and generally easy to follow procedures.

Section 105 of the Uniform Building Code contains the following language, which is similar to, if not exactly the same language found in the Standard Code and the National Code:

"The provisions of this code are not intended to prevent the use of any material or method of construction not specifically prescribed by this code, providing any alternate has been approved and its use authorized by the building official.

The building official may approve any such alternate, provided he finds that the proposed design is satisfactory and complies with the provisions of this code and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in suitability, strength, effectiveness, fire resistance, durability, safety and sanitation.

The building official shall require that sufficient evidence or proof be submitted to substantiate any claims that may be made regarding its use. The details of any action granting approval of an alternate shall be recorded and entered in the files of the code enforcement agency."

To assist in the evaluation of products and assemblies, the Underwriters Laboratories was created by the insurance industry to provide a non-profit, non biased and credible source of data.

Other insurance interests created the Factory Mutual system to research, test and evaluate products, systems and designs for fire safety.

The model code organizations have established "Evaluation Services" to evaluate new products, assemblies and technical services to respond to the need of their member jurisdictions.

These provisions are not the same as those setting forth procedures for "variances" or "appeals". A variance may also be utilized when it becomes necessary to involve an appointed group of citizens sitting as a Board of Appeals and functioning as a safety valve for the building official.

Most of the exciting and unusual structures constructed are the result of collaboration between a confident and talented professional design team and a competent building official who is willing to judge peer reviewed calculations and quality assurance plans utilizing these provisions for alternate methods.

The designers of most of the routine construction projects do not and will not in the future have any interest in performance based provisions.

Measurability

Given the public safety duties and responsibilities previously described, the task of measuring expected performance is one of the most daunting tasks resulting form "performance based" design. City attorneys and building officials must have solid data to justify any departure from the prescriptive provisions of the code. Building Officials are, in fact, paid by our citizens to be **skeptics!**

When I reflect on my nearly 50 years of experience in the construction industry (half in the private sector designing buildings and half as a building official), I often have "second thoughts" about the hundreds of alternate methods and engineered systems for which I have issued permits. Many of these systems I strongly encouraged and sometimes recommended to the Appeals Board. The Board serves as a forum to generate a full discussion of the merits, and their decision is arrived at publicly and a permanent record is generated. The minutes of the Board meeting endure as a permanent record long after the files for a specific building or project have been relegated to permanent storage. I have been gratified when one of those systems experiences an actual emergency and it really works! Unfortunately, some of them do not! It is the review of the failures that guides us in judging future practice.

Define the Performance to be achieved

At the conclusion of a seven year project, FEMA published in October 1997, the NEHRP Guidelines for the Seismic Rehabilitation of Buildings, (FEMA 273). A selection from varying performance objectives for the rehabilitation of existing buildings is now possible. The guidelines offer the owner, designer and the public an informed choice for the extent of rehabilitation, recognizing that triggers in existing codes frequently do not require rehabilitation. Calibration of these new guidelines is now underway through case studies of over 30 existing buildings by a variety of structural engineering firms. Adding to the results of this calibration, we should track the use of the guidelines on actual projects to confirm the validity of the conclusions proposed by the guidelines.

The 1997 edition of the NEHRP Recommended Provisions for Seismic Regulations for New Buildings has begun the process of offering similar choices for new buildings. As the Provisions move through the standards process and become consensus based recommendations to Building Code, co-ordination must be maintained with the IBC Performance Code Committee to assure a seamless integration of provisions as legal minimum levels of safety are determined for adoption in the code.

Define the Qualifications of the Design Professional

Performance based design requires more analysis and demands many more decisions by the designer than conventional design. Every designer holding a license is not necessarily qualified to perform this type of project and the Building Official needs guidance to judge qualifications. A method of certification similar to specialties in the medical profession may be shown to be a practical approach.

Define Designer Responsibilities

The design team has a much broader responsibility to deal with the systems approach of performance based projects. It must be clearly understood from the very beginning of the project exactly who is responsible for every facet of the design and execution.

Define required documentation

From the eyes of a building official, documentation for the use of a non prescriptive method or system must meet the intent of the tests set out by the current code language for "Alternate Materials and Methods of Construction previously quoted. Those procedures rely heavily on the credibility of the calculations, test results of laboratories and the performance history of similar assemblies or systems. A major limitation to this process is that it requires replication for each project and each jurisdiction.

Australia and the United Kingdom have for several years been working to develop "design practice" documents as guides for achieving specific design goals. The guidelines for seismic rehabilitation of existing buildings developed by NIBS/BSSC/ATC/ASCE and recently published as FEMA 273 referenced above, may evolve into just such a design practice document after validation by the trial design process. Similar guide manuals for the design of new buildings may also be a possible tool in the future.

Proper documentation is essential in performance based design to clearly identify the objectives of the analysis, the approach taken, the use of computer tools and techniques and the substantiation of how the objectives are deemed to have been met.

While each project will be unique, consensus should be developed setting forth minimum levels of documentation of such items as soils, site hazards, calculations, proposed testing, computer tools including degrees of uncertainty, and criteria for peer reviewers. Design practice manuals and educational tools must be developed and validated for training programs.

Test Protocols

From a review of the acceptance criteria and evaluation procedures currently in use for products and systems, and looking back at how UL and Factory Mutual were created, it would seem that an expansion of those techniques to serve the proposed performance design goals can be envisioned.

Quality Assurance

Criteria should be agreed upon to measure the quality assurance plan and identify enhancements needed by this more complex construction process. Observed deviations from construction documents may have more far reaching effects on performance objectives than on conventional construction.

Building Maintenance

Lessons from our failures in the past point out the difficulty of sustaining the validity of the original premises of acceptance. Getting special details constructed as designed and drawn is a major challenge in today's construction practice.

Maintenance of special methods and systems is increasingly difficult, if not impossible. How many life safety systems (pressurized stairwells, emergency generators, smoke control systems, voice fire alarm systems, etc.) will perform as designed 5 years and longer after acceptance? For example, what reliability can we expect from the elastomeric materials in base isolation systems after a few years?

How we mandate and achieve maintenance levels to assure that designs and systems will function as designed over long time periods must be developed. The use of deed restrictions, qualified certificates of occupancy and renewable certificates of occupancy should be explored.

Change of Occupancy

When assumptions are made during performance based design about the type of occupancy expected during the life of the building, do we become skeptics and insist on the worst case scenario -- thereby defeating the incentive to use economical assumptions? This has already been a problem with some high rise buildings designed as offices when a change of use to health care is later proposed.

If we design for a specific performance goal, how will we document those restrictions for future generations of building owners and building officials? A walk through a fifteen year old mall shopping center reveals that most of the original conditions of acceptance have long been abandoned, and the mall is no more than additional retail display space.

Repair, Alteration or Addition

Many of the problems associated with change of occupancy discussed above are of equal concern for repair, alteration and additions.

Building additions are generally easier to track and regulate than alterations, since permits are harder to avoid when visible additions are undertaken.

Multitudes of repairs and many alterations are undertaken by maintenance employees with inadequate engineering knowledge to understand the unexpected consequences of repairs and alterations. Architects who design tenant finishes from franchise headquarters often unknowingly compromise carefully designed structures and systems by failing to coordinate with the designer of record.

Conclusion

The principles of performance based codes have been recognized as very desirable for centuries, but the execution of such design and construction has been measured by prescriptive or "deemed to comply" regulations.

The reasons for failure to achieve performance based design and construction are plentiful, but usually fail due to a legal need to determine when the minimum code levels of safety have been attained.

I do not pretend to have solutions to the many problems and pitfalls I have described. My reflections are the result of many years of experience on both sides of the building process. My early career required the submission of alternate methods of construction and design calculations for prefabricated steel buildings long before design practices such as the AISC Plastic Design Manual were published. My later career as a building official exposed me to all levels of design and construction from the ridiculous to the sublime. It is hard not to become a <u>cynic</u> when exposed to some of the atrocious building practices that occur on a frequent basis. As stated earlier, the most exciting part of the job was working with creative designers and enlightened owners to produce unusual and imaginative projects. Many times I was expected to go out on a limb to allow some “unique” design or system. I consistently refuse to go there <u>alone</u>. The designer must be ready, willing and able to go out on that limb “arm in arm” with the building official.

I believe strongly in the need for performance based design, but my practical side tell me that the few projects that will use the new process are similar to the projects already using the current alternate procedure methods.

Regardless of my skepticism, Performance Codes are here to stay and will be used extensively in the future.

The Insurance Industry should take careful note of the potential consequences and work cooperatively to solve the problems related to subsequent changes of occupancy or lack of maintenance.

Future Issues of Seismic Retrofit

J. D. Dolan, Ph.D., P.E.

Associate Professor and Director
Center for Integrated Systems in Housing
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

Abstract

While recent building codes (last 15 – 20 years) have been revised extensively in an effort to address performance problems associated with seismic resistance, they have primarily focused on new building construction rather than existing construction. One reason for this is that new construction is easier to regulate, change, and construct in ways that provide improved performance at a "reasonable" cost. However, the huge volume of existing construction also should be retrofitted when possible to improve the life-safety of the structure and reduce damage associated with seismic events. The cost of loss of life, repair and expenses associated with loss of use can be astronomical when compared to the cost associated with retrofitting buildings to improve performance. While it is politically unattainable to require the retrofit of all buildings with significant seismic risk, many buildings should be considered for retrofit from a pure economic standpoint, while others should be considered from a societal or safety concerns. This paper investigates the issue of retrofitting existing buildings for improved seismic performance, along with what type of knowledge we currently have and what knowledge necessary for effective retrofitting is still missing. The paper also discusses projects that will help increase the knowledge base for retrofit that are currently underway or planned, along with a projection of projects that may be needed to continue to improve the technology available for retrofitting buildings.

In 1997, the National Earthquake Hazard Reduction Program (NEHRP) completed the *Guidelines for the Seismic Rehabilitation of Buildings* and the associated *Commentary*. These *Guidelines* were a significant departure from the previous efforts to write and update the *Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*. With the success of having the *1994 Provisions* adopted by all of the model building codes, and the adoption of the *1997 Provisions* as the basis for the *International Building Code* (IBC) and *International Residential Code* (IRC), NEHRP has now begun to focus on the larger problem of addressing the seismic risk of existing buildings. This paper attempts to outline the major differences between the NEHRP *Guidelines* and *Provisions*. While related in some ways, the two methodologies are fundamentally different in a) their goal, and b) the process to achieve the goal. Finally, the paper discusses some of the issues related to the development of the IRC and the potential for retrofitting residential buildings.

Introduction

Recent building codes (last 15 – 20 years) have been revised extensively in an effort to address performance problems associated with seismic resistance. The motivation for these revisions was 1) loss of life and damage experienced during various seismic events, 2) the economics associated with displaced people, loss of industrial infrastructure, and loss of municipal services resulting from earthquakes, and 3) a presidential order that all buildings associated with the federal government (owned, leased, or insured) be designed and constructed in a seismic resistant manner. Several groups have contributed to the effort. Originally, the Structural Engineers Association of California (SEAOC) lead the process by publishing the "Blue Book". A second effort was initiated by the Applied Technology Council (ATC). This second effort evolved into the National Earthquake Hazard Reduction Program (NEHRP) *Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*. The *Provisions* result from an effort to provide a wider perspective on seismic issues, and includes input from experts from all geographic regions of the United States, and a balanced committee structure including experts from industrial organizations, academics, and designers. The *Provisions* have been adopted as the basis for seismic design by all three model building codes, and the 1997 *Provisions* as the basis for the *International Building Code* (IBC) and *International Residential Code* (IRC).

While these efforts have had a significant effect on the design and construction of new buildings over the past 20 or so years, they have had a minor effect on the rehabilitation of existing construction. The reason is these documents have primarily focused on new building construction rather than existing construction. One reason for this is that new construction is easier to regulate, change, and construct in ways that provide improved performance at a "reasonable" cost. However, the huge volume of existing construction also should be retrofitted when possible to improve the life-safety of the structure and reduce damage associated with seismic events. The cost of loss of life, repair and expenses associated with loss of use can be astronomical when compared to the cost associated with retrofitting buildings to improve performance. While it is politically unattainable to require the retrofit of all buildings with significant seismic risk, many buildings should be considered for retrofit from a pure economic standpoint, while others should be considered from a societal or safety concerns.

A second reason that previous efforts have focused on new construction is that existing buildings were designed under several different methods, and trying to apply the design methods used for new construction does not always result in acceptable designs. Our understanding of how existing structures function is not as advanced as our abilities to model and design new structures.

In 1997, NEHRP completed the *Guidelines for the Seismic Rehabilitation of Buildings* and the associated *Commentary*. This effort was managed by the Applied Technology Council for the Building Seismic Safety Council, and was a process that span six years. These *Guidelines* were a significant departure from the previous efforts to write and update the *Recommended*

Provisions for Seismic Regulations for New Buildings and Other Structures. With the success of having the *Provisions* adopted by all of the model building codes, and the basis for seismic design in the IBC and IRC, NEHRP has now began to focus on the larger and more complicated problem of addressing the seismic risk of existing buildings.

Goals and Procedures

While related in some ways, the two methodologies of analyzing existing buildings and designing new buildings are fundamentally different in a) their goal, and b) the process to achieve the goal. The NEHRP *Provisions* primarily address seismic design using a goal of uniform margin of failure against a maximum earthquake level, and uses Linear Static Procedures to determine the adequacy of the design. (Linear Dynamic Procedures and other advanced analysis are allowed, but Linear Static Procedures are the principle analysis tools.) The *Guidelines* use a suite of analysis procedures to analyze the building, and a combination of applied loads and estimates of deflections are used to determine the adequacy of a building. In addition, the *Provisions* adopted a general risk of 2% chance of exceedance in 50 years for the Maximum Considered Earthquake, with the design earthquake having an amplitude of 2/3 the Maximum Considered Earthquake. In contrast, the *Guidelines* adopted the same definition of the Maximum Considered Earthquake for the seismic event for which collapse is prevented. A second earthquake with a 10% chance of exceedance in 50 years was adopted by the *Guidelines* as the seismic event for which life safety concerns are considered.

The *Guidelines* also consider several design objectives ranging from limited to enhanced performance improvement. Figure 1 illustrates three alternative rehabilitation objectives considered by the *Guidelines*. Limited objectives include simply making the building better than before rehabilitation and may simply be designed to prevent collapse and partial life safety. Basic Safety is intended to provide a low risk of endangerment of life safety for any seismic event likely to affect the building. Enhanced objectives intend to provide a low risk of endangerment of life safety for any event likely to affect the building, and to further protect the building and contents against some level of damage. These goals can be further divided into additional groups depending on how refined the definition of desired performance is.

After the performance level is defined, the rehabilitation design then follows a procedure to define the seismic events to be used in the design, determine the structural integrity of the existing structure, and determine the structure's load and displacement capacity. Acceptance criteria are then compared to determine how much strengthening the structure requires and the location of the additional work. Many times the need to strengthen a will be due to the original structure's inability to sustain the large inelastic deformations associated with seismic loadings. A flowchart showing the process for designing a retrofit for seismic strengthening a building is provided in Figure 2.

Finally, cost will always be of concern in retrofitting a structure. While the added cost associated with seismic design in new construction is relatively small when compared to the

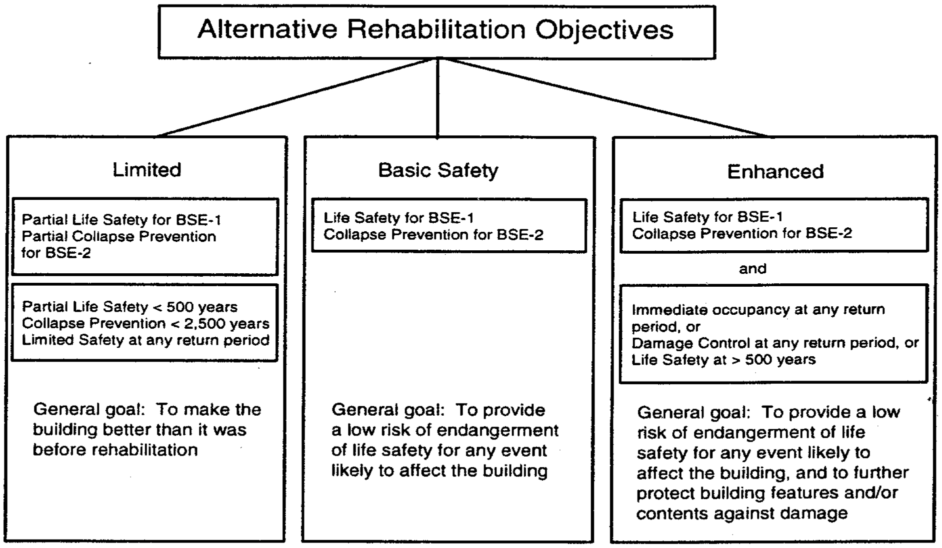


Figure 1. Alternative rehabilitation objectives use in the NEHRP *Guidelines*.

overall cost of the project. Rehabilitation of existing structures with today's technology is almost always expensive. This is due to the inability to access the structural components and add effective ductility of continuity to the structure. Also the higher the performance demanded, the higher the associated cost usually will be. Figure 3 illustrates the concept of how cost is associated with intended performance level. The *Guidelines* then require the designer and client to jointly determine what level of performance the retrofit will use as its objective.

Missing Information

While our society has come quite a long way in developing technology and design tools that have improved our ability to design and construct new buildings that perform well in seismic events, there is a large void of understanding how existing structures behave and how various proposals for retrofitting buildings will improve or harm building performance. Research in the general area of earthquake engineering has primarily focused on large structures such as high-rise buildings and bridges. This is due to the perception of importance of high cost structures justifying significant investigation to ensure good performance and the perception by academics that these large structures are interesting. However, a parameter that is not often acknowledged is that large structures are generally more repetitive in how the structure is planned and therefore easier to analyze with existing tools. Larger structures have also been given priority when instrumented for strong motion measurement. Together, these historical precedents have resulted in a better understanding of how large steel and concrete frame buildings perform, but a virtual void of understanding of how low-rise masonry and light-frame buildings perform. In addition, most of the seismic design procedures are based on the response of high-rise buildings, which may not be indicative of the response of low-rise buildings. When one considers the

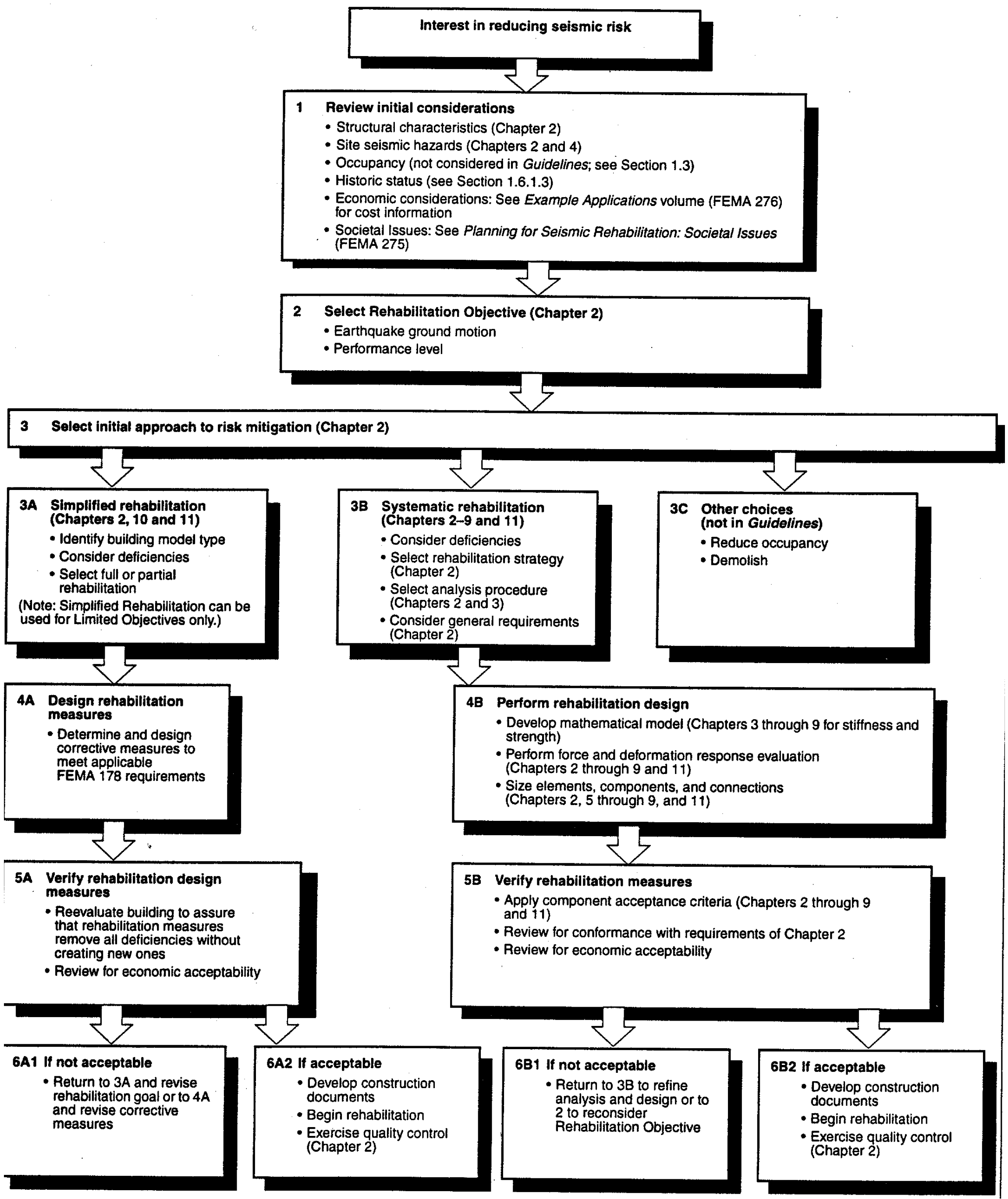


Figure 2. Rehabilitation Design Process Flow Chart.

