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# HIGH CONSEQUENCE LOW PROBABILITY EARTHQUAKE ISSUES

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## *Abstract*

The authors were involved in organizing a workshop on seismic hazard and design uncertainty issues in the Central United States, an area that can be defined as a high consequence-low probability region. Considerable controversy had been raised by a number of local and regional engineers following publication of the International Building Code in 2000 with statements like: 1) "The United States Geological Survey National Seismic Hazard Maps portray the Central United States as a worst case," and 2) "Kentucky should not be placed in a hazard category twice as dangerous as California or China – not reasonable." In addition, the following points were made about the International Building Code: 1) Overstates earthquake risks during the useful life of a building; 2) Designates the New Madrid Seismic Zone as the most hazardous/highest risk in the lower 48 states; 3) Not cost effective for life safety, as it includes elements of property loss reduction; 4) Does not reflect safety, economic, and political realities of the community; and 5) Will not promote voluntary compliance. In addition, concerning the impact of cost for building construction following the adoption of the International Building Code, it was stated that: "Anticipated cost increases above the Southern Building Code 99 (current adopted code) for new building construction in the following categories are: 1) Residential, 10% to 15%, 2) Commercial, 10% to 15%, 3) Light industrial, 15% to 25% and 4) Heavy industrial, 25% to 35%." This paper provides a summary of the workshop and discusses some key issues that many high consequence-low probability regions around the world may face as these regions attempt to adopt seismic building codes to reduce losses. The paper also adds some new findings that were not available at the workshop or in the workshop proceedings that shed considerable light on the cost of seismic design in the central and eastern United States, i.e., the cost of adopting the International Building Code is not as high as many have perceived.

*Keywords: high consequence; low probability; building codes; seismic construction cost; and risks.*

## 1. Introduction

The Council for Disaster Risk Management (CDRM) of the American Society of Civil Engineers (ASCE) [1] was one of ASCE's primary resources for disaster-related issues. CDRM had provided national and international leadership in disaster risk management, founded the journal Natural Hazards Review [2], acted as an advisory council, sponsored workshops and reports on disaster risk management [3 thru 11], and its members served on numerous national and international activities/committees. Due to recent reorganization within ASCE, CDRM activities have now been combined into the Infrastructure Resilience Division [12].

One major area of interest CDRM had undertaken before the reorganization was the understanding of societal and financial issues from seismic hazard in high consequence-low probability (HCLP) earthquake regions around the world. Typical locations of such regions are: 1) Hanwang, Sichuan Province, China [13]; 2) Baroda, Gujarat, India [14]; and 3) Memphis and Shelby County, Tennessee (MST), United States (US) [9]. Most HCLP earthquake regions are intraplate regions of the world as would be expected, i.e., the low probability (LP) half of the HCLP acronym. However, such events can occur in interplate regions as did the Tohoku, Japan earthquake in 2011, which may explain in part why the Tohoku event surprised/shocked the Japanese and the rest of the world [15 and 16].

## 2. MST, US.

The third HCLP earthquake region cited above, MST, represents: 1) the genesis of this paper, 2) CDRM's interest in the area, and 3) issues related to the adoption of a seismic building code on the basis of the International Building Code's (IBC) seismic provisions for the region [17]. MST represents the high consequence (HC) half of the HCLP acronym for the region. In addition to MST being the HC half of the HCLP acronym, losses in St. Louis, Missouri, will also contribute to the HC half of the acronym because of its proximity to the New Madrid Seismic Zone (NMSZ) as shown in Fig. 1 [18].