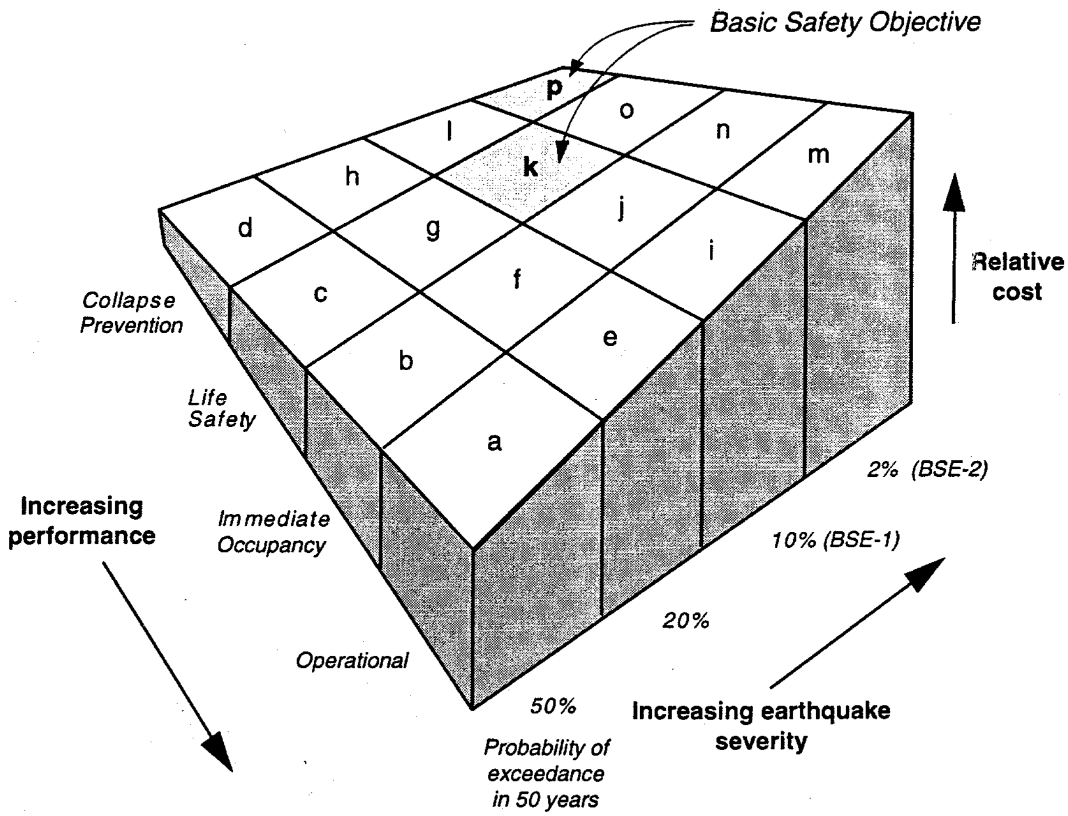


Figure 3. Relation between rehabilitation goal and associated costs.

volume of construction completed in the United States each year for low-rise construction when compared to high-rise construction, the effort expended to date on these two types of construction seem out of line.

Substantial research has been performed to investigate the seismic response of individual components, with associated improvements in design and construction. However, how the different sub-assemblies or components interact and function as a three-dimensional system is not understood well, and as a consequence, the seismic performance of low-rise structures is primarily based on the wall performance. Interelement connections, the effect of flexible foundations associated with upper stories, relative stiffness of diaphragms and shear walls, and the effect of folded diaphragms such as roofs all need to be quantified in order to move design from the component stage to the system stage. In addition, how elements of dissimilar materials respond when forced to act in unison needs to be quantified. Currently, dissimilar material response is not allowed to be considered as additive, and therefore, many of the retrofit methods can not take full advantage of the materials used. This research is required in order to improve either design of new buildings or for retrofit of existing buildings.

Currently, there is one major project underway to investigate the seismic response of low-rise construction. The CUREe – Cal Tech Wood Frame project is a multi-milion dollar research project with the objective to mitigate seismic losses in wood frame construction. This project will include the experimental study of components and full-scale buildings under cyclic and seismic loadings. The project will also begin to develop three-dimensional analytical tools that are validated with the experimental results, and has a duration of three years. Hopefully, this project will provide information on systems other than those typically used in new construction.

Another project is the SAC project for steel framing. While this project is not explicitly directed toward low-rise construction, the results of the project continues to provide significant information on the seismic performance of steel structures, and will improve the understanding of steel structural systems and improve analytical tools for design.

A major shortcoming in the current design procedure is in the way the design forces are determined. Currently, the seismic accelerations are modified by a structural response factor, or R-factor. This factor has traditionally been set using engineering judgment and post event investigations on the performance of structures. However, there is virtually no scientific background to this factor and it could as easily be considered as a calibration factor rather than a rationally determined variable. The Building Seismic Safety Council has funded a small preliminary effort to develop a rational procedure for determining the R-factor. They have developed a proposal that will be forwarded to FEMA and NSF in an effort to obtain funding for a 3 year project to quantify the method and refine it. Current R-factors could easily be to high and the relative values for different systems are also probably not correct. Hopefully, this effort will provide the science needed in the one part of the process that has not had scientific input.

A second effort that is currently being proposed to the National Science Foundation is the establishment of a National Engineering Research Center on Integrated Systems in Housing. This effort will develop design tools that provide a three-dimensional, integrated environment to analyze building performance for light-frame construction. The project will investigate the interaction of different materials and composite systems to achieve improved performance in terms of structural response and other criteria. The effort is lead by the Center for Integrated Systems in Housing at Virginia Tech.

Currently, there is not coordinated effort to investigate the design and/or retrofit of unreinforced masonry structures. While this type of structure makes up one of the larger segments of the current building stock, they also have a reputation of poor performance in seismic events. Little is known on how to retrofit these structures to improve the life-safety and other performance parameters, and there is a real need to begin investigating economic retrofit strategies. This is especially evident when the buildings located in the New Madrid seismic area are considered.

Future Direction of Seismic Design

In the near future, seismic design will continue to be primarily a linear static procedure. With the exception of the R-factor values, the procedure has been effective and will continue to be used by the engineering community for quite a few years to come. The NEHRP *Provisions* is currently adding non-linear procedures in the 2000 edition for comment. They are currently proposed to be added as an appendix, and will be reviewed and updated in the 2003 revision cycle.

Long-term, there are two efforts to change the design procedures for seismic design underway. These include a move to a displacement-controlled method and another is based on energy methods. New Zealand and the NEHRP *Guidelines* both include displacement demand criteria for design, and several of the parties involved in the NEHRP *Provisions* effort have indicated a desire to move the *Provisions* in that direction. Since seismic response is a displacement driven phenomena, this move has some benefits in insuring ductile response.

Energy-based methods for seismic design are in their infancy. A few of the materials groups have begun to fund research on defining parameters for design on an energy basis. The intent is to account for the energy dissipation qualities of some types of construction and to try and account for event duration. Generally, the more ductile and redundant systems will benefit from this type of design, while the brittle materials will not be able to take advantage of the procedures as effectively.

Building Codes

The International Building Code and International Residential Code both use the 1997 edition of the NEHRP *Provisions* as the basis for seismic design. The IBC is intended for engineered construction, while the IRC is intended for prescriptive construction. While the IBC is a step forward, it is not drastically different from any of the three model building codes currently in use. However, the IRC is a dramatic step forward in the area of seismic design.

For the first time the model prescriptive building code will have an engineering basis for the seismic design requirements. The predecessor (CABO One- and Two-Family Dwelling Code) virtually neglected seismic design requirements, and this was the primary reason many of the seismicly active regions of the Western United States did not adopt this code. The IRC adopts the 1999 NEHRP requirements with a few modifications. First, the basis for the seismic loading is the same as the NEHRP *Provisions*, except the default soil condition is D class rather than B class. The seismic maps have also been redrawn to eliminate as many contours as possible and include the soil factor in the map. This allows the designer to simply locate the building site on the map and directly determine the Seismic Design Category. Another change is that the irregularities outlined in the NEHRP *Provisions* for restricting conventional construction have been adopted. If a building design is outside of these irregularity requirements, the irregularity will have to be engineered to ensure the forces are properly accounted for. Finally, weight limitations have been incorporated in the IRC, and one- and two-family detached buildings in locations with Seismic Design Categories A, B, and C are exempt from the seismic requirements.

Providing an engineering basis for the prescriptive building code will help improve the quality of code changes in the future. The rationale for future structural code changes will have to show how the code is deficient in addressing the loading requirements and how the change addresses the change effectively.

How future code changes are made and whether the seismic provisions will remain in the codes or referenced standards or other documents is yet to be decided. There are arguments for both options and both options have benefits and disadvantages. For the near future, seismic provisions will continue to be included in the building code. Changes to the NEHRP *Provisions* will be promoted to the IBC and IRC by the Code Resource Support Committee. This is a committee funded by FEMA, and consists of representatives from Building Seismic Safety Council, the American Society of Civil Engineers, the Structural Engineers Association of California, and a couple of other organizations. The intent is to have proposals for change in seismic provisions made to a group of experts from a variety of organizations and provide discussion from a broad body of interested parties. This allows for a more in-depth discussion of individual proposals and allows issues to be discussed and changes made prior to the short and intense arguments at the building code technical hearings.

The IBC/IRC drafting process highlighted some of the weaknesses in understanding of structural behavior. One of the big areas of misunderstanding is how different materials effect each other. Building construction has evolved through a process of in-kind replacement of elements and components. This process has allowed individual systems and products to optimize their product without regard to the effects on the overall structure. Examples include light-weight floor systems that resulted in safe floors with annoying vibrations, and external insulation systems that resulted in moisture problems in wall systems. In addition, the drafting process highlighted how some of the codes actually conflict in how they try to achieve their respective goals. An example is the energy and structural codes. The energy code provides motivation to replace structural sheathing with sheathing that provides higher insulation characteristics, while the structural code provides motivation for higher amounts of structural sheathing for improved structural performance. There are other issues that require investigation and solutions found, but they are to many in number to address in this format.

Conclusion

While there are dissimilarities between the NEHRP *Guidelines for the Seismic Rehabilitation of Buildings* and *Recommended Provisions for Seismic Regulations for New buildings and Other Structures*, both documents provide guidance in designing buildings to resist earthquakes. The *Provisions* have begun to mature and have been adopted by the model building codes, while the *Guidelines* are still in their infancy. However, both efforts would be more widely applied if incentives rather than mandates were made for their use. Retrofitting buildings can reduce the risk of damage or collapse of buildings, and while quantifying the change in risk might be difficult, insurance is one of the potential motivation tools.

In addition, while our understanding of component response is quite good, there is a real need to investigate the system response in order to quantify the building performance effectively.

Effects of multi-story buildings on component response and the behavior of discontinuous load paths need to investigated in order to reach a level of understanding that will allow seismic design to be effective in reducing risk of damage and loss of life.

References

Building Seismic Safety Council, *NEHRP Guidelines for the Seismic Rehabilitation of Buildings*, FEMA 273, Federal Emergency Management Agency, 1997.

Building Seismic Safety Council, *NEHRP Commentary on the Guidelines for the Seismic Rehabilitation of Buildings*, FEMA 274, Federal Emergency Management Agency, 1997.

Building Seismic Safety Council, *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures – Part 1 Provisions*, FEMA 302, Federal Emergency Management Agency, 1997.

Building Seismic Safety Council, *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures – Part 2 Commentary*, FEMA 303, Federal Emergency Management Agency, 1997.

International Code Council, *International Building Code – 2000*, Final Draft, July 1998, ICC, Falls Church, Virginia.

International Code Council, *International Residential Code For One- and Two-Family Dwellings – 2000*, Final Draft, September 1998, ICC, Falls Church, Virginia.

The Insurance Industry's Role in Building Codes and Loss Mitigation Advocacy

By David Unnewehr, AICP

Policy Development & Research

American Insurance Association

Background

Passage and rigorous enforcement of comprehensive statewide building codes has significant potential for reducing both catastrophe and more routine property losses. Currently, only 23 states in the U.S. mandate a model code or state code to cover all buildings and occupancy classifications. Twenty states do not have state-mandated building codes covering the entire state, but generally have codes governing building activity in larger cities. An additional eight states mandate building codes for commercial and institutional property, but exempt one and two-family dwellings which are typically much more vulnerable to wind, hail, and other sources of loss. A number of states in hurricane-prone areas including Texas, Louisiana and several other Gulf coast states and earthquake-prone areas such as Missouri still have no widespread or statewide building code requirements. Missouri, in fact, has a legislative prohibition on the ability of all but its largest jurisdictions to enact and enforce a building code.

Insurers are also concerned about ongoing non-catastrophic losses from fires and other perils that cause damage to life and property. In addition to codes provisions relating to high winds, hail, and seismic activity, life safety and property protection provisions of building and fire protection codes are an essential area of focus. How codes address smoke alarms, residential sprinklers, the safety and performance of alternative building materials, problems associated with ice damming are topics in which insurers have a keen interest. Building codes provisions and amendments are generally researched, proposed, debated and passed by three model code organizations:

- Building Officials and Code Administrators International Inc. (BOCA)
- Southern Building Code Congress International, Inc. (SBCCI) and
- International Conference of Building Officials (ICBO)

There are also other organizations that formulate more specific provisions fire protection and for one and two-family dwelling units. Often these are adopted or referenced by the three model codes. The National Institute of Standards, an agency within the Department of Commerce, also plays a role in the development of building codes by defining engineering standards for wind, snow, seismic loads, and other features that define building strength and design.

BOCA generally serves Midwestern and Northeastern states, SBCCI is prominent in the South, while ICBO is the predominant organization in the West. These three organizations are cooperating on the compilation of a unified International Building Code (ICB) that should include the best features of each of the three codes. However, the three model code organizations will continue to exist for the time being as research and development, service, and training organizations for code enforcement officials after the ICB is officially adopted in 2001 or 2002.

In many other states, codes are inadequately enforced due to a variety of factors ranging from understaffing to lack of training. There have been a number of studies that have documented the importance of code enforcement, including those comparing the generally good performance of North Carolina coastal codes through severe hurricanes in the 1980s and 1990s with hurricanes of similar strengths affecting other states. Estimates are that inadequate enforcement of Dade County building codes caused Hurricane Andrew insured losses to be at least 25% ($4 billion) greater than they would have been with proper adherence to the code. This additional damage impacted insurance capacity and availability, rendered more people homeless, ruined irreplaceable possessions, and increased the burden on taxpayers, government agencies and charities. Better staffing and training of local building departments will help improve building code enforcement in catastrophe prone areas.

New York currently follows an outdated building code that needs to be updated to include, among other things, higher wind speed requirements to reflect the hurricane risk on Long Island. South Carolina and Florida have recently enacted and are in the process of implementing comprehensive statewide building codes. Texas implemented a new code for its hurricane-exposed coastal counties with strong support and input from AIA. However, Texas is one of 20 states that has no state-mandated building codes which has major implications for homeowners and insurers in non-coastal counties in the states.

Other mitigation strategies can also help to reduce catastrophe exposures, such as educational programs and publicity that encourages homeowners to invest in cost-effective home improvements or retrofitting.

In recent years, insurers, planners, architects, the Federal Emergency Management Agency (FEMA) and other groups have begun to focus on the role of land use policies and planning that could limit building in very hazardous areas, or areas subject to repeated losses from natural hazards. FEMA has recently begun to purchase and convert to parkland properties that are subject to repeated flood losses, and following the 1993 Mississippi floods, the federal government relocated an entire town that had been subject to multiple floods. A combination of land use policies and very strict building codes can help to reduce catastrophe exposures in areas at great risk such as coastal barrier islands, or at least help to encourage quality building that can withstand the risk.

AIA Position

AIA supports enactment of statewide comprehensive building codes in all states. State-wide codes have the advantage of uniformity and clarity that help to promote training and better understanding of code provisions by developers, builders, sub-contractors, building materials manufacturers, and building officials. These attributes ultimately will lead to better compliance and enforcement than currently exists. Comprehensive and uniform codes often help lower costs and increase efficiency for builders who can deal with one document rather than a confusing patchwork of regulations from one jurisdiction to the next. However, it is critical within the context of a statewide code to permit local counties or municipalities to enact specific amendments that address high hazard areas of a state. Often the comprehensive codes automatically handle higher hazard areas through maps that call for more stringent provisions in specific high-hazard zones. Examples include regions subject to greater hurricane risk such as Florida and other states with coastal areas along the Atlantic Ocean and Gulf of Mexico, seismic zones, and other geographic areas especially prone to high wind and hail. Building codes are important for inland areas as well. A statewide code, if properly crafted, can include stricter hurricane provisions, for example, for South Florida and other coastal counties in the state, while maintaining a largely uniform code for with respect to other code provisions for the State of Florida as a whole.

Although passage of statewide building codes should lead to some immediate improvement in enforcement and compliance with building codes due to the factors mentioned above, AIA also believes that the state and local governments need to continue to make rigorous enforcement a high priority. The insurance industry should also continue to encourage improvement in community building code enforcement, staffing, and professionalism through implementation of the Insurance Service Offices' Building Code Enforcement and Grading System (BCEGS).

AIA supports land use planning as an effective loss mitigation tool that can help people, insurers, local communities, and disaster agencies by limiting building in very hazardous areas subject to repeat losses, or ensuring that areas with higher risks are subject to higher standards of protection.

AIA also supports a rate structure that encourages homeowners to undertake steps to mitigate losses. State insurance department should allow insurers to use higher deductibles for customers that do not take steps to mitigate losses. The insurance industry should also seek ways of involving the mortgage lending industry in strategies to encourage mitigation such as lower cost loans for homeowners who undertake retrofitting or those building or purchasing homes with superior construction with respect to life safety and property loss reduction.

Activity Status

In 1997, the insurance industry formed an informal coalition (Insurer Building Code Coalition) to lobby for comprehensive statewide codes that includes AIA, other trades, and several insurers. This group is also looking for ways to bring insurers back into the model code-making process on code provisions that impact safety and property protection. Code hearings tend to be dominated by home builders, building officials, and materials manufacturers. Where key debates impact important aspects of property protection and life safety, insurers need to participate. Three major building code-making organizations which in the past have published their own model building codes are in the process of creating a uniform model International Building Code (IBC). Thus the next several years will be an important period of time for industry input. AIA is also working with the Institute for Business and Home Safety (IBHS) which conducts ongoing research on the value of code enforcement and other mitigation strategies. IBHS has produced a number of publications raising the visibility and importance of mitigation strategies for retrofitting existing buildings, stronger wind resistance, seismic safety, and better roofing products. With regard to FEMA, AIA and member companies are looking at opportunities for involvement with FEMA's Project Impact, a program to encourage local counties and communities to undertake actions to make themselves more resistant to natural disasters.

Currently, there are a number of important building code issues and objectives that AIA and the industry are monitoring or actively supporting in key states:

1. **Florida:** Recent passage of a comprehensive statewide building code should have overall positive implications for quality construction, better training of builders and building officials and enforcement of building codes. However, Florida has chosen the Southern Standard Building Code as the model code for the state. It is less stringent on all-important hurricane resistant provisions than the South Florida Code, which was upgraded significantly following Hurricane Andrew. In addition, homebuilders are using the statewide code process to attempt to overturn stricter wind resistant provisions including wind-born debris protection, stronger anchoring, and roof protections. AIA and the industry will continue to advocate for strong wind resistant provisions as the statewide building code is debated and implemented over the next year.

2. **Missouri:** Insurers achieved a major step forward in Missouri in 1999 where legislation was passed by the legislature authorizing a Governor's Study Commission on whether there is a need to adopt a model statewide building code. Current law prohibits the majority of Missouri counties, including most in the New Madrid earthquake region, from adopting a building code. AIA and the industry coalition will support the work of the commission and the enactment of a statewide code.

3. **New York:** Although New York has a statewide building code, it is considered by many experts to be substantially out of date and it is not based on national model code. The Governor and a number of elected officials are supporting adoption of an update statewide code, based on one of the current national models, or the planned International Building Code. In supporting adoption of a modern statewide code, key issues for AIA will be

ensuring that there are adequate windstorm resistant provisions for Long Island and other coastal counties and seismic provisions in those areas of the state subject to earthquakes.

4. **Pennsylvania**: Working together, insurers and homebuilders have come very close to passage of a statewide building code during the last two sessions, but legislation has fallen short due to opposition by key legislators who want to keep more stringent provisions now in effect in some local codes. AIA and the coalition will continue to work with key interest groups and legislators to achieve legislation.

5. **Texas:** Although the state took an important step forward in 1997 when the Texas Insurance Department implemented a much more stringent building code for coastal counties, many other areas of the state still lack building codes.

6. **California:** In a state subject to multiple natural hazards, including earthquakes, flooding, mudslides, and wildfires building codes and land use policies are especially critical. After every major earthquake, the state and local communities have generally done a good job of updating building codes to reflect the latest technical understanding of the risk. However, enforcement can be improved and building in hazardous areas subject to wildfires and mudslides is still a major problem. More attention must be paid to identifying specific code improvement needs for California.

7. **Arkansas, Louisiana:** The Arkansas Insurance Commissioner and others have expressed interest in working toward statewide building codes following passage of legislation aimed at increasing the percent of property owners purchasing earthquake insurance. In hurricane-prone Louisiana, interest in statewide building codes surfaced following a study regarding the need and feasibility of a catastrophe fund.

8. **Wisconsin, Iowa:** These two states have indicated an interest in adopting statewide building codes but are waiting for completion and adoption of the International Building Code (IBC) which combines features of the three current national model codes.

AIA and industry coalitions should continue to look for opportunities for increasing the number of states with statewide building codes and for improving existing codes and enforcement.

Building Code Effectiveness Grading Schedule

Ralph Dorio
Technical Coordinator
ISO

Abstract
This report provides a brief overview of Insurance Services Office, Inc. (ISO) and explains the development of the Building Code Effectiveness Grading Schedule (BCEGS). The report also reviews and interprets the results of recent BCEGS evaluation of communities in the New Madrid Seismic Area and compares those findings with BCEGS data from the Western States Seismic Area and from the rest of the United States.

ISO in the property/casualty insurance industry
Insurance Services Office, Inc. (ISO) is the premier source of information about property and liability risk. ISO provides statistical, actuarial, underwriting and claims information and analyses; consulting and technical services; policy language; and information about specific properties. The company offers services for a broad spectrum of insurance lines and maintains one of the largest private databases in the world.

Each year, ISO collects some 1.2 billion detailed records of insurance premiums collected and losses paid. At any one time, ISO's statistical database contains more then 5.5 billion records. For commercial lines, the data represents almost 75% of the industry's premium volume, and for personal lines, the data represents nearly one-third of all written premiums.

ISO professionals analyze insurer statistical data and turn it into meaningful information. ISO develops advisory prospective loss costs (projections of average future claim payments and loss adjustment expenses) for various lines of insurance. The company also submits summaries to insurance regulators, to help regulators evaluate the price of insurance in each state.

BCEGS evaluates communities' building-code enforcement
The building Code Effectiveness Grading Schedule (BCEGS) assesses the building codes in effect in a particular community as well as how the community supports and enforces those codes. ISO has developed the BCEGS program in conjunction with the three national model code groups, the Institute for Business and Home Safety, information from 1,500 building code officials and pilot testing in 154 communities. BCEGS particularly emphasizes building code requirements designed to mitigate losses from natural hazards. The result is a rating and underwriting tool based on a building code classification developed for each community. It is not intended to analyze all aspects of a comprehensive building code enforcement department. The BCEGS concept is similar to that used for public protection classification, which classifies municipal fire suppression capabilities and has been used by insurers for decades.

How the program works
ISO distributes detailed questionnaires to the building officials of all municipalities in a state. Upon receiving a completed questionnaire from a city or town, ISO arranges for a trained field

representative to meet with the building code official. The ISO field representative and building officials review and verify the community's capabilities, and the ISO representative seeks clarification and obtains supporting documentation as necessary. The review may include a visit to construction sites by the ISO representative and building official.

The ISO field representative evaluates the community utilizing to a point system detailed in the grading schedule, then they tabulate the points to determine a numerical classification from 1 (exemplary building-code enforcement) to 10 (minimal code enforcement). ISO designates departments that fail to meet minimal BCEGS requirements (detailed below) as Class 99. ISO publishes community classifications and makes them available to all ISO participating insurers.

The BCEGS program works like ISO's Public Protection Classification (PPC) program, which helps insurers evaluate municipal capabilities for fire suppression. The major difference between the two programs is the portion of the community affected by the evaluation. A community's PPC classification affects the rating of insurance for all properties in that municipality, while a BCEGS classification affects only buildings built *after* the grade went into effect. The survey questionnaire and grading schedule for the BCEGS program produce a snapshot in time of a jurisdictions building-code enforcement department. Buildings constructed *before* a community's most recent BCEGS survey are subject to the classification in effect when those buildings were built.

An example helps to clarify this principle. If Sampletown has a BCEGS classification of 3 when ABC Complex is built, the complex will always be eligible only for Class 3 credits. Subsequent changes in the community's classification — good or bad — will not affect ABC Complex's eligibility for BCEGS classification credits.

The BCEGS program does have a provision allowing for a building to receive an individual classification; if the building's construction followed the natural-hazard provisions of nationally recognized code. Under that provision, a registered design professional must certify that the building was designed and constructed according to the nationally recognized code. In such a case, the building will receive the highest possible classification and associated credit, regardless of the surrounding community's BCEGS grading.

The Building Code Effectiveness Grading Schedule is equally applicable to all communities — large and small. This versatile schedule can be applied to all code enforcement departments that meet the following three minimum conditions.

BCEGS requirements for code enforcement

ISO applies BCEGS to code-enforcement departments that meet three minimal requirements:

1. The department must be a permanently organized unit, established under applicable state or local laws and must serve an area with definite boundaries. The organization should include one person responsible for operation of the department (usually with the title Building Official), though the Building Official may also serve in other capacities. If a jurisdiction does not have a building department operated solely by or for the governing body of that jurisdiction, the building department providing such service must do so under a legal contract

or resolution. When a building department's service area includes two or more jurisdictions, the department should execute a contract with each jurisdiction served.

2. The department must enforce codes that require buildings to have the structural strength and stability necessary to provide resistance to natural hazards common to the community's geographic region.

3. The department must review construction documents and monitor building construction for compliance with the adopted building codes.

Three criteria for the grading schedule

BCEGS examines building-code enforcement departments according to three categories of criteria:

1. Administration of codes — This criterion focuses on the jurisdiction's support for code enforcement. The criterion emphasizes adopted building codes and modifications to the codes through ordinances; code enforcers' qualifications, such as experience and education; zoning provisions; contractor/builder licensing requirements; public awareness programs; the department's participation in code-development activities; and the department's administrative policies and procedures.

2. Plan Review — This criterion examines the jurisdiction's plan-review function to assess the staffing levels, personnel experience, performance-evaluation schedules, review capabilities, and review of construction documents for compliance with the adopted building codes.

3. Field Inspections — This criterion evaluates the department's field-inspection function to determine the staffing levels, personnel experience, performance-evaluations schedules, review capabilities, and review of building construction for compliance with adopted building codes.

BCEGS classifications and premium credits

ISO awards points for each criterion. A jurisdiction can score from 0 to 100 points, with 100 being a perfect score. Based on the point score, ISO determines a numerical classification as follows:

CLASSIFICATION	point spreadS
1	93.00 – 100.00
2	85.00 – 92.99
3	77.00 – 84.99
4	69.00 – 76.99
5	61.00 – 68.99
6	51.00 – 60.99
7	39.00 – 50.99
8	25.00 – 38.99
9	10.00 – 24.99
10	0.00 – 9.99

ISO has filed advisory rating programs, including rating credits for the commercial fire and allied lines, business owners, homeowners, and dwelling lines of insurance. Most states have approved schedules of credit ranges for those lines.

Under the ISO advisory plan:

- buildings constructed under code-enforcement departments with classifications 1 through 3 are eligible for the maximum credit in the approved schedule
- buildings constructed under code-enforcement departments with classifications 4 through 7 are eligible an intermediate credit in the approved schedule
- buildings constructed under departments with classifications 8 and 9 are eligible for the minimum credit in the approved schedule
- buildings constructed under departments with a classification of 10 are not eligible for credits

BCEGS was developed as a credit-only program, but certain states do require negative incentives.

Code enforcement in the New Madrid Seismic Area

Countrywide data on BCEGS classified communities can be used to compare differences in regional building-code enforcement and effectiveness. Making those comparisons can help promote hazard-mitigation strategies and can lead to a better understanding of underwriting risk. Since the initial pilot program in 1994, ISO has evaluated more than 3,600 code-enforcement departments, including eight hundred departments from the six states in the New Madrid Seismic Area. (Mississippi has an Independent Rating Bureau, so ISO does not grade communities in that state.) ISO has also graded more than 600 departments from the Western States Seismic Area. (Idaho and Washington have Independent Rating Bureaus, so ISO does not grade communities in those states. Alaska is currently in the process of being evaluated.).

Figures 1 through 5 compare BCEGS classifications in the New Madrid Seismic Area, the Western States Seismic Area, and the rest of the United States.

Figure 1 illustrates the differences in code-enforcement between the New Madrid and Western Seismic Areas. Forty-one percent of the people — the largest single population grouping — in the western states live in Class 3 communities. In the New Madrid region, 34% of the people — again, the largest single population grouping — live in communities that fail to meet the minimal requirements of BCEGS for code enforcement (Class 99). Figure 2 repeats this picture, but shows percentages of total communities rather than percentages of population.

Figures 1 and 2 also show that code-enforcement departments graded 3 or above protect a low percentage of the population — and low percentage of communities — in the New Madrid region. Only 5% of the population in the New Madrid Seismic Area enjoy protection by such departments, while 53% of the population in the western states enjoy that level of protection

Figures 4 and 5 compare the New Madrid region's BCEGS classification to the remainder of the country. In the New Madrid Seismic Area building code departments with classifications 1 to 4 serve 19% of the population and only 5% of the communities. But in the rest of the country, departments with equal classifications serve 58% of the population and 21% of the communities. Figure 5 summarizes the data, and further draws out regional differences in the percentages of population served by code-enforcement departments classified 99 compared with those classified 1 through 3.

Public officials of communities in the New Madrid area — and of other cities and towns across the United States — have choices to make about the kind of communities they live in. If community leaders choose to invest in their building-code enforcement department, their communities are likely to benefit from lower property damage and losses — especially losses from seismic damage. Making those investments can also help reduce loss of life and the economic and social disruption that results from natural catastrophes.

New Madrid Vs. Western States
by Classification Number

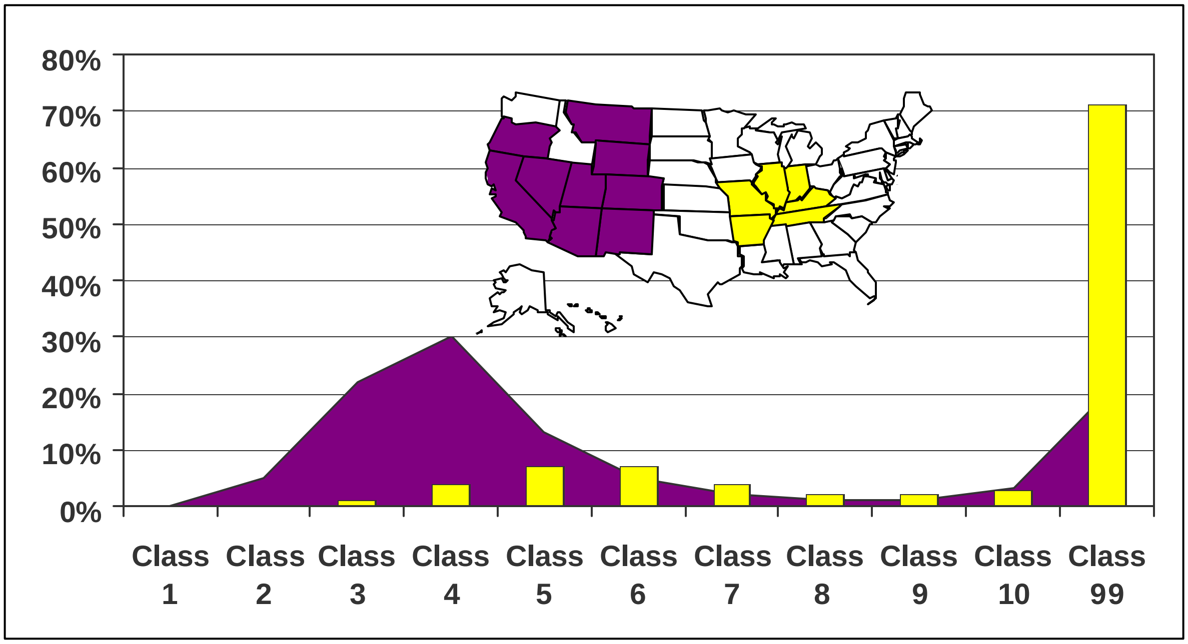


Table 1

New Madrid Vs. Western States
by Population

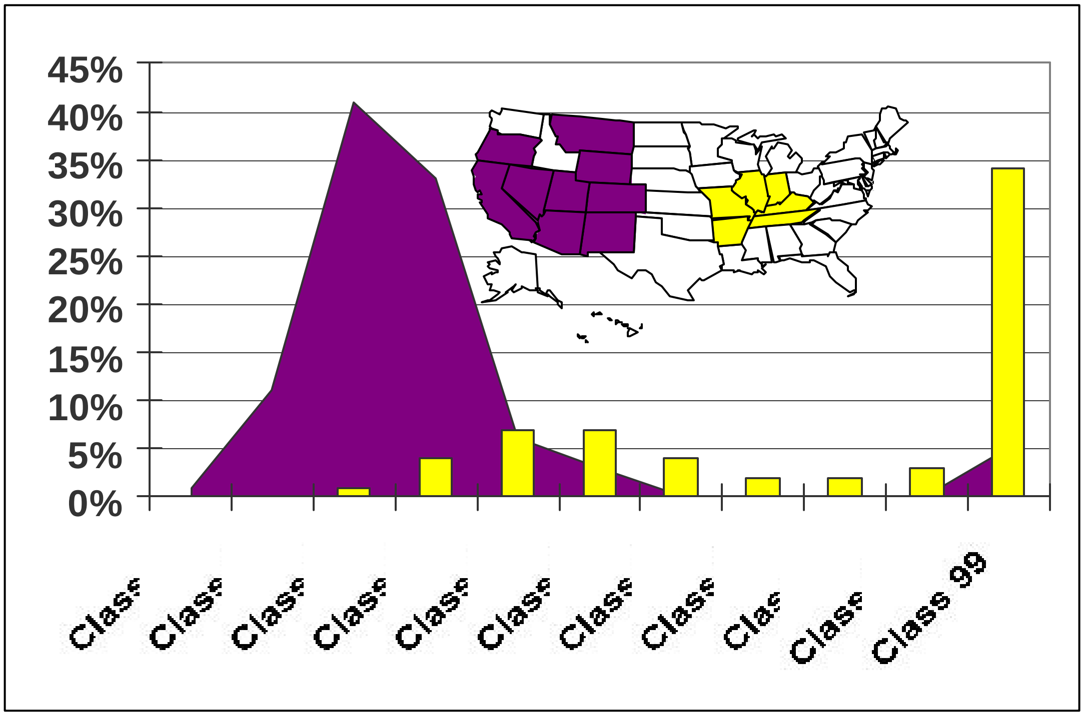


Table 2

New Madrid Vs. Remainder of Country
by Classification Number

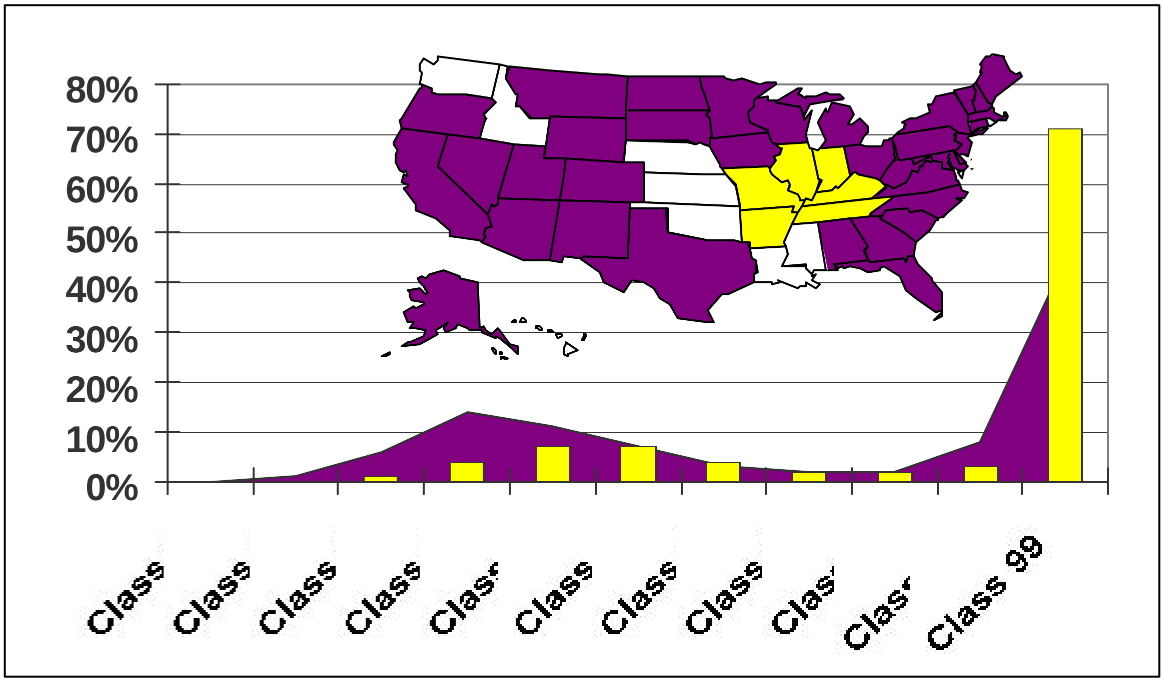


Table 3

New Madrid Vs. Remainder of Country
by Population

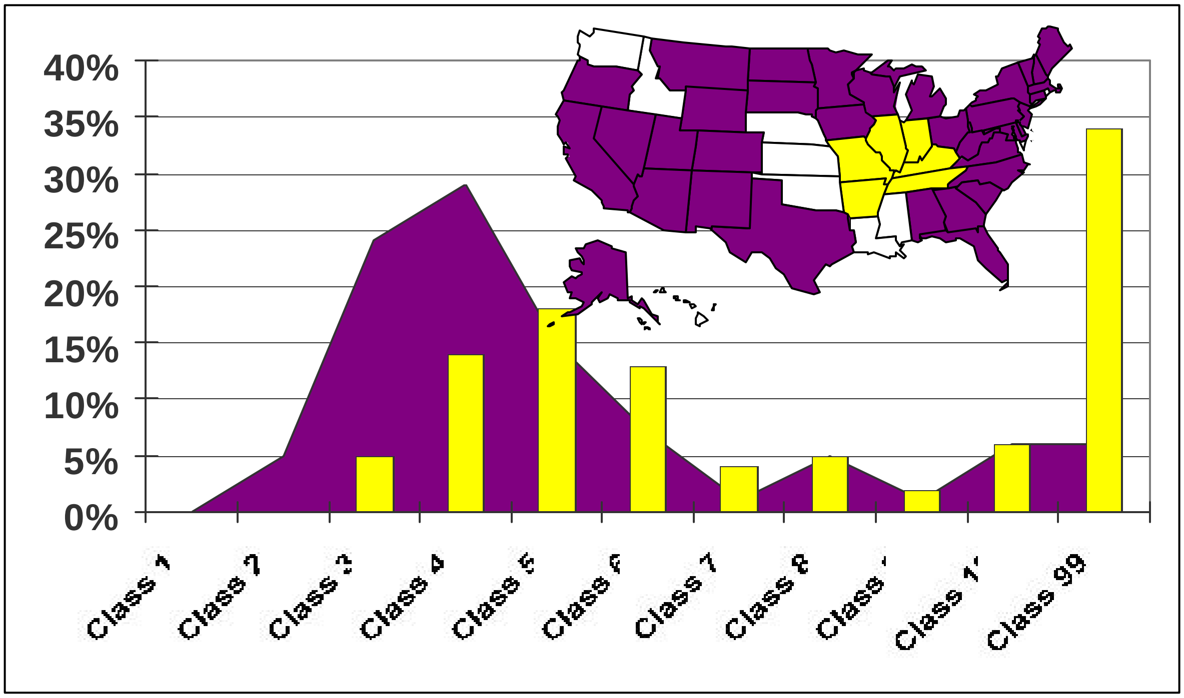


Table 4

% Of Population Served

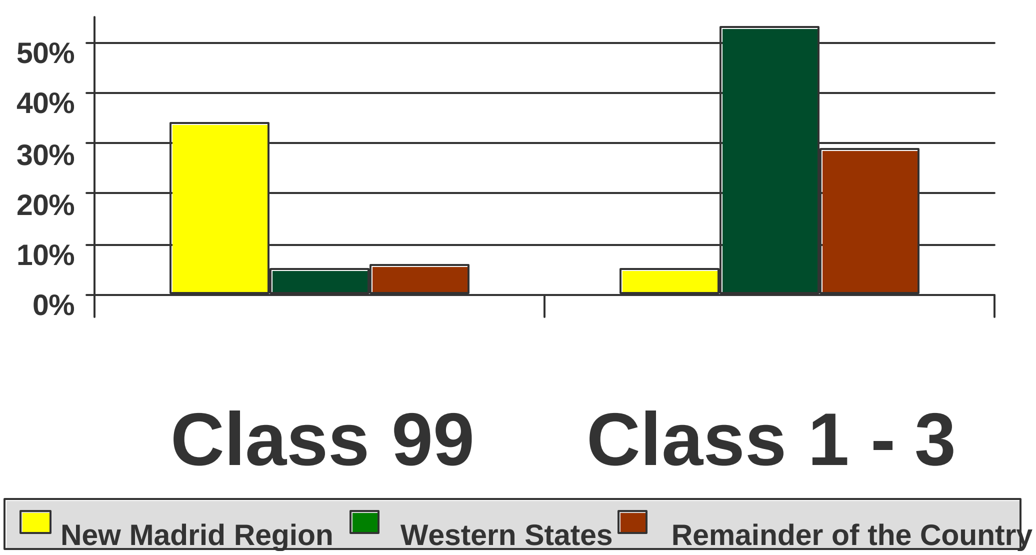


Table 5

THE NEED FOR INSURANCE SUPPORT OF SEISMIC RETROFIT

Paul Devlin, Vice President and Jim Russell, Vice President
Institute for Business and Home Safety

Do we really need to retrofit structures in seismic zones to enhance their resistance to vibrations? In one word, yes. Our country has a massive inventory of buildings vulnerable to but not prepared for the next earthquake and more buildings like them are coming on line very day. We are not doing enough to address the problem in new buildings, much less in the constantly expanding inventory of existing buildings. Most people view building codes as the solution to this problem. Others might add land use planning. Building codes and land use planning are important tools in any effort to correct this situation, but they do have limitations and they generally do not touch the buildings already in place.