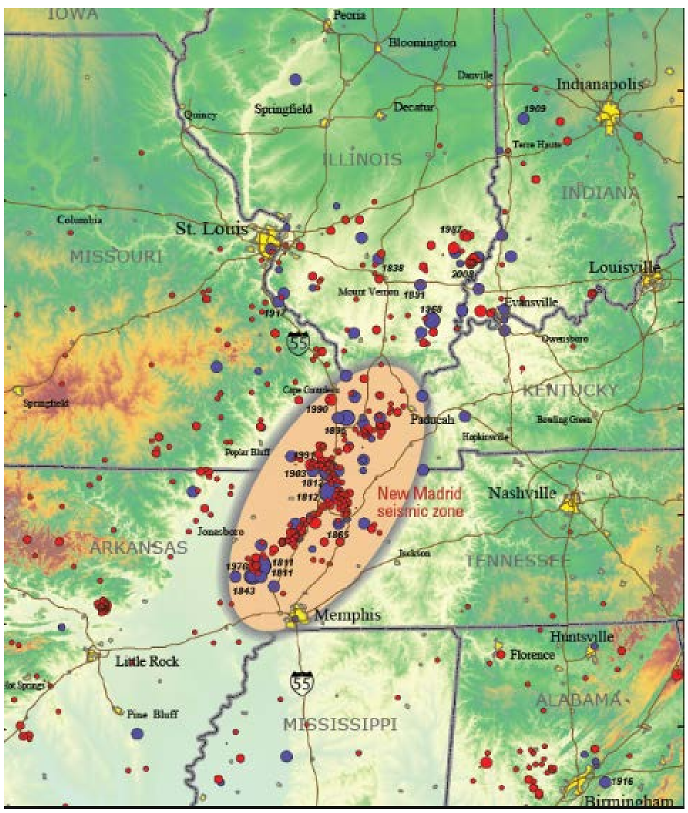

**Fig. 1 - New Madrid Seismic Zone [18]**

The authors' may have miss-defined the third HCLP earthquake region as: "MST, US" in that the source of the seismic hazard driver for that region is actually the NMSZ as mentioned in the previous paragraph and shown in Fig. 1. The NMSZ is where the largest earthquakes known to ever occur in the contiguous US [19], other than the 1906 San Francisco earthquake (20), occurred in 1811 and 1812. Three of these earthquakes had magnitudes, **M** values, estimated at 7.5, 7.3, and 7.5 occurring on December 16, 1811, 2:15 am (local time); January 23, 1812; and February 7, 1812; respectively. In addition to these three major events during that three-month time frame and to March 15, 1812, the first and largest aftershock occurred on December 16, 1811, 7:15 am with a magnitude of 7, ten additional aftershocks also occurred having magnitudes greater than 6.0 and about 100 aftershocks had magnitudes greater than 5.0 [19].

Fortunately, no major damaging earthquakes occurred in the Central United States (CUS) during the twentieth century, a time when the population in the US went from 75 million to 280 million. When the New Madrid earthquakes occurred, the population in the US was a little over 7 million [21] compared to today's 300 million. More specifically, in 1820, eight years after the 1811 and 1812 earthquakes the recorded population of Shelby County, Tennessee, the county where the city of Memphis was founded in 1819, was only 364 and the population of the to be Memphis area was 354 [22 and 23]. In 1830 the county and city had grown to 5,648 and 5,562, respectively [22, 23, and 24]. Plotting a single curve representing Shelby County and Memphis population average growth from 1820 to 1900 is shown in Figure 2. Projecting this curve backward to 1800 shows that the population of Shelby Country and Memphis when the 1811-1812 earthquakes occurred would have been well below zero, i.e., nonexistent as shown in Fig. 2, except for the indigenous people. Today, the largest populated area within the NMSZ is MST (Fig. 1) with a total population make up of about one million people with the city of Memphis being about 650 to 700 thousand of that one million [25]. A repeat of one of the New Madrid earthquakes of 1811-1812 MST could result in over 3,500 deaths [26].

The potential HC losses mentioned above for MST should be evidence enough to justify a community to adopt a seismic building code, but until recently MST have been resistant to the adoption of seismic standards based on the populace and local professional understanding of seismic risk for MST. However, as discussed below the authors are pleased to announce that MST recently adopted the IBC (27).