BUILDING CODES

Building codes are not the total solution. They are just a part of the solution. In a perfect world, every state and every community would have and enforce a code that reflects current engineering knowledge about the risk of earthquakes and their effects on structures. The real world is a different place.

Building codes have four basic limitations as tools for addressing the existing inventory of seismically vulnerable structures: they are hardly universal, they are often out of date, they do not emphasize the protection of property from earthquake damage, and they are not always enforced.

Take the New Madrid seismic zone. It reaches into Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri and Tennessee. Three of these seven states do not require their communities to have any building code for any purpose. Two others have a statewide code but do not require it for houses. Here is a thumbnail status of statewide codes in these states:

Arkansas: a non-current (1991) statewide code covers all occupancies.

Illinois: no statewide code.

Indiana: a statewide code does not cover one and two-family dwellings.

Kentucky: a statewide code covers all occupancies.

Mississippi: no statewide code.

Missouri: no statewide code.

Tennessee: a statewide code does not cover one and two-family dwellings.

Of this group, only Kentucky has an up-to-date code covering all occupancies. Missouri is at the other extreme. It actually forbids 93 of its 114 counties from enacting any building code for any reason.

Even where codes are in place, they are not always current. Better understanding of the earthquake risk and better understanding of how construction features react to the stresses of an earthquake have led to improvements in our model building codes. Research into the failures of steel-frame connections in the 1994 Northridge event, for example, are now resulting in changes at the model code level. But these model code enhancements can be late in getting to the states with mandatory codes and, naturally, may never get to other states.

Another reason why building codes are only part of the answer is that life safety is their primary function. They assume that, given an agreed-upon baseline for earthquake risk, a building should not collapse on its occupants and kill them. If the building is standing after the earthquake, the designer and builder have done their jobs. The building may be a total loss because of cracked walls, crumbling mortar, and shaky connections, but at least its occupants survived. While this situation is good, it not good enough for insurers.

A final difficulty with building codes is in enforcement. The insurance industry knows from firsthand observation that code compliance is wishful thinking in many instances.

LAND USE

Land use planning is also part of the solution. It can reduce earthquake losses in a number of ways, like controlling the type and density of development in seismic zones and making sure that a community can handle the demands a development places on earthquake response and recovery. But land use planning techniques have an even thinner penetration than building codes. Of the seven states listed above, only Kentucky requires local planning, and only in its larger counties. Furthermore, Kentucky does not require that its local planners take earthquakes into account.

Mississippi is at the opposite end of this limited spectrum. It has gone to the trouble of enacting a law authorizing every community in the state to ignore its neighbors when it makes land use decisions, in case it chooses to engage in land use planning at all. In other words, if a locality decides to plan, it can coordinate with its neighbor if it wants to, but the state says it does not have to. Earthquakes are perfect examples of the sort of events that have no respect for political boundaries and that beg for coordination among localities. Not exactly a ringing endorsement of land use planning.

Each of the states on the West Coast -- California, Oregon and Washington -- requires its localities to have land use plans that take their seismic risk into account. The New Madrid states have a long way to go by comparison.

THE INVENTORY

The lack of attention to building standards in many states, to the protection of property in building standards where they exist at all, and to basic land use planning means that mid America has an enormous inventory of vulnerable buildings. And the inventory is growing every day. The National Association of Home Builders estimates that only two percent of the stock of detached single-family housing is new each year. The turnover rate for other buildings is probably not too far off that figure.

The result is that even if we had the best building codes and land use laws in force everywhere with unfailing compliance, we would still need to address the inventory of building already in place.

THE COSTS

When an earthquake hits, the property losses can be enormous. The Northridge earthquake (1994) erased over 25 years of earthquake insurance premiums in California. The common estimate of the insured losses from Northridge is $12.5 billion. The IBHS paid-loss database, which collects actual payments by insurers over time, indicates a total insured loss exceeding $15 billion. Even this figure pales in comparison to projected total losses from two other likely events:

- Magnitude 6 in the New Madrid zone: about $60 billion
- Magnitude 7.8 in San Francisco: about $200 billion

These numbers stretch the abilities of insurers to pay and communities to recover. Because building codes and land use planning are not going to bring the numbers down to any reasonable level, retrofit is a critical component of the answer.

RETROFIT

Retrofit is the only way to get at our massive inventory of vulnerable structures. Retrofitting a home or office for seismic resistivity is fairly easy and inexpensive for nonstructural items like bookshelves, computers, water heaters and the like. But it is often expensive and complex for the structural features of a building. As a result, property owners are generally not inclined to undertake it. The only way to succeed is to reduce the cost and complexity of retrofitting – as IBHS has demonstrated with residential roof sheathing in wind-prone areas – and give property owners some incentive to act.

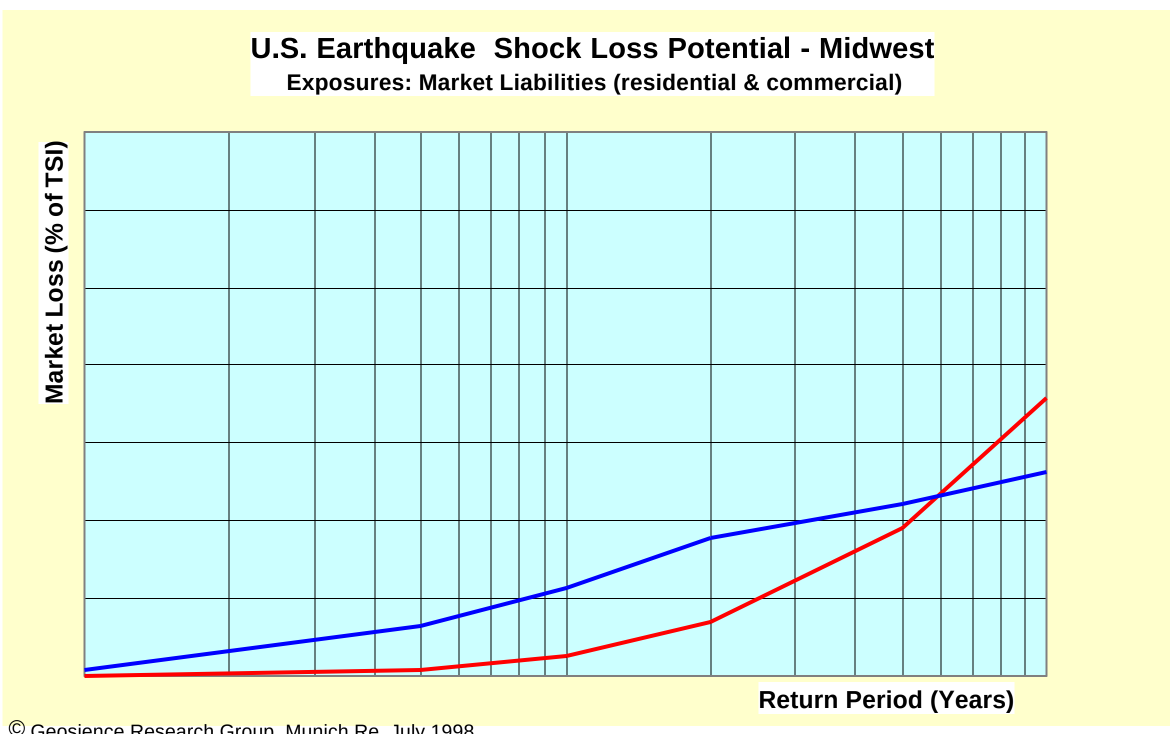
The first step is to identify new retrofit possibilities. A national conference of leaders and experts can brainstorm to generate ideas. The next step is to test the most promising possibilities in research laboratories and universities and then let people know about them. Each of these steps will take time and money, but if they result in just a few homes or businesses saved, the investment will be worth the cost.

Earthquakes in the Midwest – What do the Uncertainties do to the Insurance Industry?

Anselm Smolka
Geoscience Research Group
Munich Reinsurance Company
Email: asmolka@munichre.com

1. Introduction

The question posed in the title can most easily answered by the following graph which presents the results of two models offered for the region by different modelling firms. The models differ to an acceptable degree in the low probability range of about 0.001 p.a.. For more rare and more frequent events the difference becomes larger to such an extent that the average annual loss calculated by these models varies by a factor of three. This is hardly a satisfactory situation, but it clearly demonstrates the problems we are faced with in view of the uncertainties about earthquakes in the Midwest.



Assessing the probable maximum loss (PML) arising from rare, large events and the average annual loss (AAL) related to the entire range of possible events in a certain area are the two basic elements for a solid underwriting policy in the field of natural hazards insurance. The PML serves to the primary insurer as the measure against which he has to decide on how much of the risk he can retain for himself and how much is to be reinsured so as to guarantee his solvency in the case of a large loss. The AAL determines the net technical price he has to charge in order to cope with the overall risk. The two loss curves reproduced above show us that in the Midwest uncertainty lies in the low and medium frequency range of the curve as well as in the high frequency range. In the following sections these uncertainties will be discussed in more detail. The discussion is organized according to the risk equation which reads in the insurance context as follows:

$$\text{risk} = f(\text{hazard, vulnerability, insured values})$$

where hazard means the occurrence probability of an earthquake of a certain intensity within a certain time span, vulnerability is expressed as the expected mean percentage loss as a function of a ground motion parameter and insured values represent the total replacement values of the insured objects.

2. Hazard uncertainties

The main uncertainties for modelling the hazard in the Midwest arise from the following issues:

- active earthquake sources and earthquake source zones
- maximum magnitude and seismicity rates
- attenuation of ground motion
- source depths
- stress drop
- deep soil effects

Active sources: Johnston and Schweig (1996) have summarized the state of knowledge regarding the source of the 1811/12 earthquake in the New Madrid zone.
Notwithstanding their complete and conclusive discussion, uncertainties with regard to modelling the sources within the framework of a hazard model remain. Questions to be asked are:

- Are the fault segments activated in the 1811/12 sequence the only specific faults in the area? There are other candidates like the Crittenden fault zone or the Crowley ridge.
- The Bootheel enigma: According to Johnston and Schweig's preferred model the Bootheel lineament was activated by the first of the three principal shocks of the 1811/1812 series. Today the lineament is seismically very quiet as opposed to the other fault segments which moved in 1811/12. It has been suggested (Schweig, personal communication) that the reason for this observation is either a less favourable orientation with regard to the local current stress field or a possibly simple geometry of the corresponding fault, but so far these explanations are speculative.
- Does the complex rupture pattern of the 1811/12 earthquake series represent a typical rupture mode for the zone?. According to paleoliqefaction features there is evidence for one similar event at about 900 A.D., but other events seem to have been smaller, i.e. not the total fault complex moved in these events.

Maximum magnitude and seismicity rates: The evaluation of a recent GPS campaign by Newman, Stein et al. (1999) has revived the discussion on maximum magnitudes and seismicity rates of the New Madrid earthquake zone (e.g. Pratt 1994). Their findings indicate much lower M_{max} and seismicity rates than those reported in the Johnston and Schweig model. The conclusions drawn by Newman et al. are probably stricter than justified by their data at the present stage and will have to be confirmed by future repeated measurements. If confirmed, reconciling the two competing models would be a formidable task. Even without the new GPS data there is sufficient uncertainty about where the New Madrid source stands in its life cycle and if activity will continue at the same level as suggested by paleoseismological works.

Attenuation of ground motion: Equations proposed to describe the attenuation of ground motion in the Midwest have been numerous and introduced very considerable uncertainty in older hazard models for the regions. The differences between the results in older, first generation models were much more pronounced than shown in fig.1. In recent years progress has been made by means of simulating ground motions stochastically (e.g. Toro et al. 1992). There is a consensus now that older equations have overestimated the size of the affected areas considerably, although the fact remains that ground motions decrease much less with distance than in the Western United States. However, there is an interesting case made by Hanks and Johnston (1992) that this behaviour applies only to very large events of the 1811/12 style and to abnormally deep events (see below). Starting from the evaluation of isoseismals of 16 Western US (WUS) and 8 Eastern North America (ENA) earthquakes, Hanks and Johnston argue that, whereas felt areas are clearly larger for ENA earthquakes, this does not necessarily hold true for damaging intensity levels of MMI>VI. Another interesting feature in this context is the role played by critical reflections at the crust/mantle boundary which leads to ground motions levelling off at a distance range of 60-120 km. This is a critical distance for e.g. St. Louis and could mean that ground motion would be higher there than predicted by most attenuation functions which assume a continous decrease with distance. The effect has been taken into account by the model of Toro et al. (1992).

Source depth and stress drop: ENA earthquakes can be grouped in two classes, namely earthquakes with shallow sources rooted some 10-15 km deep, and events with deeper sources (some 25 km) rupturing the whole crust. The two classes differ strongly in their attenuation characteristics (e.g. Hanks and Johnston 1992). For the deeper class, surprisingly small magnitudes suffice in order to produce comparatively large motions at great distances. An example is the Saguenay earthquake of 1988 (M=5.9) which produced isolated damage even in Montreal at a distance of 375 km. Only scarce data are available in order to determine the occurrence frequency of such deep events as compared to shallow ones, but the question is clearly of considerable relevance for modelling the hazard in the ENA including the US Midwest.

Deep soil conditions: The role of subsoil conditions in earthquakes is generally known, but the problems posed by the considerable thickness of fluvial deposits together with their flatness are almost unique in the Midwest as discussed by Herrmann (Herrmann 1999, this volume).

3. Vulnerability issues

It is well known that average Midwest constructions are less earthquake-resistive than structures in the WUS. The question is to what extent less? Several arguments can be put forward in this context:

Construction style: compared to the WUS there is much more (and more vulnerable) unreinforced masonry and brick veneer construction on the one hand and less (and less vulnerable) wooden buildings on the other hand.

Building regulations: Research in the framework of the Building Code Effectiveness Grading Schedule (BCEGS, Dorio 1999, this volume) has shown that code enforcement in the Midwest is much lower than in the WUS and even compared to the rest of the US including the East.

Loss experience: Loss experience for significant earthquakes in the Midwest does not exist. Looking beyond pure buildings the vulnerability of „contents“ (ranging from simple household goods in dwellings to electronic equipment, machinery, installations and stock on commercial and industrial premises) is a particularly important topic from an insurance perspective, as it is loss to contents and non-structural building components which accounts for by far the greatest proportion of insured earthquake losses (Smolka and Berz 1988). This is a universal problem which tends to be neglected by structural engineers. Relevant loss statistics are hardly available even for regions other than the Midwest as under commercial lines buildings and contents are often insured under combined policies which do not break down values as to buildings and contents. In loss models contents vulnerability may be treated quite variably. Sometimes it is considered a function of building loss, sometimes more a function of the occupancy class. Correlating contents loss to building loss is not straightforward unless the building collapses, or contents are tied to building components in order to prevent it from moving around in an uncontrolled manner during earthquakes. In contrast to a common understanding that contents are less vulnerable than buildings, the opposite may well apply if contents have not been tied down. This is usually the case in regions where risk awareness is low and seems to be a safe assumption for the Midwest in view of the BCEGS survey.

The role of low intensities: As shown in fig.1 the high and medium frequency portions of loss curves constitute at least as much a problem as the low frequency part. The question is: Where (in the curve) do insured losses begin to appear? Or, to put it more specifically: What is the average expected loss for low ground motions? This observation has a particular impact in modelling the earthquake risk in the Midwest because of the large affected areas. The impact is twofold:

- For a rare PML event MMI VI (or an equivalent ground motion level) may contribute almost 50% to the total loss burden depending on the average loss percentage anticipated for this ground motion level.
- In an analogous way small earthquakes with only moderate intensities may dominate the overall risk premium, i.e. the AAL. Given the earthquake history of the Midwest this seems at odds with observed earthquake damage which has been quite insignificant so far.

It is stressed here that the problems discussed under this sub-heading are of a more universal than Midwest-specific character, but nevertheless they are especially relevant in the Midwest for the reasons discussed.

4. Conclusions

In summary it can be stated that enormous progress has been made in elucidating Midwest seismicity and risk in recent years. However, open issues remain which introduce considerable uncertainties to risk assessment:

- Activity of sources other than the 1811/12 source
- typical rupture modes (complex vs. simple events)
- GPS measurements against other observations
- the role of „deep“ events
- the role of stress drop
- the influence of deep soil deposits
- the frequency and degree of the damaging effect of low loss events and intensities.

There is a wide scope for the scientific community and a great demand from the insurance industry for future research aimed at clarifying these issues and at reducing the concomitant uncertainties.

References

Dorio, R. (1999). Building code effectiveness grading schedule for seismic design. *(this volume)*

Hanks, T.C. and Johnston, A.C. (1992). Common features of the excitation and propagation of strong ground motion for North American earthquakes. *Bull. Seism. Soc. Am.*,82,1, pp1-23.

Herrmann, R.B. (1999). Will new maps lower or raise the hazard? *(this volume)*

Johnston, A.C. and Schweig, E.C.(1996). The enigma of the New Madrid Earthquakes of 1811-1812. *Annual Review of Earth and Planetary Sciences*,24, pp1-65

Newman, A.V., Stein,S., Weber, J., Engeln,J., Mao, A. and Dixon, T. (1999). Slow Deformation and Implied Long Recurrence Intervals From GPS Surveys Across the New Madrid Seismic Zone. *Science*, 284.

Pratt, T.L.(1994). How old is the New Madrid seismic zone?. *Seism. Res. Letters*, 65,2, pp172-179

Toro, G.R., Silva, W.J., McGuire, R.K. and Herrmann, R.B.(1992). *Seism. Res. Letters*,63,3,pp 449-476

Smolka, A. and Berz, G. (1988): The Mexico Earthquake of September 19, 1985 – An Analysis of the Insured Loss and Implications for Risk Assessment. *Earthquake Spectra,* 5,1,pp 223-248

The Need for Seismic Retrofit —

Unreinforced Masonry Basements

Stephen M. Marlin, assistant vice president
Property Claims and Catastrophe Operations, USAA

Earthquake Damage Mitigation

When the insurance industry reviews the issue of earthquake damage mitigation, the issue can be broken down into two basic categories: new construction and existing building stock. New construction issues are tied to building codes, development of stronger codes, adoption of codes and enforcement of codes in order to mitigate damages caused by the earthquake peril. Existing building stock issues relate to the need to retrofit structures to protect the inhabitants and reduce the amount of damage to the structure. This discussion will focus on the retrofit issue.

Insurance Claims Experience

It is important to note that the insurance industry in this country has limited experience with earthquake. Most of the events in recent years have been on the West Coast, California, Oregon and Washington. When we compare the West Coast to the Midwest, we anticipate some significant differences in soil types, ground water tables and building designs. Experience has taught us that rocky soils tend to reduce the amplitude of ground movement, while sandy alluvial soils tend to transmit the shock waves over greater distances. Structures with foundation systems on bedrock tend to perform better than building constructed on backfill. High water tables increase the potential for ground liguidfication, which in turn increases the potential for structural damage. Building design and building materials can be a key factor in the amount of damage sustained by a structure. Typically, masonry construction does not perform well during an earthquake. Moreover, we have very little experience with basements as the foundation system. Most of our earthquake experience has been with slab on grade or pier and beam foundation systems, since basements are not typically used on the seismicly active West Coast.

The peril of earthquake causes damage to a structure that is unlike the damage caused by the more common insured perils such as wind, fire or water. The up lifting and twisting of a structure during an earthquake can result in damage that may go unnoticed to the untrained eye. As a result, we updated our training for adjusters to address this type of damage and understand that invasive tearout will be necessary to understand the full extent of the damage.

When a major event occurs in the Midwest, we anticipate that residential structures may not perform well owing to the soils, high ground water, extensive use of masonry construction and presence of basements. In some cases, older structures may not have interior framing, and the load-bearing walls consist of double row brick. Major components of the structure may not be tied together so that gravity may be the only thing holding the structure together. Of greater concern is unreinforced masonry basements. Since the basement is essentially the foundation system, failure of the basement will most likely result in greater failure of the load bearing walls, which in turn will drive a greater frequency of collapse.

Seismic Retrofit

The insurance industry views seismic retrofit as falling into two categories: non-structural and structural. Non-structural retrofits are those actions that can be done easily and without great cost to the homeowner. Examples include securing shelves, bookcases, cabinets, appliances and water heaters to reduce the likelihood these items may fall over during an event.

Structural retrofits can be more complex, with significant cost. Examples include foundation work, wall systems, chimneys, garages, etc. In many cases the homeowner may require the services of a construction professional or, possibly, an engineer.

Unreinforced Masonry Basements

To date, the insurance industry has been unable to estimate the amount of existing building stock exhibiting unreinforced masonry basements. It is possible that there is a significant inventory, especially with older building stock throughout the New Madrid area.

When a major event occurs, we anticipate those structures built on unreinforced masonry basements will suffer catastrophic failure. The failure of the foundation system will result in the failure of the building with extensive collapse of structures. The structural failures may well result in a higher frequency of injury and death to the occupants, particularly if the event occurs during evenings or weekends.

The Need for Seismic Retrofit

There is a need for seismic retrofit for unreinforced masonry basements. Today, nothing exists to help a homeowner determine if the basement is unreinforced. There is nothing in terms of retrofit design to assist a homeowner in the retrofit of a basement. Basement retrofit may be complex and is viewed today as probably being too costly for a homeowner to justify. In many cases the homeowner may not even realize that a problem exists or comprehend the extent of peril for the family.

What is needed is research and laboratory testing of designs to effectively retrofit unreinforced masonry basements. The retrofit needs to be cost-effective, yet efficient, in reducing the probability of catastrophic structural failure. Saying that “nothing exists” or that “it’s too complicated” is not the answer.

Mid America at Risk: Insurance and Natural Disasters

Walter W. Hays

Senior Program Manager Technical and International Activities Division
American Society of Civil Engineers

Abstract

Insurance against natural hazards is a business involving: accountants, actuaries, salespersons, brokers, claims adjusters, managers, and executives; other property casualty insurance companies; reinsurance companies; and state regulators. Insurance is a product providing value to the insured at the cost of a premium. In theory, insurers can offer protection to the insured against any risk that they can identify, as long as they can obtain reliable information about the frequency and magnitude of potential losses, and they have the freedom to set realistic premiums. Every year, the Earth's atmospheric, geologic, and hydrologic systems generate 100,000 thunderstorms, 10,000 floods, thousands of landslides, over 100 earthquakes large enough to be damaging, hundreds of wildfires, scores of windstorms (hurricanes, cyclones, typhoons and tornadoes), and dozens of volcanic eruptions, tsunamis, and droughts. Fortunately, extreme events (e. g., 500-year floods, category 5 hurricanes, magnitude 8 or greater earthquakes, large-volume explosive volcanoes, large-volume landslides; tsunamis affecting the entire Pacific rim, wide spread, long-duration wildfires, and long duration droughts) and combinations of extreme events (e.g., earthquakes - tsunamis - landslides - floods -fires; or hurricanes - floods - landslides - coastal erosion) are rare occurrences.

The bad news of the 20th century is that insured losses and overall economic losses from natural hazards are increasing with time. Natural hazards do not respect geographic or political boundaries, seasons, schedules, time of day, a business' balance sheet, or a community's state-of-preparedness, losses are increasing due to rapid growth of population and the increasing vulnerability of cities and megacities having large concentrations of people living and working in disaster-prone regions and buildings surrounded by fragile infrastructure, neither of which were planned, located, designed, and constructed to be resilient to floods, severe storms, earthquakes, landslides, volcanoes, wildfires, tsunamis, and droughts.

Natural disasters represent policy failures. The financial sector, business, industry, governmental and non-governmental organizations, and the citizens and policy makers (i.e., mayors, city managers, city councils can work together as partners, as for example in the Central United States, to make natural disaster reduction a public value.

Introduction

The purpose of this paper is to provide a framework for thoughtful considerations by all community stakeholders, including insurers, of the kinds of actions that are needed to overcome the challenges represented by a vulnerable built environment and unacceptable risk and to specify cost-effective ways for all stakeholders to work together to make mitigation a public value in their communities. Mid America is singled out for attention because of the potential for a catastrophic earthquake. The aim of the paper is to provide a framework of understanding about earthquakes, communities at risk, insurance, partnerships, and mitigation in the context of all natural hazards (e.g., floods, severe storms, hail, landslides, wildfires, volcanic eruptions, tsunamis, and droughts). Natural disaster reduction is a challenge, because it requires coordinated actions based on consideration of the view points of a diverse group of stakeholders encompassing insurers (e.g., accountants, actuaries, salespersons, brokers, claims adjusters, managers, and executives of property casualty companies, state insurance regulators; and reinsurers) as well as their counterparts in businesses, industrial organizations, utility companies, academic organizations, health care organizations, volunteer organizations, architectural and engineering firms, and public- and private-sector professional organizations (e.g., earth scientists, engineers, architects, planners, emergency managers).

What is a Community?

Each community differs in size, political leadership, stakeholder composition, value at risk, goals, and linkages with other local, regional, national, and international communities. Each community consists of many diverse stakeholders having great variability both within a sector and among sectors. No stakeholder sector is homogeneous. For example, property casualty insurance companies are comprised of accountants, actuaries, salespersons, brokers, claims adjusters, managers, and executives who have to deal with state insurance regulators; and reinsurers.

It might be convenient to think of a community as comprised of three distinct and diverse groups who make decisions concerning insurance and mitigation. They are:

1) Individual residents, perhaps the most important sector of all, the individual citizens, a highly diverse group of individuals who make up the political constituents for the public officials and who provide the pressures for changing public policies. They are also the customers and employees of the local businesses and government and are the customers of the insurers and other stakeholders involved in local commerce.
2) Community policy makers (e.g., mayors, city managers, city councils), who make the decisions concerning the adoption and implementation of public policies, but who are influenced by individual residents and overriding state/Federal regulators and legislatures.
3) Community stakeholders (e.g., insurers and other private businesses, industrial organizations, utility companies, academic organizations, health care organizations, professional organizations (e.g., earth scientists, engineers, architects, planners, emergency managers), religious organizations, volunteer organizations, and architectural and engineering firms.

All of these groups have to work together if unacceptable risk to the community is to be mitigated, reduced, and managed over the long-term in a cost-effective manner.

What is Risk?

Risk is the likelihood of the occurrence of a damaging natural hazard with its disaster agents, including fire, multiplied by its potential consequences expressed in terms of economic or societal values such as: economic loss, deaths, injuries, damage, and loss of function. These potential consequences must be classified as either acceptable or unacceptable by the community's residents, policy makers, insurers and stakeholders before realistic risk management can be effected.

An acceptable level of risk is a threshold which varies significantly from community to community, depending upon an individual's or a stakeholders level of risk aversion. For a community in general, it is the threshold above which the perceived likelihood and consequences of an earthquake are considered so adverse that they justify public and private investment on a grand and sustained scale to mitigate, prevent, or reduce the potential losses to the community as a whole. For the individual member of the community, whether a resident (owner or renter), or a business owner, or an employee, acceptable level of risk would be based upon that individual's level of risk aversion.

Acceptable risk and unacceptable risk for the community as a whole are established through the process of public consensus, with neither risk being fixed nor static. Not unlike the variance among individuals and businesses within the community, acceptable and unacceptable risk varies from community to community and from nation to nation as a function of time, location, and circumstances.

What is the Role of the Community's Stakeholders and Policy Makers in Managing their Community's Perceived Risk?

Risk management (i.e., mitigation, preparedness, emergency response, and recovery and reconstruction measures and regulations) is needed when the community's consensus, based on scientific, technical, administrative, political, legal, and economic considerations, is that the overall risk for the community is unacceptable.

A Role for Insurers in the Central United States Partnership

The Central United States Partnership (CUSP) (2) was formed informally on March 2, 1999 and established formally on May 27, 1999. The goal is to develop and implement a long-term strategic plan to reduce the unacceptable risk from a catastrophic earthquake in the Central

United States (Tennessee, Missouri, Kentucky, Illinois, Indiana, Arkansas, and Mississippi). A catastrophic earthquake is inevitable in the Central United States (hereafter referenced as CUS). At present, without implementation of the strategic actions identified in this plan, a catastrophic earthquake would be devastating to the people, urban centers, businesses, buildings, critical infrastructure, and environment in the CUS.

CUSP consists of public and private sector organizations, many of whom have worked together in the past. They are available to provide leadership, resources, and political capital for implementing a comprehensive loss reduction plan throughout the CUS. At present, CUSP, a unique partnership led by the Central United States Earthquake Consortium (CUSEC), is comprised of: the following public-private sector partners:

1) three core organizations: a) the CUSEC State Geologists (CSG), b) Institute for Business & Home Safety (IBHS), and c) Mid America Earthquake Center (MAE),
2) an interim secretariat, United States Geological Survey (USGS), and
3) eight partners: a) Department of Transportation (DOT), b) Federal Highway Administration (FHWA). c) Association of Contingency Planners, (ACP), d) Disaster Recovery Business Alliance (DRBA, e) Extreme Information Infrastructure (XII), f) Institute of Gas Technology (IGT), g) American Society of Civil Engineers (ASCE), and h) Mid Continent Mapping Center (MCMC) (a part of the USGS)

Other public-private organization will be invited to join and help to achieve CUSP'S common agenda, which is to seek new and innovative ways to make earthquake loss reduction a public value in the CUS. CUSP exists to enhance the long-term capability of each partner to carry out its basic mission and to take advantage of new opportunities for political, financial, and technical support of programs and activities that will reduce potential catastrophic losses to buildings and critical infrastructure, protect people, businesses, critical infrastructure, and communities, and assist "Project Impact" communities and "Showcase Communities" to reach their goals.

The Earthquake Threat in the CUS

Experts believe that catastrophic earthquakes—earthquakes whose effects are so severe that they cause unacceptable levels of damage to buildings and infrastructure, economic loss, mortality, morbidity, and adversely affect the environment, production facilities, economic markets, and distribution systems--are inevitable in the central United States. They believe that it is only a matter of time before the CUS pays a heavy price for not marshaling its intellectual and political capital to assess its hazard and built environments and enact and implement realistic public policies to cope with the extraordinary threat posed by a catastrophic earthquake.

The severity of a catastrophic earthquake in the CUS depends on four principal factors: 1) the magnitude, or "size," and depth of the earthquake, 2) its location and proximity to urban centers, 3) the time of day and the season of the year when it strikes, and 4) the public policies for mitigation and preparedness that have been implemented as "works in progress" to reduce vulnerabilities in the built environment of each urban center and the corresponding unacceptable risks. Only one of these factors--public policies--can be controlled; the remaining three can not.

On the basis of what has happened in past earthquakes in the CUS and throughout the world in hazard and built environment analogs, along with preliminary loss modeling, it is well known that catastrophic earthquake leave an indelible mark on individuals, businesses, communities, infrastructure, insurers, and the Nation. They adversely affect the environment, and they overwhelm production facilities, distribution systems, and economic markets, jeopardizing the financial stability of business, communities, and the Nation. Experts believe that the economic losses from a catastrophic earthquake occurring today in the CUS will be in the range of $ 100 billion. The physical effects of such an earthquake would damage, destroy, and disrupt the normal functions of government, community safe havens, essential facilities, critical facilities, and business; disrupt local and regional infrastructure; leave tens of thousands dead, injured, homeless, and jobless; divert tourism, reduce the tax base; divert resources planned for health care, education, and other social programs; and deplete insurance and financial resources.

When compared with California, Alaska, or the Puget Sound area, the central U.S. faces an unprecedented catastrophe because of its unique hazard environment (i.e., the geologic, geophysical, and geotechnical setting of the region that controls where, why, and how frequently earthquakes occur, how big they are, and the severity of their effects) and the vulnerability or fragility of its built environment (i.e., the buildings and infrastructure in urban centers at risk). Damaging earthquakes are inevitable in the central U.S., even though the CUS is far away from the geologically young and unstable seismogenic belts along the west coast in California, the Puget Sound area, and Alaska or the mid-Atlantic ridge in the Atlantic Ocean marking, respectively, the western and eastern boundaries of the North American plate. The most likely locations include: a) the New Madrid seismic zone where magnitude 6.5-6.8 earthquakes occurred near Memphis in 1843 and near St. Louis in 1895, and four magnitude 8 or greater earthquakes and scores of moderate-to-large-magnitude aftershocks occurred in the winter of 1811-1812, and b) the Wabash Valley area northeast of the New Madrid seismic zone where damaging moderate earthquakes have occurred.

The CUS faces unprecedented unacceptable risk because of its unique hazard environment characterized by the New Madrid seismic zone and the Wabash Valley seismic zone, the vulnerability or fragility of its built environment containing buildings and infrastructure that were not constructed in accordance with modern codes and standards, and a flawed policy environment. Each urban center within the CUS has an inventory of existing buildings and infrastructure that will fail because of flaws in planning, siting, design, and construction that occurred when they were added to the inventory. The current inventory of buildings and infrastructure in the CUS at risk from ground shaking and ground failure, the principal disaster agents of earthquakes, is valued in the trillions of dollars. The current perceived risk to existing buildings, infrastructure, and people in the CUS has reached the level where it is socially unacceptable. That is, there is a sufficiently high probability of loss to the elements of the built environment at risk as the result of the occurrence, physical and societal consequences of the earthquake that investments in mitigation and preparedness measures and regulations are needed to reduce it to acceptable levels before the earthquake occurs.

.

The CUS faces an unacceptable level of unacceptable risk because of flaws in public policies. At present, consensus public policies based on social, technical, administrative, political, legal, and economic factors to cope with an inevitable catastrophic earthquake are lacking in the CUS. This gap reflects the urgent need for a forum and a process for making decisions about plans, laws, and professional practices to reduce unacceptable risk to people, property, and infrastructure in the CUS's urban centers.

A Role for Insurers in CUSP's Strategic Plan for the CUS

CUSP's strategic plan calls for the following coordinated actions:

1) CUSP is calling for individuals, businesses, communities, insurers, professionals, and local, state, and Federal governments to face the inevitability of a catastrophic earthquake in the Central United States. They should assess the threat it represents to their homes, businesses, schools, hospitals, critical infrastructure, and communities, and invest in mitigation and preparedness, the two most cost-effective long-term public policies, while continuing to improve the capability for emergency response and recovery and reconstruction. Investments in mitigation, preparedness, emergency response, and recovery and reconstruction measures and regulations are urgently needed in the CUS's urban centers. They should be in proportion to their size, population, and value of the buildings and infrastructure at risk.

2) CUSP is calling for the implementation of 44 strategies for: a) living with earthquakes, b) building for earthquakes, and c) learning about earthquakes, as shown in Tables 1 and 2.

Table 1: Overview of partners and strategies in CUSP.

CUSP (See Reference 2)	LEARNING ABOUT CATASTROPHIC EARTHQUAKES (See Chapter 4)	BUILDING FOR CATASTROPHIC EARTHQUAKES (see Chapter 3)	LIVING WITH CATASTROPHIC EARTHQUAKES (See Chapter 2)
CUSEC (THE LEADER)	X	X	X
CSG	X	X	X
MAE	X	X	X
iBHS	X	X	X
DOT	X	X	X
FHWA	X	X	X
IGT	X	X	X
XII	X	X	X
DRBA	X	X	X
ACP	X	X	X
ASCE	X	X	X
MCMC	X	X	X
USGS	X	X	X

3) CUSP is calling for active support of all “Project Impact” and “Showcase “Communities” in the central U.S. Project Impact is a 1997 initiative of the Federal Emergency Management Agency (FEMA) to build disaster resistant communities and “Showcase Communities” is a similar initiative of IBHS. Project Impact challenges the Nation to create partnerships and initiate actions that protect families, businesses, and communities, and reduce the adverse consequences of earthquakes and other natural hazards through the efforts of local public and private sector partnerships (2).

4) CUSP is calling for the establishment of CUS Seismic Advisory Council in 1999 to provide exert guidance for a period of at least 10 years (2).

Insurance and Natural Hazards

Natural hazards are naturally occurring phenomena having atmospheric (i. e., severe storms, wildfires, and droughts), geologic (i.e., earthquakes, landslides, volcanic eruptions, and tsunamis), and hydrologic origins (i.e., floods) which adversely impact

Table 2: Forty-four earthquake loss-reduction Strategies to be implemented by CUSP.

CATEGORY OF ACTIVITY	STRATEGIES THAT WILL BE PROMOTED
LIVING WIT H QUAKES	1) Inform all sectors of the public about the potential impacts of a catastrophic earthquake, 2) Promote the development of comprehensive and cost-effective mitigation approaches that are CUS specific, 3) Increase the desire and ability to act in every individual, home, school, business, and community, 4) Promote the improvement of K-12 school preparedness and its extension to colleges, universities, businesses, and professionals, 5) Improve communications for everyone: individuals homes, schools, businesses, professionals, and communities, 6) Improve health care response for everyone. individuals homes, schools, businesses, hospitals, and communities, 7) Improve search and rescue capability, 8) Improve capability to collect, analyze, and disseminate damage data, 9) Establish a recovery/reconstruction plan for every CUS urban center, 10) Improve interim and long-term housing for the recovery and reconstruction period, 11) Streamline the permitting and rebuilding process for the recovery and reconstruction period, and 12) Ensure accurate and timely information flow to everyone.

BUILDING F OR QUAKES	1) Promote the provision of incentives to retrofit, 2) Promote the initiation of broad educational efforts, 3) Promote the development of effective methodologies for mitigation, 4) Promote upgrade of vulnerable buildings and other structures, 5) Promote seismic safety of all new construction, 6) Promote the development of an integrated approach to seismic design, 7) Promote the adoption of CUS-specific standards, 8) Promote performance based research that can be applied in performance based codes and standards, 9) Promote performance standards for infrastructure, 10) Promote an understanding of secondary effects, 11) Evaluate and prioritize mitigation, and 12) Promote retrofit of critical infrastructure.
LEARNING ABOUT QUAKES	1) Promote the improved use of geoscience data, 2) Promote the application of consistent standards in the acquisition, analysis, and application of geoscience data, 3) Look for opportunities to show cost-effectiveness of the use of geoscience data in mitigation methodologies, 4) Promote support for ongoing research to close gaps in knowledge, 5) Promote the establishment of an integrated program of risk assessment and risk reduction, 6) Look for ways to demonstrate the applicability of research and technology to risk reduction, 7) Look for ways to demonstrate the benefit of the research and technology, 8) Foster coordination of ongoing research, 9) Promote competency of professionals, 10) Increase public awareness, 11) Inform public officials, 12) Promote the establishment and expansion of K-12 programs, 13) Look for ways to demonstrate cost-effectiveness of mitigation and preparedness, 14) Look for ways to develop incentives; and remove barriers, 15) Promote adoption of standards for protection of property in codes, 16) Promote protection of infrastructure, 17) Promote incorporation of earthquake hazards data in general plans, 18) Promote the development of seismic zonation techniques,19) Promote the development of advanced mitigation techniques, and 20) Promote the protection of the land.

people, property, infrastructure, resources, and the environmental quality in a community. Natural hazards do not respect geographic or political boundaries, seasons, schedules, time of day, a business's balance sheet, or a community's state-of-preparedness, and they are transformed into disasters when the stricken community is unable to respond in a timely and effective manner as a consequence of the nature and degree of disruption to essential social structures and functions in the community. The severity of a natural disaster is typically measured in terms of: economic loss, deaths, injuries, damage, loss of function, homelessness, joblessness, loss of resources, adverse environmental impact on air, water, and soil, and the time, resources, and international assistance required for response, recovery, and reconstruction.