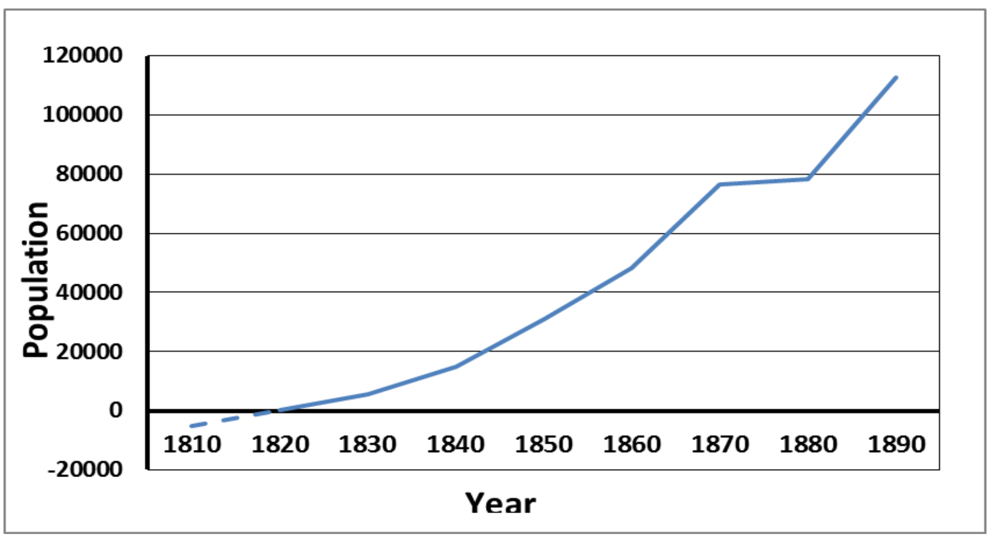


**Figure 2. Early Memphis-Shelby County Population Growth**

## 3. Problems Dealing with HCLP Earthquake Regions.

A major problem when dealing with HCLP earthquake regions comes from the right half of the HCLP acronym, the LP aspects. Since the NMSZ represents an area with little or no major seismic events, a low seismic hazard region, the public does not perceive the need for buildings to be designed and/or retrofitted to seismic resistant standards. The major question(s) that arises from the public when the subject of seismic design and/or retrofit comes up is simply: "Why?''. This simple one word question is often expanded to “Why should we, the people, spend a lot of money to design and/or retrofit our buildings to be earthquake resistant when our community has not had a damaging earthquake in our, our parents, or our grandparents’ life times?”

The above question(s) were the kind of reactions engineers supporting the adoption of seismic design would get from the MST community and engineering leaders when supporting the adoption of a seismic building code. This lack of support is nothing recent in MST, it has been going on since the late 1960’s and into the 1970’s when the late Warner Howe, a registered professional engineer started supporting the concept of adopting a seismic code for MST following the 1971 San Fernando, California earthquake [28]. Mr. Howe was significantly criticized by the MST community and engineering leaders for his support in the adoption process of a seismic building code [29].

The above type of resistance to the adoption of a seismic building code continued to exist for over 40 years as demonstrated at a meeting of the Advisory Committee on Earthquake Hazard Reduction (ACHER) in Memphis in November of 2010 [30]. At this meeting, local engineers stated that the seismic hazard design values in the IBC [17, 31] and the ASCE Standard 7-10 [32] were too high, in many cases, higher than in California. In addition, these engineers also made the following statements about the IBC and the ASCE standard: 1) Designates the NMSZ as the most hazardous/highest risk in the lower 48 states (contiguous US); 2) Not cost effective for life safety as it includes elements of property loss reduction; 3) Does not reflect safety, economic, and political realities of the community; and 4) Will not promote voluntary compliance. It was also shown that the anticipated cost increases above the Southern Building Code (SBC) 1999 [33], the MST adopted seismic code in place in 2010, versus using the IBC and ASCE Standard 7-10 represented a significant increase in cost as shown in Table 1.

Table 1 - Seismic Design Cost by Building Type (30**)**

| **TYPE** | **Cost Increase (%)** |
|---|---|
| Residential | 10 to 15 |
| Commercial | 10 to 15 |
| Light Industrial | 15 to 25 |
| Heavy Industrial | 25 to 35 |

## 4. Moving Forward in HCLP Earthquake Regions

### 4.1 Workshop Organization

The results that occurred at the ACEHR meeting in November 2010 were the main genesis of this Seismic Hazard Workshop and a brief agenda for that workshop is shown in Table 2. At the workshop, the authors of each paper presented a brief summary of their paper. To review each paper in its entirety, the reviewers of this paper are directed to the workshop proceedings titled: “Seismic Hazard Design Issues in the Central United States” [9] that can be obtained by ordering copies from ASCE’s website [1]. In addition, another goal of the workshop organizers was to reflect a better estimate of the actual seismic design costs when conducting seismic design in the CUS, i.e., a study being conducted by the National Institute of Building Sciences (NIBS) that would reflect the cost of including seismic design above and beyond the SBC [33] using the newer IBC [31] and the ASCE 7 Standard [32]. This seismic cost study had begun at least a year before the ACEHR meeting in November 2010, but was not completed until December 2013 [34]. In the case of the of the two papers missing from the ASCE monograph and the results of the NIBS cost study to finalize the recommendations and conclusions of the intent of the CDRM Seismic Hazard Workshop the authors of this paper talked with each missing paper author to summarize there presentation/paper as discussed in the next section.