Natural hazards are inevitable, but natural disasters are not (6,7). In many cases, they can be prevented, or at least their impacts can be minimized (1). Every year, the Earth's atmospheric,

geologic, and hydrologic systems generate 100,000 thunderstorms, 10,000 floods, thousands of landslides, over 100 earthquakes large enough to be damaging, hundreds of wild fires, scores of windstorms (hurricanes, cyclones, typhoons and tornadoes), and dozens of volcanic eruptions, tsunamis, and droughts. Fortunately, extreme events (e.g., 500-year floods, category 5 windstorms, magnitude 8 or greater earthquakes, large-volume explosive volcanoes, large-volume landslides; tsunamis affecting the entire Pacific rim, wide spread, long-duration wildfires, and long duration droughts) and combinations of extreme events (e.g., earthquakes - tsunamis - landslides - floods -fires; or hurricanes - floods - landslides - coastal erosion) are rare occurrences.
Natural Disasters represent policy failures in the community, region, and nation. The root cause is lack of anticipation and inadequate integration of the social, technical, administrative, political, legal, and economic factors of the community., which affect where, when, and how the community at risk plans and prepares for the consequences of the inevitable natural hazard. Policies to make the community's development sustainable and resilient to natural-hazards must be based on the available scientific and technical knowledge on the location, severity, and frequency of each inevitable natural hazard and the nature, distribution, and extent of the likely damage and societal impacts.

The bad news of the 20th century is that insured losses and overall economic losses are increasing rapidly with time due to rapid growth of population and the increasing vulnerability of cities (and megacities) having large concentrations of people living and working in disaster-prone buildings surrounded by fragile infrastructure, neither of which were planned, located, designed, and constructed to be resilient to floods, severe storms, earthquakes, landslides, volcanoes, wildfires, tsunamis, and droughts. Natural disasters worldwide have claimed over 3 million lives and adversely affected the lives of nearly 1 out of every 4 people in terms of economic, health, and impact on the environment.

Even worse is the fact that we keep relearning the same scientific, technical, and policy lessons from each natural disaster while continuing unwise use of scarce and inadequate economic resources to respond, rebuild, and recover without correcting the policy failures (1,3,4).

The good news which was highlighted during the decade of the 1990's is that loss of life is decreasing with time. This accomplishment represents a return on capital investments by communities and nations to: 1) improve forecasts of eminent hazardous events, 2) implement effective warning systems and evacuation programs to alert people and to get them out of harm's way, 3) prevent mortality, morbidity and loss of function in modern building by adopting and enforcing effective regulations for new construction and land use, and 4) strengthen existing buildings and infrastructure to protect inhabitants and function.

The most vulnerable locations in every community are:1) close to the water's edge, 2) on unstable slopes, 3) in the flood plain of rivers, 4) in or adjacent to an active fault zone, 5) on soft and/or unstable soil, 6) on the flanks of an active volcano, and 7) near an urban-wilderness interface. Development at these locations should either be avoided, or require more stringent land use planning and engineering.

Earthquakes

Earthquakes threaten the environment, quality of life, and the economic stability of communities, businesses, and the insurance industry in nine earthquake-prone regions of the United States and in many countries throughout the world. Small earthquakes occur daily throughout the world. Although relatively infrequent, large-magnitude earthquakes have a greater sudden-loss potential than floods and severe storms. Earthquakes are dangerous because they can trigger disasters in a minute or less. are unpredictable and strike without warning, forecasts of their physical effects are ambiguous, and estimates of losses are uncertain. Submarine earthquakes can also generate tsunamis affecting nearby as well as distant locations. Communities and community development in or adjacent to active fault zones, on soft and/or unstable soil, on unstable slopes, and near the water's edge are especially vulnerable to ground shaking, permanent ground failure, surface faulting, earthquake-triggered fire, aftershocks, seiches, and tsunami flood waves (3,4).

Some of the notable earthquake disasters include:

- The Kobe, Japan earthquake disaster of January 17, 1995.--This M 6.9 earthquake which struck at 5:46 a. m. caused the world's worst earthquake economic disaster---an estimated $ 140 billion. Centered 20 km (12 miles) from Kobe, the earthquake destroyed 200,000 homes, triggered 600 fires, knocked the Port of Kobe out of operation, severely damaged the elevated Hanshin Expressway, and left 6,000 dead and 34,000 injured.
- The Northridge, California earthquake disaster of January 17, 1994.--This M 6.8 earthquake which struck at 4:31 a. m. adversely affected 3.5 million people and resulted in the highest earthquake insurance payment in history--an estimated payment of over $ 13 billion for claims. Centered 20 km (12 miles) from downtown Los Angeles, the earthquake caused economic losses exceeding $ 40 billion, damaged portions of the elevated freeway system, and left 50,000 homeless and 15,000 injured, but only 61 dead.
- The Tangshan, China earthquake disaster of_July 28, 1976.--This M 7.8 earthquake, which struck at 3:42 a. m. while most of the 1 million people who lived and worked in this industrial and coal mining center of northern China were sleeping , was totally unexpected. The result was a catastrophe. The earthquake ground shaking devastated the city comprised mainly of unreinforced masonry buildings. It left at least 240,000 dead and an estimated 800,000 injured. Reconstruction and recovery took over ten years.

Floods

Floods happen more frequently than any other natural hazard. They occur annually and in every season of the year, primarily in river flood plains and as flash floods caused either by extreme precipitation or by rapid melting of ice and snow. Coastal communities and those near the water's edge and in the flood plain are most vulnerable. Floods cause damage, social disruption, health care problems, and environmental impact from inundation, excessive discharge, soil erosion, soil scour, and pollution. Some of the notable flood disasters include:

- The flood disaster in the Midwest in April 1997 and the Eastern United States in January, 1996.-- Heavy snowfall followed by rapid thaw of the snow and ice combined with heavy rain caused flooding in North Dakota in 1997 and in the Eastern United States along rivers from New York to Philadelphia to Virginia in 1996. More than 100,000 people and entire communities were evacuated. Economic losses exceeded $ 2 billion, mainly from damage to buildings, infrastructure, dams, and bridges.

- The Mississippi River flood disaster in July 1993 in the Midwestern United States,--Swollen by as much as 75 cm of rain in a three month period, flooding streams inundated more than 20 million acres of farmland in nine states. Economic losses reached an estimated $ 15-20 billion. Only forty-eight died.
- The flood disaster of July 1935 on the Huang He River, China. A total area of 16 million square kilometers was inundated and several million homes were washed away. The death toll was beyond reckoning.

Severe Storms

Severe storms (i.e., hurricanes, cyclones, typhoons, and tornadoes):, like floods, occur annually, but they are seasonal and more restricted geographically than floods. Coastal communities near the water's edge are most vulnerable. They cause damage and social disruption from high velocity winds, floods from storm surge, extreme precipitation, beach and coastal erosion, lightning, and hail. Some of the notable severe storm disasters include:

- Tropical cyclone in Bay of Bengal in 1970.--An estimated 500,000 were killed in Bangladesch from the storm surge and high velocity winds.
- The flood disaster in Bangladesch on April 30, 1991.--Flooding from an 8-meter storm surge generated in a tropical typhoon reached the city of Chittangong after midnight on April 30, affecting over 15 million people. More that 1.5 million buildings were damaged, leaving 10 million homeless and an estimated 200,000 dead and 139,000 injured. The success of the early warning system, evacuation, and cyclone shelters helped to lessen the losses from those of 1970.

Landslides

Small-to large-volume landslides on unstable slopes occur daily throughout the world. Communities and community development on unstable slopes are especially vulnerable to the permanent ground displacements caused by falls, topples, slides, spreads, and flows of soil and rock which can be generated either as a result of extreme precipitation or earthquake ground shaking. A large-magnitude earthquake can trigger tens of thousands landslides. Notable landslide disasters include:

- The earthquake/landslide disaster of May 31, 1970.--The M 7.6 earthquake centered 25 km (15 miles) off the coast of Chinbote in the north of Peru caused the largest earthquake/landslide disaster ever recorded in Latin America. A mass of ice at the 5,500-6,000 m level (17,200-18,800 feet) level on Mount Huascaran fell, slid on a glacier, and dropped and additional 10 km (6 miles) before reaching Yungay and Ranrahirca three minutes later. It buried these towns, killing all but 400 of the 20,000 inhabitants. In

Chinbote, ninety-six percent of the adobe houses were destroyed by ground shaking and more than 1,000 were killed.

Volcanic Eruptions

Eruptions of the World's 500 active volcanoes occur much less frequently than occurrences of the other natural hazards, but volcanic eruptions can have far reaching and devastating consequences when they occur. Communities near an active volcano are especially vulnerable to the effects of ash clouds (which can be a serious threat to aviation), lateral blasts, tephra, pyroclastic flows, lava flows, and lahars. A large-volume explosive volcanic eruption can impact the climate on a global scale. Notable volcano disasters include:

- The eruption of Mount Pinatubo in the Philippine Islands in June 15-16, 1991.--The largest volcanic eruption of the 20th century, the 15-hour eruption sent ash 30 km (18 miles) into the atmosphere and triggered pyroclastic flows and lahars. Over 200,000 people, including Clark Air Force base, were evacuated --the largest evacuation in history before a volcanic eruption. The effects of typhoon Yunya passing 50 km (30 miles) north added to the disaster. The death toll was only 320 because of the successful evacuation, but the region was devastated economically. Strategic military alliances were irreversibly changed by the eruption.
- The eruption of Nevada del Ruiz in Colombia on November 13, 1985.--After being dormant for 140 years, Nevada del Ruiz erupted during the afternoon and night of November 13. Hot pyroclastic material melted the ice cap rapidly, triggering lahars (i.e., debris flows) which traveled at an average speed of 30 km/hour (18 miles/hour) along the channels of four rivers. The lahars reached the towns of Armero and Chinchina around 10:30 p. m., burying the towns, destroying 5,680 homes, and leaving 24,740 dead and 5,485 injured.

Wildfires

Thousands of wildfires occur annually throughout the world. Communities located along wilderness-urban interfaces are especially vulnerable. Many occur as a consequence of hot, dry summers, with lightning being the principal causative agent. Others are caused by fires ignited by lava flows or triggered during earthquakes. Some are the result of arson. Notable wildfire disasters include:

- The Great Khingan Range, China wildfire disaster of May 6, 1987.--Fanned by strong winds over a period of 20 days, the fire consumed 750,000 cubic meters of forests in an area covering one million hectares, 13 percent of the forest. This loss represents approximately 20 percent of the annual wood production. The death toll was 191.

Tsunamis

Tsunami flood waves are generated mainly by submarine earthquakes. Tsunamis can travel across oceans with the speed of a jet airliner, impacting coastal communities with high-velocity flood wave having vertical heights in excess of 30 meters (100feet). Coastal communities are especially vulnerable to flooding from the wave run up and the impact of the high-velocity waves. Notable tsunami disasters include:

- The Valdiva, Chile earthquake/tsunami disaster of May 22, 1960.--This M 9.5 submarine earthquake, which occurred at 3:05 p. m., caused a catastrophe. This earthquake caused damage along 1,000 km (600 miles) of Chile's coastline, destroying an estimated 400,000 houses, and leaving over 5,000 dead. It produced strong ground shaking that lasted 3 1/2 minutes, caused subsidence of up to 2 meters (7 feet), triggered extensive liquefaction, and generated several tsunamis having flood wave run up of up to 10 m (33 feet). Tsunamis affected every Pacific rim country, damaging ships, flooding coastal areas, and destroying buildings and factories.

Droughts

Drought episodes are caused by lack of precipitation and vary greatly in frequency throughout the world, ranging in from annual occurrences to once every several years. Droughts can last several years or more, causing a loss of agricultural productivity, desertification, and adverse environmental impacts. Notable drought disasters include:

- Drought disaster in the Sahel, Africa, 1969-1973.-- Beginning in 1968, a long-term drought in western Africa resulted in the rapid southward spread of the Sahara desert in the Sahel countries of Mauritania, Senegal, Mali, Niger, Burkina, Faso, and Chad. This drought was no worse than many previous droughts, but its effect on humans and livestock culminated in a catastrophe. Approximately 250,000 people died and millions of refugees poured into cities during the drought. Millions of head of cattle died. Agricultural production dropped to 20 to 70 percent of the pre-drought production.
- The "Dust Bowl" drought disaster of the 1930's in the United States.--The drought of the 1930's was widespread, encompassing the entire Great Plains from North Dakota to Texas and lasting ten years. In addition to the dry weather and the dust storms, severe environmental problems occurred. Average wheat and corn yields dropped by 50 to 75 percent. Hundreds of thousands were forced to relocate from the Great Plains to other states in the western United States.

Property Casualty Insurance

Property casualty insurance companies are the main source of insurance against natural hazards throughout the Nation, and therefore, the business bearing the greatest share of insured losses after a disaster. In 1996, the property casualty insurers in California had a total premium income of $32.6 billion for all coverages. Of this total, approximately $ 1.5 billion was for residential and commercial earthquake insurance (8).

A property casualty insurance company's book of business typically is comprised of singlefamily dwellings, commercial properties, and the related coverages for contents, business interruption, and workers compensation and other lines. Insurance is a business involving: accountants, actuaries, salespersons, brokers, claims adjusters, managers, and executives; other property casualty companies who are competitors; state insurance regulators; and reinsurers. Insurance is a product having value to the insured, as well as a cost, the premium. The cost to the insurer is determined only after the product is sold and claims are paid out to the insured following a disaster (8). Most insurance policies have some form of deductible, which means that the insured and the insurer share in the loss. An additional choice is for the insurer to have reinsurance, which provides the same kind of protection for the primary insurer that the insurance policy provides for the policyholder.

Insurers manage the business of insurance through two processes: underwriting and rating. Underwriting determines the price to charge the insured for insuring the risk. Rating determines the proper amount that can be charged per $ 1,000 of coverage, given the characteristics of the risk for the particular peril. The underwriting process must consider the natural hazards (or "perils") to be insured against and "the amounts of coverage (values)" to be provided (5). Included in this underwriting process, as used by Kunreuther and Roth (5), is not only the selection criteria by which risks are insurable but also the actuarial soundness of the rates charged for the risk. In theory, property casualty insurance companies can offer protection to the insured against any risk that they can identify, and for which they can obtain information about the frequency and magnitude of potential losses, as long as they have the freedom to set premiums at a realistic level. Insurance is an economic institution that allows the transfer of financial risk from an individual or a pooled group of risks by means of a two-party contract. The insured obtains a specified amount of coverage against an uncertain, low probability-high impact event (e.g., an earthquake) for a smaller, certain payment (i.e., the premium) (5).

The principal natural hazards that property casualty companies insure single family dwellings, apartments, condominiums and commercial structures against are described below. The key questions for the underwriter are:1) "Where will the natural hazards occur?" 2) " How often will they occur?" 3) "How severe in space and time will the societal and economic consequences of the disaster agents generated by each natural hazard be?" and 4) "How vulnerable to damage and subsequent loss of use are the personal residences, business structures, critical public facilities, and the community's infrastructure?" For the insured, the key questions are: 1) "How much will it cost? 2) "What is covered?" 3) "What is not covered?" and 4) "What is the claims handling process if I have a claim after a catastrophe?"

Insurance Considerations Against Earthquake

Insurance against earthquake-induced damage from ground shaking can be included, but is not automatically included, in homeowners' insurance policies for an additional premium, except in

California. In California, the California Earthquake Authority has a unique role in making insurance available (8).

The disaster agents (i.e., the physical effects that cause societal disruption) of an earthquake include: ground shaking exceeding damage and collapse thresholds that are a function of the building's characteristics during various exposure times; ground liquefaction and lateral spreading, including sustained creep; landslides, surface fault rupture; regional tectonic deformation; flooding caused by tsunami wave run up or seiches, conflagration; and aftershocks, which can trigger a repeat of all of the above.

A typical residential earthquake policy insures for loss against structural damage, damage to contents, and loss of use. Commercial property earthquake insurance policies generally provide indemnification to the policyholder for direct damage to *insured* structures, building contents, and business personal property as well as indirect damage incurred by an insured outage of their business.

The direct damage to insured structures and business personal property includes payment for the repair or replacement of the damaged property in accordance with the coverage stated in the policy. Loss of net income and continuing expenses from the interruption of business can also be insured. A business can insure the following types of personal property: 1) building structures, 2) other structures, and 3) furniture, fixtures, equipment, supplies, machines and machinery, and stock (raw, in-process, and finished). Most commercial property insurance policies exclude: foundations and other underground property (e.g., pipes and drains); grading, excavations, and filling; plants, lawns, trees, shrubs, growing crops, and land; paved surfaces, roads, bridges, piers, wharves; detached signs, antennas, fences, and other outdoor items; building glass; retaining walls that are not a part of a building; vehicles licensed for road use, watercraft, and aircraft. Coverage for excluded items is often covered by endorsement. Some confusion may occur from the fact that all buildings are structures; but all structures are not buildings. Examples of non-building structures include silos, water towers and tanks, swimming pools, oil tanks, wharves and piers, bridges, covered bridges and enclosed walkways.

Earthquakes threaten the environment, quality of life, and the economic stability of communities throughout the United States. Small earthquakes occur daily in most states throughout the Nation. Although relatively infrequent, large-magnitude earthquakes have a greater sudden-loss potential as individual events than floods and severe storms. Earthquakes are dangerous because they can trigger disasters in a minute or less, they are unpredictable, and they strike without warning. Forecasts of their physical effects are ambiguous, and estimates of losses are uncertain. Submarine earthquakes can also generate tsunamis affecting nearby and distant coastal communities. Communities having development and infrastructure located in or adjacent to active fault zones, on soft and/or unstable soil, on unstable slopes, and near the water's edge are vulnerable to ground shaking, permanent ground failure, surface faulting, earthquake-triggered fire, aftershocks, seiches, and tsunami flood waves.

At present, insurers are seeking high benefit/cost solutions for: a) Strengthening unreinforced masonry and concrete, b) Adequate and continuous load paths, and c) Nondestructive evaluation methods to evaluate existing structures, three of the "Ten Most Wanted Improvements."

Insurance Considerations Against Floods

Since 1968 when congress created the National Flood Insurance Program, insurance coverage for floods is available on a nationwide basis through the cooperation of the Federal government and private insurers. Floods happen more frequently than any other natural hazard. They occur annually and in every season of the year, primarily as riverine and flash floods caused either by extreme precipitation or by rapid melting of ice and snow. Coastal communities and those near the water's edge and in the floodplain are most vulnerable. Some of the notable flood disasters include the Mississippi River flood disaster in July 1993 in the Midwestern United States, in the Eastern United States along rivers from New York to Philadelphia to Virginia in 1996, and flooding in North Dakota in 1997.

The disaster agents include: extreme precipitation, inundation after dams or levees are breached, high-velocity peak discharge, scour, water-borne debris, and erosion.

At present, insurers are seeking high benefit/cost solutions for: a) Buildings elevated in flood-prone areas, one of the "Ten Most Wanted Improvements."

Insurance Considerations Against Severe Storms

Hurricane wind damage and windblown water damage are included as part of the basic wind coverage in most property insurance p09licies. Flood damage, resulting from hurricanes is not included in property insurance policies, but can be purchased separately under the National Flood Insurance Program. Severe storms: (i.e., hurricanes, and tornadoes), like floods, occur annually, but they are seasonal and more restricted geographically than floods. Coastal communities near the water's edge are most vulnerable to hurricanes, whereas interior states are most susceptible to tornadoes. Both cause damage and social disruption from high velocity winds, floods from storm surge, extreme precipitation, beach and coastal erosion, lightning, and hail. The most notable hurricane disaster is Hurricane Andrew, which struck South Florida in the pre-dawn hours on Monday, August 24, 1992 before continuing westward to strike Louisiana.

The disaster agents include: flood waves from storm surge, high velocity wind fields, wind-blown and water-borne debris, effects of extreme precipitation or the runoff from heavy snow melt, beach and coastal erosion, lightning, and hail.

At present, insurers are seeking high benefit/cost solutions for: a) Secure roof coverings, b) Secure building envelope, and c) Glazed openings protected from wind-borne debris, and d) adequate attachment of commercial roof edge metal flashings. four of the "Ten Most Wanted Improvements."

Insurance Considerations Against Hail

Hail, a product of thunderstorms, is insured in residential and commercial policies nearly everywhere in the United States.

The disaster agents include: the size, velocity, and distribution of the hail stones.
At present, insurers are seeking high benefit/cost solutions for: a) hail-resistant roofs, one of the "Ten Most Wanted Improvements."

Insurance Considerations Against Landslides

Landslides are normally not considered an insurable peril by private insurers. Small-to large-volume landslides occur daily on unstable slopes throughout the Nation. Community development on unstable slopes is especially vulnerable to the permanent ground displacements caused by falls, topples, slides, spreads, and flows of soil and rock which can be triggered either as a result of earthquake ground shaking or extreme precipitation. The Loma Prieta earthquake, in 1989, and El Nino, in 1997-1998, triggered tens of thousands of landslides in California.

The disaster agents include: falls, topples, slides, spreads, and flows of soil and rock.

Insurance Considerations Against Volcanic Eruptions

Damage caused by volcanic eruptions is included in most property insurance policies. Eruptions of the United States' 70 active volcanoes occur much less frequently than occurrences of the other natural hazards, but volcanic eruptions can have far reaching and devastating consequences when they occur. Communities near an active volcano are especially vulnerable to the effects of lateral blasts, tephra, pyroclastic flows, lava flows, lahars, and ash clouds (which can be a serious threat to aviation). A large-volume explosive volcanic eruption can impact the climate on a global scale. Notable volcano disasters in the United States include the eruption of Mount St. Helens in Washington state at 8:32 a m on May 18, 1980.

The disaster agents include: ash clouds, which can affect global climate change, tephra, pyroclastic flows, lava flows, lahars, lateral blasts, poisonous gases, fire, and flooding from breached dams or levees.

Insurance Considerations Against Wildfires

Wildfires can be included in most property insurance contracts. Thousands of wildfires occur annually in the United States. Communities located along wilderness-urban interfaces are especially vulnerable. Many occur as a consequence of hot, dry summers, with lightning being the principal causative agent. Others are caused by fires ignited by lava flows or triggered during earthquakes. Some are the result of arson. Notable wildfire disasters include the Oakland, California wildfire of October 20, 1991, which at that time was the worst wildfire in the history of the United States, and the wildfires in Florida in July 1998.

The disaster agents include: incineration, smoke, and increased susceptibility to erosion.

At present, insurers are seeking high benefit/cost solutions for: a) Non-combustible roofs, one of the "Ten Most Wanted Improvements."

Insurance Considerations Against Tsunamis

Tsunami flood waves are generated mainly by submarine earthquakes. Tsunamis can travel across oceans with the speed of a jet airliner, impacting coastal communities with high-velocity flood wave having vertical heights in excess of 30 meters (100feet). Coastal communities are especially vulnerable to flooding from the wave run up and the impact of the high-velocity waves. Notable tsunami disasters include those that struck Mayaguez, Puerto Rico in 1918, Crescent City, California in 1964, and Hawaii, many times.

The disaster agents include: high-velocity waves, flooding, coastal inundation, and coastal erosion.

Insurance Considerations Against Droughts

Drought episodes are caused by an extreme lack of precipitation. They vary greatly in frequency throughout the United States, ranging from annual occurrences to once every several years to decades. Droughts can last several years or more, causing a loss of agricultural productivity, desertification, and adverse health and environmental impacts.

The disaster agents include: loss of agricultural productivity and insect infestation.

Conclusions

We have pointed out that there is a potential role for every stakeholder and policy maker in reducing and managing their community's risk, and that everyone--ranging from insurers to local, state, and Federal governments and their agencies, to individual businesses, to individual citizens--can forge partnerships, such as CUSP, and contribute to making their community safer from natural hazards, and in the long-term, nattural-hazard-resistant. Accountants, actuaries, salespersons, brokers, claims adjusters, managers, and executives; other property casualty insurance companies; reinsurance companies; and state regulators all have roles. So do the insured. In theory, insurers can offer protection to the insured against any risk that they can identify, as long as they can obtain reliable information about the frequency and magnitude of potential losses, and they have the freedom to set realistic premiums (5) Finding the points of intersection of the interests of community stakeholders, individually and collectively, and the interests of community policy makers is the key to success.

REFERENCES

(1) Federal Emergency Management Agency, 1998, Project Impact, Mitigation Directorate, Washington, D.C., 40 p.

(2) Central United States Partnership, 1999, A Strategic Plan to Reduce the Unacceptable Risk From A Catastrophic Earthquake in The Central United States, IBHS, Boston, MA, 126 p.

(3) Hays, Walter W., and Dennis Fasking, 1999, Earthquakes: Cahses, Consequences, and Considerations for Insurance, Draft Monograph, Institute of Business & Home Safety and the United States Geological Survey, Boston, MA, 140 p.

(4) Hays, Walter W., B. Mohammadioun, and J. Mohamadioun, 1998, Seismic Zonation: A Framework for Linking Earthquake Risk Assessment and Earthquake Risk Management, Monograph, Ouest Editions, Nantes, France, 157 p.

(5) Kunreuther, H., and Richard Roth , (eds.), 1998, Paying the Price-The Status and Role of Insurance Against Natural Disasters in the United States: National Academy Press, Washington, D. C., 300 p.

(6) National Academy of Sciences, 1991, A Safer Future: Reducing the Impacts of Natural Disasters, National Research Council, National Academy Press, Washington, D. C., 67 p.

(7) Office of Science and Technology Policy, 1996, Natural Disaster Reduction–A Plan for the Nation: Report of the Subcommittee for Natural Disaster Reduction: Washington, D. C., 44 p.

(8) Roth, Richard Jr., 1998, Earthquake Insurance Protection in California, in Kunreuther, H.., and Richard Roth, (eds.), Paying the Price-The Status and Role of Insurance Against Natural Disasters in the United States: National Academy Press, Washington, D. C., pp. 67-95.

Earthquake Benefit/Cost Study

Can Mitigation As A Public Value Be Achieved Without It?

By

Dennis Fasking
Allstate Insurance Company

Prologue

Mitigation, in the sense of selecting where to build and how to build stronger, safer structures in which to live and work, should be the goal of all the stakeholders:

- **Owner** – has a financial interest in preserving the value and usability of the structure, its contents, and in maintaining its functionality.
- **Occupant** – has an emotional and financial interest in preserving personal safety and that of loved ones and pets, possessions, and in not having his or her comfortable surroundings and routines disturbed during the time a severely damaged home or business is restored or replaced; in the case of a business, the main goal is to preserve business continuity.
- **Insurer** – as a recipient of a transferred portion of a covered loss and as a partner with their insureds in helping them manage the risk each faces, it has a financial interest in minimizing the damage and loss of functionality of each of their insured risks and a desire to help its insured know the risks and what can be done about them; and in the aggregate sense, it is interested in achieving a reasonable spread of risk, an efficacious use of available capital and its resources, and a reliable stream of reasonably stable future earnings to enable it to be financially strong in a healthy market-driven and competitive environment that maximizes availability and affordability to the extent possible.
- **Reinsurer** – as an assumer of a transferred portion of a covered loss for an individual or portfolio of risks from one or more insurers, it has a financial interest in minimizing the damage and loss of functionality of an aggregation of all the risks on which a transfer is to take place.
- **Others** involved with competing transfer mechanisms, such as securitized risk instruments [like Cat Bonds] - as an assumer of a transferred portion of a covered loss from an event or series of events that affects large sections of the population, it has a financial interest in minimizing the damage and loss.
- **Government** – actually there are three levels of government who hold a stake: Federal, State and Local.
  - **Federal** – has a financial interest in reducing the need for federally funded disaster assistance; and if federal legislation to set up federal reinsurance program is passed, it would have a similar interest to that discussed above for reinsurers.
  - **State** – has a financial interest in reducing the need for disaster assistance; an interest in maintaining a sustainable population, development and a safe environment; an interest in sustained and financially sound business environment; and it has a broad legislative and regulatory interest.
  - **Local** – has a financial interest in sustained community and the safety of its inhabitants and sustainability of its services, its businesses, and its citizens' places of residence, etc.; and it needs to have critical facilities that can remain functioning after the worst disasters to take of the victims.

If the interests and perceived benefits of the many stakeholders are so obvious and the solution is simply a matter of carefully choosing where and how to build stronger, safer structures, why aren't there more structures being built or retrofitted to make them stronger and safer to protect the inhabitants and their possessions? Is there some way that the research community, perhaps the MidAmerica Earthquake Center or others, can partner with stakeholders to encourage individual owners and occupants to take steps to strengthen and make safer their homes and businesses and therefore to mitigate damage from future earthquakes? What information and analytical tools are available today and what might be missing to further this worthy objective?

In the remainder of this paper, I will provide a general outline of what analytical tools exist today and how additional research can improve or cause them to be used more effectively to do benefit/cost analyses as respects different mitigation scenarios.

What is the problem? Don't the historical loss records tell the story? Can't they be used to support incentives to mitigate?

The short, simple answer is "no".

The Frequency and Severity Challenge of Earthquakes in the Midwest

Earthquakes are of such high severity, low frequency events and it would take thousands of years of loss history to gain a reasonable data base from which to estimate future expected losses from earthquakes in the Midwestern United States. Most insurers' historical earthquake loss records probably go back no more than twenty five or thirty years, a time during which no damaging earthquakes have occurred in the Midwest. The last great destructive earthquake for the region was a series of three very strong quakes over a three month period at the end of 1811 and the beginning of 1812. These were the great quakes along the New Madrid fault and they were strong enough to make the Mississippi run backward and to ring church bells as far away as Boston.

Changing Mix of Where and How Structures Were Built

Even if such a long historical record of the frequency and severity of earthquakes were to exist, there would the problem of a constantly changing mix and composition of structures built in harm's way. Over time, more and more people settled in the area and the construction materials and methods have changed continually throughout the time period. So if historical loss records existed for the 1811/1812 quakes, the losses expected from a repeat of that event would be significantly different, (significantly more severe), because of more structures, greater values over time, and different structural vulnerability dependent upon how they were built and with what materials.

Impact from an Evolving Science and Technology

Roughly twenty years ago, a physical scientist theorized that the known history of earthquake activity could be explained by the earth's crust being made up of a fractured outer surface shell, whose huge slabs floated over a molten rock core of magma. And so plate tectonics was born as a theory. That scientist found few supporters for his theory among his contemporaries and died without knowing that his theory would become so commonly held by his peers as it is today.

Today, we all seem willing to accept that the boundaries of these free floating continental and oceanic plates are the site sources for most of the earthquakes, volcanoes, and seismically created tsunamis around the world. Why? Because the scientists have been able to extensively study the visible faults through a variety of means, including ground based and satellite instruments throughout the world. They have mapped historical earthquakes and we can use them to visualize the plate boundaries by where they continually occur, such as the much publicized "Ring of Fire" that so graphically defines the Pacific Ocean Plate boundaries.

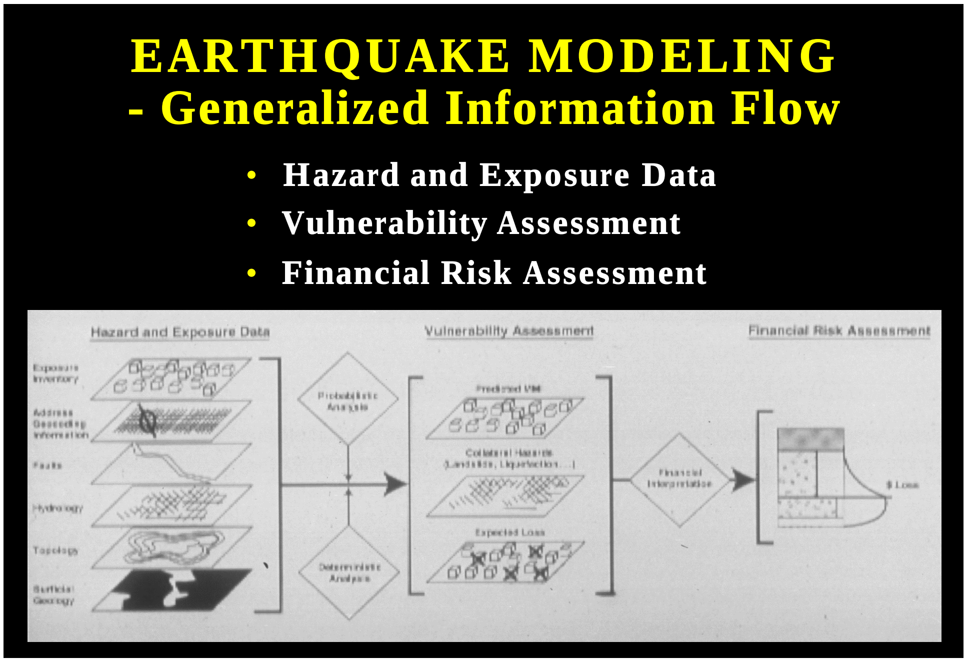
But scientific exploration and new theorizations haven't stopped. Scientists have coined new sciences such as paleoseismology to describe explorations of areas in which a longer term record of major earthquakes can be mapped from a study of the effects such earthquake had on the environment. Once such method is trenching along known fault boundaries and studying the evidence of past earthquakes, such as large sand blows or violent uplifts of large slabs of earth and rock that could only occur in such events. These are then dated by carbon-dating the materials found in that same strata being observed. These new pioneers are discovering ancient earthquakes and filling in more of the puzzle. New theories are formed to explain more about the way earthquakes act along different types of faults and still more scientific exploration results as the scientists attempt to explain what happened in the past or in a new earthquake that happens in a location heretofore not thought to contain a fault or acts so differently from what previous earthquakes had.

Each new earthquake during the last two decades has brought new learnings as experts, structural engineers and seismic scientists and others, have studied what happened and tried to explain why. In California, this has led to building code enhancements, focused primarily on life safety, that has caused new structures in that state to be built stronger and safer than those built in times past.

The Emergence of Catastrophe Simulation Modeling Technology

Another advancement came with the technology revolution that saw cumbersome and expensive mainframe processing and data base systems replaced with plentiful powerful and inexpensive personal computers and more efficacious relational databases and cheap storage. From that revolution came the ability to store, process, and retrieve millions of pieces of information cheaply and efficiently. And it fostered a separate explosion of new data processing tools for the end user and specialty modeling firms that sprang up to take advantage of the new capabilities. It changed our companies and it changed the capabilities of scientists, academicians, and other researchers and its reverberations continue to be felt in the physical and other sciences.

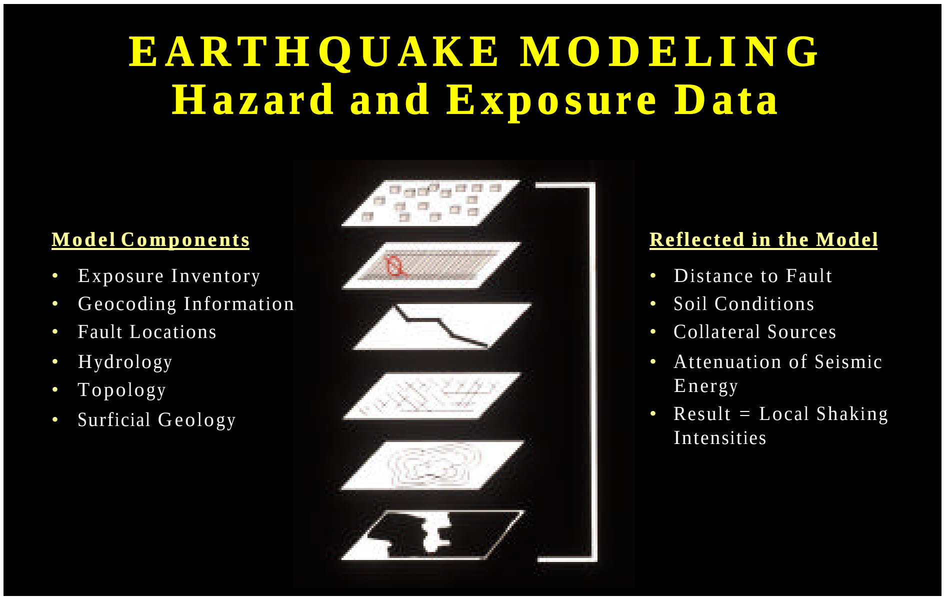
Out of this new world came a synthesis of different disciplines initially by new catastrophe modeling firms like Applied Insurance Research, Inc. (AIR), E.W. Blanche, Inc. (EWB), Risk Engineering International, Inc. (REI), and Risk Management Solutions, Inc. (RMS). Joined by still more such as AON Corporation, Applied Research Associates, Inc. (ARA), Earthquake Engineering International, Ltd. (EQE), and others, these firms have sought to continually gather the following types of data and information and to make use of the continually changing and improving "state-of-the-earthquake-science" and the exponential increased capability and speed of new computing and storage technologies.



It should be noted that much of the publicly available data, research, and other needed information would not have been possible without the financial and human and equipment and technology investment that the government has made in the study of earthquakes. This author believes that future advances are needed and that governmental support must continue to promote continued advances in this field, especially for areas east of the Rockies, such as the New Madrid and Wabash Valley seismic areas in Mid-America and in the Charleston, SC seismic area.

Input Data for Catastrophe Simulation Modeling

The first of the three sections involves the input section of the model and includes both historical data on earthquakes, but also insured exposure information.



- Historical inventory of earthquakes in the United States and throughout the world, along with the best available information, (whether instrument-calculated or estimated by experts), about the likely energy release, the epicenter location, the fault involved, the rupture length, the attenuation (or decreasing shaking intensity as the shock waves travel through different surface mediums), the damage pattern observed or theorized for different structural types, the impact of site conditions such as evidence of differences by soil type, landslide-prone areas, liquefaction, etc.
- Historical inventories have been supplemented with new or better information as new earthquakes have occurred since the original inventory was created and by studying highly correlated parts of the environment to discover better information and/or to discover the existence of older pre-inventory earthquakes.

- Geographic positioning to better pinpoint locations on the globe so that layering of related and crucial information can be accurately overlaid on locations of exposed structures. Various data layers that may be useful in the resultant earthquake simulation modeling might include:

  - Locations of exposed structures.
  - Location, length, depth, orientation and type of faults.
  - Site conditions such as the type of surface media, (i.e., soil is sand, compressed sand, aluvium or other sediment, rock, etc.); presence of water and loose particulate matter in the soil that could become liquefied; elevation because hilly terrain is more susceptible to landslide; etc.

- Historical inventory of quakes recorded for each fault, since this leads to an estimate of either a series of likely earthquakes (a fairly open-ended distribution both severity and frequency of occurrence) or possibly a conclusion of the experts that the distribution is capped at a characteristic earthquake (much like a tuning fork would settle out at a certain vibration when struck with sufficient force); expert opinion on the shaking intensity felt at varying distances from the epicenter and fault rupture in past earthquakes; etc.
- Collateral sources at risk, such as water, gas, and other utilities that could impact an area hit by an earthquake and any conflagration that ensued.
- Brush fire areas or presence of vegetation that might suggest greater danger of conflagration.
- Infrastructure and essential services that might impact how rescue and mitigation of further damage by aftershocks or fire following or loss of use after an earthquake.
- In order to estimate damage impacts on individual structures from the full theoretical distribution or one or more of a set of the historical earthquakes' shaking and any accompanying conflagration in the historical inventory, the following kinds of information on the exposed structures is needed:
  - Location and orientation on the property.
  - Replacement value of the structure.
  - Construction type and any other available information on the way the particular structure is built.
  - Age and the building code in effect when the structure was built suggests how the particular structure should have been built and what might be hidden from view.
  - Insurance coverages, limits, and deductibles applicable for each exposed structure.
  - Existence of any per risk reinsurance that might apply to the structure.

Simulation Modeling

The modeling firm staff usually include professionals with expertise in the following disciplines: seismic and structural engineering; data processing; actuarial; etc. so that they can create a model that attempts to run theoretical simulations of next year events that run the full gamut of possibilities for at least the most significant variables that can be estimated.

Modeling Stochastic Earthquakes

Since a model is essentially a set representation of dynamic events, each of which are defined by what can and does happen in the assumed reality, the modelers attempt to model a reasonably complete set of possible events by:

- Identifying the most important variables present in historical and theoretical earthquakes and then associating a theoretical distribution of possible values for each such variable. An example would be the energy release possible along a given fault could range from very small to very large, depending on how much energy had built up and how much is released. By letting this variable range from very small to very large, the impact of such variation along the fault can be reflected in the model.
- By defining all important variables and their likely distribution and upper and lower limits, based on the most up-to-date scientific information available, a tremendous

number of combinations of variables is possible, and taken together in randomized selection from their respective distributions, a wide range of possible earthquakes can be simulated.

- Using current "state-of-the-science" probabilities of different variables occurring for each known or hypothesized fault location that the scientific community has established as most likely, then each simulated possible earthquake can be associated with its likelihood of occurring. The different models estimate these earthquake probabilities a little differently, but all can be successful in estimating a best guess estimate of the probabilities.
- Refinement of the distributions for the important variables is possible from studying what happened in recent earthquake.

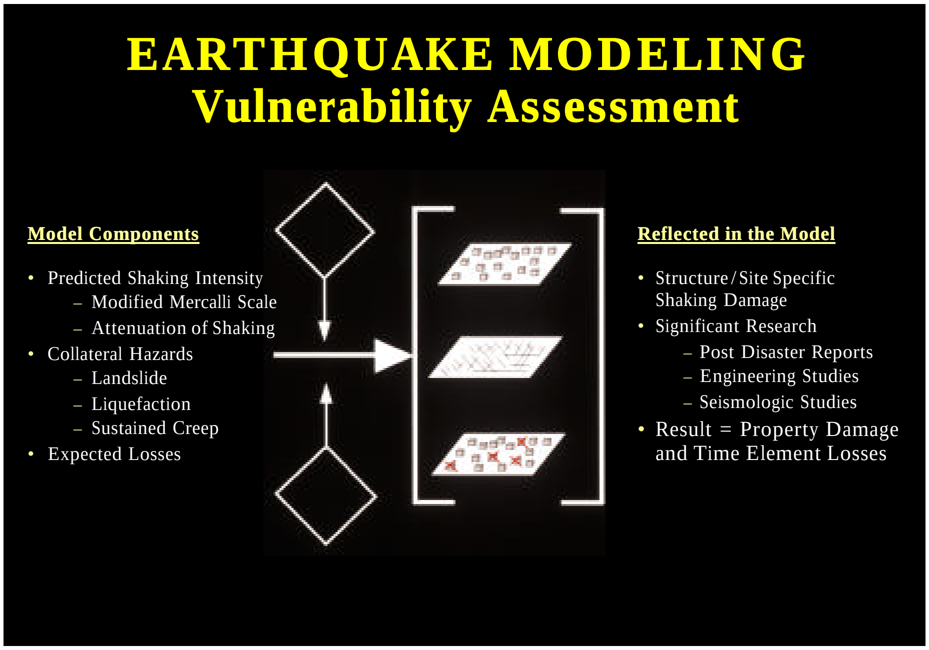
Modeling Deterministic Earthquakes

If one wants to then pre-determine the value of the important parameters to either replicate a historical earthquake or to examine the impact of the maximum likely or other wise determined earthquake on a specific fault, then the model can be run for such an event by simply fixing each of the variables to pre-set values.

So the 1811/1812 earthquake can be replicated by setting the variables in the model to those listed in the historical inventory and running a single earthquake on the New Madrid fault in the same location and with the same rupture length, energy release, etc.

But it would also be possible to run out the full theoretical distribution of likely future (next year) events along with their probability of occurring. Essentially, this is the stochastic set described in the previous section.

Vulnerability Analysis in the Model for the Exposed Structures



The model goes beyond simply estimating the energy release and the physical shaking intensity at different locations away from the epicenter and fault rupture to estimate how different structures in different locations are likely to be affected by the simulated event (in the case of a deterministic earthquake) and by the full distribution of simulated events (in the case of stochastic earthquakes).

The models usually include primary structure characteristics, which are the ones most likely to be determined from the insurance company's policyholder records. In addition, if the insurance company can determine more of the structural characteristics, the models can reflect them as secondary structure characteristics. Obviously, the more information on the structure, the better, in determining how it would respond to the shaking and other characteristics of the modeled earthquake(s).

Here too, the advances in science are continually being reflected in the models. A good example would be the movement away from the use of categorizing shaking intensity at a site for a building based on a subjective interpretation of the observed damage in accordance with the moment magnitude index (MMI) scale. In addition to being subjective, the resulting distributions used to estimate damage in the models were based on a somewhat flawed set of distributions based on the expert opinions from ATC13 (Applied Technology Council) by structural engineering experts using the Delphi method to arrive at a consensus opinion of the mean damage and the variance around that mean.

Most models today are using spectral acceleration of the structures at the site related to the peak ground acceleration expected to occur at that site for each simulated earthquake. Essentially, this will more properly take into account the structure's likely response to the energy that reaches it at that site on the kind of soil and other factors associated with it.

Of course, a frame structure will perform differently from an unreinforced masonry structure and from a reinforced masonry structure. Also, the footprint of the building and the number of stories are important. The models attempt to model the relative differences in how these drastically different performing structures will respond to the shaking intensities of the vertical and horizontal ground motions expected from the different simulations.

This component of the modeling determines the damage expected from each of the simulated earthquakes. Now we must turn to how that translates into insured loss and a distribution of the damages to the different parties who share in that loss.

Financial Distribution Modeling of "Who Pays What, Given The Expected Damage?"

For each insured structure, the damage must be divided such as follows:

- Portion that the structure owner is responsible for due to not having any insurance.
- For the insured owner, the portion retained is determined by the deductible carried, the limits and any co-payment provisions within the policy.

- The direct insurer's portion is the remainder less that portion transferred to a reinsurer under a facultative reinsurance program or through some quota share reinsuring arrangement.

After making adjustments such as shown above on a policy by policy basis, the next step is to aggregate all the insureds into a portfolio of risks, for which further division of the responsibility may be necessary, such as:

- Portion of the aggregate losses transferred to a reinsurer(s)
- Portion transferred through one or more securitized instrument, such as catastrophe bonds

The model must reflect these different parties' responsibilities in accordance with contractual agreements that have been shared with the modeler or the modeler will simply model only the individual policy conditions and leave the transference steps to the client. I suspect that either and both are done as a matter of practice.

Making Necessary Adjustments - Underlying Exposure Base Changes

If the model has been run at an earlier time and the exposures used were from an earlier time frame and have changed significantly in the meantime, then the modeled output must either be rerun or adjusted to account for those significant changes in exposure numbers or mix. This could occur because of significant growth or decline of the numbers or values insured or because of a change in the distribution of that business relative to the risk of loss from earthquakes.

Often, adjustments must be made for changes in the exposure that will take place because of some actions being taken by the company, such as a roll-on of deductibles, a change in the underlying policy coverages or limits, or because of some exposure management program being implemented. Any of these that can be expected to have an impact on the overall modeled results should be reflected by either rerunning the model with a new exposure file reflecting the changes or the output adjusted for those changes in a manual or additional modeling process.

Often in responding to rating agency inquiries or to prospective reinsurers or financial institutions to obtain rate quotes or to evaluate such rate quotes for risk transfer proposals, modeled results for some future period of time is necessary, such as projected to the current yearend or to the end of a roll-on period. In using modeled results for such purposes, a projected exposure file will need to be run through the model or adjustment made for the anticipated future exposure changes.

Mitigation Benefit/Cost Study

Using Catastrophe Modeling to Measure "What-If's" for Mitigation Alternatives

In order to measure the benefit to an insurance company of one or more mitigation alternatives, it is necessary to first define the steps to be taken in the mitigation alternative, a benchmark situation, and then run the model three times:

- To determine the full expected future loss distribution for the exposures insured "as currently built", being careful to retain loss detail for each structure and for the aggregation of all insured structures. The expected annual losses would be usable for ratemaking purposes and various layers of losses would be usable for exposure management purposes.
- To determine the same detail of information for the same exposures for a selected benchmark class, say for a structure of this type built with no assumed mitigation features, i.e., "no mitigating features".
- To determine the same detail of information for the same exposures for each set of mitigation alternatives for which expected losses will be estimated. Suppose there was an interest in only estimating the value of a mitigation alternative that called for bracing the cripple walls on houses built over crawl spaces. Then the model would be run for any house for which this mitigation alternative was possible as though the cripple wall had been braced in a specified fashion.
- If creating a classification system, like that filed recently by the Florida Wind Underwriting Association, the modeled results for each mitigation alternative (or classification) would be measured relative to the benchmark class, perhaps the "no mitigation features" alternative. So this class would be set at 1.00 and then lower relativities would be established based on how much lower were the modeled expected lossess for the mitigation alternatives. If bracing the cripple walls would mean 20% lower modeled expected losses, then the relative factor for this class would be .80. The same procedure would be followed for each mitigation classification.
- Though treated in the rules differently, essentially a set of discounts for a variety of mitigation alternatives is a form of classification plan, only with just a few classifications.

Picking From Among Different Possible Mitigation Possibilities?

Most insurers do not employ structural engineers who can provide them with expert opinion about what steps should be taken to strengthen and make a structure safer in the event it is subjected to the full range of future earthquakes. So there needs to be a methodology to follow that identifies the more effective of the different possible mitigation alternatives:

- Understanding the shaking and other stresses to which structures will have to be strong enough to withstand, structural experts will need to be consulted about what would be the most effective mitigation alternatives to consider. This might involve testing using scale models on shake tables or expertise formed from years of observing what did and did not fail during previous earthquakes. Regardless of how it occurs, there is a need for expert opinion about what mitigation alternatives should be researched and its impact on expected losses measured.

- Next that expert opinion as to how different structures will respond under a non-mitigated and as mitigated using a given alternative must be codified in such a way that it can be incorporated into the catastrophe models.
- Once that has been done, then the different mitigation alternatives can be run through the as model discussed above. The financial **Benefit** for the insured is simply then the absolute dollar amount or relative reduction in the expected future losses from taking the mitigation action being evaluated. Of course, this stream of future savings could be discounted back to a present value over the perceived life of the structure or for the period of ownership assumed to add a degree of sophistication to the process. Regardless of the process used, it must result in a measurement of the estimated Benefit that can be properly compared to the Cost associated with the same mitigation action. This reduction in expected losses would likely be reflected in a lower rate level charged the customer, so it does not simply flow to the bottom line of the company as some would suggest. The real financial **Benefit** to the insurance company would be in the efficiency gain in its utilization of available capacity, allowing it to grow and stabilize earnings.
- The financial **Cost** to the insured is the cost of doing the mitigation steps, less any financial incentives that his or her insurer or other stakeholders might provide for their taking the responsible action to mitigate future expected losses. The financial **Cost** to the insurance company would include the expense of implementing a process to gather the necessary additional information on the structures it insures, verifying that the mitigation steps had actually been taken, the cost of revising their internal data processing and other systems, etc.
- For each such stakeholder, a comparison of the **Benefit/Cost** relationship of different mitigation alternatives should be made to decide if the effort is cost-justified to be considered as part of the ultimate decision as to whether to take the considered action or not. Of course there are also non-financial considerations as well, but this paper is only dealing with the financial part of the decision the stakeholder must make.

Without Having a Benefit/Cost Study That Justifies The Mitigation Action, Is It Reasonable to Assume Widespread Proliferation of Mitigation Incentives By Insurance Companies?

A Benefit/Cost Study is certainly not a necessary and necessarily sufficient pre-condition for an insurance company or any other stakeholder to decide on offering an incentive for a structure owner who significantly strengthens his structure against future strong earthquakes. Some such companies may choose to make that decision on the basis of other than financial reasons. But it is much more likely that a profit-motivated business will seek to build a strong financial business case and a solid Benefit/Cost Study will be needed to meet that need. So, in order to encourage widespread availability of mitigation incentives for property owners, it is suggested that certain actions should be taken to make Benefit/Cost studies easier for insurance companies to perform and to reduce the level of uncertainty in the models that are used therein:

- Access to more information on individual structures that can be used to improve the estimate of expected future earthquake losses for each structure as built currently and to make it possible to do sufficiently detailed Benefit/Cost analyses of "what-if?" mitigation alternatives.

- Additional research be funded by the government and others to continue to advance the "state-of-earthquake-science" to further improve the technology that underlies catastrophe modeling.
- That the levels of uncertainty within current catastrophe modeling be identified and efforts made to reduce the uncertainty in each of the components of the model that contribute to the overall uncertainty of the model, including the following:
  - The inputted data layers that have been used in the models, including the historical earthquake inventory and the associated details for each, the expected frequency and severity distributions, etc.
  - The scientific underpinning of the simulation modeling, including the default selections for the variables and the choice of theoretical distributions used for the variables.
  - The fragility curves used for different structure types.
  - The way that secondary building characteristics are treated in the model.

Conclusion

Stakeholders such as insurance companies will most likely require that Benefit/Cost studies be completed in order to begin to provide a widespread offering of financial incentives to their customers. These studies could be accomplished if a process for collecting the necessary detailed structural information for specific structures could be devised. Then using this information along with the existing catastrophe models to do the analyses would enable stakeholders such as the insurance companies to gather the information they are likely to need to financially justify the offering of mitigation incentives.

It is also clear that the insurance industry needs and could benefit from better performance data on single family residences and for smaller commercial structures during predictable large shaking events in the more heavily populated seismic regions east of the Rockies.

It is the author's belief that the MAE Center could potentially improve the Benefit/Cost analysis that would serve to encourage insurance companies or other stakeholders to provide mitigation incentives by:

1.) Improving the models through focused research that reduces the uncertainty inherent in the catastrophe models in use today.
2.) Promoting ways for gathering more construction information on each individual structure so that a more specific estimate of the expected losses for a specific structure could be determined. This would be instead of using default or average structural characteristics to do the estimating for the "as is built" condition and for certain mitigation "what-if?" alternatives.
3.) Conducting the actual benefit/cost analysis for representative structures, (both with and without being built stronger and safer), under likely catastrophe shaking scenarios and for different soil or other site-specific conditions.

But if these actions by the MAE Center are not done, it will not necessarily preclude individual companies from completing their own Benefit/Cost analyses and then to offer mitigation incentives based on analysis tools already available to them.

APPENDIX D

WORSHOP ATTENDEES

Mid-America Earthquake Insurance Workshop
July 28 and 29, 1999
Peabody Hotel
Memphis, TN

Dan Abrams
Director
Mid-America Earthquake Center
University of Illinois
1245 Newmark Laboratory
205 N. Mathews Ave.
Urbana, IL 6180

Keith Barkalow
Vice President
American Family Insurance Group
6000 American Parkway
Madison, WI 53783-0001

James Baxter
Vice President Underwriting
Allendale Group
P.O. Box 7500
Johnston, RI 02919

Jim Beavers
Deputy Director
Mid-America Earthquake Center
University of Illinois
1241 Newmark Laboratory
205 N. Mathews
Urbana, IL 61801

Jerry Bell
Asst. VP Commercial & Property Lines
National Association of Independent Insurers
2600 River Road
Des Plaines, IL 60018-3286

Tracy Bertram
Insurance Analysis Principle
Kentucky Department of Insurance
215 W. Main St.
Frankfort, KY 40601

Rick Bradford
USGS
1400 Independence Road
MS 511
Rolla, MO 65401

Kathy Carstens
Personal Lines Underwriter
SAFECO
3637 Deyer Rd.
Sunset Hill, MO 63126

Peter Colket
Vice President
American Re-Insurance Company
555 College Road East
Princeton, NJ 08543-5241

Larry Cook
Attorney
Kentucky Department of Insurance
215 W. Main St.
Frankfort, KY 40601

Mark Doerner
Missouri Department of Insurance
301 West High Street, Suite 630
Jefferson City, MO 65101

Dan Dolan
Associate Professor
Virginia Polytechnic Institute
1650 Ramble Road
Blacksburg, VA 24061-0503

Kevin Donaldson
Underwriting Consultant
Nationwide Insurance
One Nationwide Plaza
Columbus, OH 43215-2220

Ralph Dorio
Insurance Services Office
Locator Code 1614
Safety
7 World Trade Center
New York, NY 10048-1199

Arnold Dutcher
Chief Deputy Director
Illinois Department of Insurance
100 West Randolph, Suite 15-100
Chicago, IL 60601

Mike Elam
Vice President
Union Insurance Company
3641 Village Dr.
Lincoln, NE 68508

Terry Elliott
Earthquake Underwriter
State Farm Fire & Casualty Company
One State Farm Plaza
Bloomington, IL 61710-0001

Jeff Estes
Personal Business Manager
SAFECO
3637 South Geyer Road
Sunset Hills, MO 63127-1203

Dennis Fasking
Senior Actuary
Allstate Insurance Group
Suite C
North Plaza
2775 Sanders Rd.
Northbrook, IL 60062-6127

Gary Ford
Vice President, Planning & Research
Shelter Insurance Companies
1817 West Broadway
Columbia, MO 65218

Karen Gahagan
AVP, Information Services
Institute for Business & Home
175 Federal Street, Suite 500
Boston, MA 02110-2222

Michael Griffin
EQE International
1848 Lackland Hills Parkway
Maryland Heights, MO 63146

Walt Hays
Senior Program Manager
American Society of Civil Engineers
10211 Tamarack Dr
Vienna, VA 22182-1845

Carl Hedde
American Re Insurance Company
555 College Road East
Princeton, NJ 08543

Gary Heidelman
Underwriter
Tennessee Farmers Mutual Ins. Co.
147 Bear Creek Pike
Columbia, TN 38401-2266

Bob Herrmann
Saint Louis University
Earth & Atmospheric Sciences
3507 Laclede Avenue Blvd.
St. Louis, MO 63103

Norm Hester
CUSEC
State Geologists
611 North Walnut Grove
Bloomington, IN 47405-5067

Coit Holbrook
Director of Consumer Insurance
Tennessee Dept.of Commerce & Ins.
500 James Robertson Parkway
Nashville, Tn 37243-0574

Thomas Hudock
AVP, Staff Operations
Westfield Companies
One Park Circle
Westfield Center, OH 44251-5001

Natalai Hughes
NAIC
120 West 12th St.
Suite 1100
Kansas City, MO 64105

Judy Jao
Underwriting
Farmers Insurance Company
4700 Wilshire Boulevard
Los Angeles, CA 90010

Arch Johnston
CERI, University of Memphis
3890 Central Avenue
Memphis, TN 38152

Gerry Jones
Chairman
Multi-Hazard Mitigation Council
1100 West 122 St.
Kansas City, MO 64145

Frank Kwiatkowski
Director Residual Markets
Nationwide Insurance
One Nationwide Plaza
Columbus, OH 45504

Dale Lauer
Senior Vice President
SAFECO American States
500 North Meridian Street
Indianapolis, IN 46204-1275

Stephen Marlin
USAA
9830 Colonnade Boulevard, Suite 600
San Antonio, Texas 78230-2239

Roy Nixon
Deputy Commissioner
Tennessee Dept.of Commerce & Ins.
170 North Main St., 12th Floor
Memphis, TN 38103

John Oyster
Regional Property Loss Manager
Liberty Mutual Insurance Company
P.O. Box 3206
Naperville, IL 60566-3206

W.R. (Ronn) Padgett
Chairman of the Board, CUSEC
Kentucky Div. of Emergency Mgmt.
100 Minuteman Parkway, Bldg. 100
Frankfort, KY 40601-6168

Gary Patterson
CERI, University of Memphis
3892 Central Avenue
Memphis, TN 38152

Daniel Poledna
VPof Comm. Lines, Underwriting
SAFECO American States
500 North Meridian Street
Indianapolis, IN 46204-1275

James Russell
Vice President Outreach
Inst. for Business & Home Safety
175 Federal Street, Suite 500
Boston, MA 02110-2222

Harvey Ryland
President & Chief Executive Officer
Inst. for Business & Home Safety
175 Federal Street, Suite 500
Boston, MA 02110-2222

Ira Satterfield
Geologist, MS Geological Survey
Missouri Dept. of Natural Resources
111 Fairgrounds Rd.
Rolla, MO 65401

Don Schricker
Vice President Personal Lines Insurance
Cincinnati Insurance Company
6200 S. Gilmore Rd.
Fairfield, OH 45014

Yvette Segura
Asst. Vice President Loss Prevention
USAA
9800 Fredericksburg Road
San Antonio, TX 78288

Dale Smith
Shelter Insurance
1817 West Broadway
Columbia, MO65218

Anselm Smolka
Seismologist, Munich Reinsurance Company
Muenchener Reuckversicherungs
Gesellschaft, Koeniginstr 107
D-80791 Muenchen, Germany Phone
49-89 38915294

Teri Spalding
Manager Research
State Farm Fire & Casualty Co.
One State Farm Plaza
Bloomington, IL 61710-0001

Fred Spencer
Enforcement Officer
Kentucky Department of Insurance
215 W. Main St.
Frankfort, KY 40601

Tim Stone
SAFECO
1551 Juliette Road
Stone Mountain, GA 30083-0310

Mani Subramani
Impact Forecasting
230 West Monroe Street
Chicago, IL 60606

W. Donald Sullivan
Executive VP & Chief
Administrative Officer
State Farm Fire & Casualty Co.
One State Farm Plaza
Bloomington, IL 61710

Thomas Teeters
Natural Hazards Modeling
Superintendent
State Farm Fire & Casualty Co.
One State Farm Plaza
Bloomington, IL 61710

William Thomas
Senior VP Personal Lines
Underwriting
SAFECO
SAFECO Palza; T-14
Seattle, WA 98185

Dave Unnewehr
American Insurance Association
1130 Connecticut Avenue, NW
Suite 1000
Washington, DC 20036

Mike Vallejos
EQE International
1111 Broadway
10th Floor
Oakland, CA 94607

Jim Wilkinson
CUSEC
2630 E. Holmes Rd.
Memphjs, TN 38118

Don Windeler
Risk Management Solutions
149 Commonwealth Dr.
Menlo Park, CA 94025

Jerald Wise
Indiana Department of Insurance
311 W. Washington Street, Suite 300
Indianapolis, IN 46204-2787

Peggy Young
Administrative Officer
CUSEC
2630 E. Holmes Rd.
Memphis, TN 38118