Table 2 – Seismic Hazard Design Issue Papers in the CUS

| No. | Presentation/Paper Topic |
|---|---|
| 1 | The Seismic Design Values, $S_{DS}$, History and Issues. Beavers, et al. |
| 2 | A New Approach to $M_{max}$ for the Central United States from Seismic Source Scaling.* |
| 3 | Seismic Design for Schools in the Midwest, Lessons from the State of Oregon, Wolf, et al. |
| 4 | The 2008 Sichuan Earthquake in China . . . for the Central United States, Taylor, et al. |
| 5 | A Multihazard Perspective for the Central US, Schneider. |
| 6 | Geotechnical Issues and Site Response in Central US, Hashash, et al. |
| 7 | Major Changes in Spectral Shapes for Critical Facilities in . . . United States, Hunt. |
| 8 | The International Building Code and the Tennessee Adoption Process, Mauer et al. |
| 9 | Seismic Design in Western Kentucky, Wang. |
| 10 | Seismic Design and ASCE 7*, Harris. |
| 11 | Seismic Design in Memphis is not Designing to California, The Risk Targeted Approach*, Luco. |
| 12 | New Directions, i.e., Design Costs of the NEHRP*, Harris |
| 13 | Developing Resiliency Measures to Reduce Seismic Hazard Impact in the CUS, Mujumder. |

* Paper was not published in the proceedings

## 4.2 Summary of Workshop Papers

### 4.2.1. Paper No.1, by J. Beavers; W. Hall; and R. Hunt

Beavers, Hall, and Hunt [9] discuss the background of seismic history in the US with a focus on the development of seismic codes in the Central and Eastern US (CEUS). They also discuss the seismic design advances made in the IBC and ASCE 7 since 2000, and briefly highlight some of the work that came from Project 97 [35] which in part resulted in the first issue of the IBC in 2000 and work that came from Project 07 [36] that represented some major seismic design process advances in the IBC and the ASCE Standard. In conclusion the authors went multi-hazard addressing what they called: “A Touch of Reality” and discussed tentative design and evaluation suggestions for violent natural hazards, i.e., earthquakes, high velocity winds and tornadoes, snow and ice, and floods.

### 4.2.2. Paper No. 2, by A. Johnston

This was the first paper in Table 2 that was identified as not being published in the workshop proceedings. As a result, the first author recently talked with Johnston [37] who provided some additional information to include in this paper summarizing his subject matter, i.e., “What was the maximum magnitude of the New Madrid earthquakes of 1811 and 1812?” Johnston assessed recent advances in understanding CUS seismic hazard by focusing on one critical parameter: $\mathbf{M}_{max}$, the moment magnitude of the largest credible earthquake that can occur in the region. The most recent editions of the USGS national seismic hazard maps (1996 – 2014, updated every 6 years) all assume that the size of the largest of the 1811-12 New Madrid earthquakes provides a credible estimate of $\mathbf{M}_{max}$ for the CUS. The obvious problem of course is that for this historical but pre-instrumental event, estimates of its magnitude, based on qualitative and incomplete intensity reports, are highly uncertain, hence highly contentious. Seismic Source Scaling (or S-cubed) is an alternative approach to intensity-based **M**-estimates for historical events like New Madrid. Here moment magnitude is correlated with faulting parameters such as rupture fault length, fault area and/or average fault slip. The occurrence of the 2001 **M**7.6-7.7 Bhuj earthquake in the Kutch rift zone of western India finally provided the large magnitude, instrumentally recorded data point needed to apply S-cubed to the New Madrid/CUS $\mathbf{M}_{max}$ problem. As detailed in [14], the similarities between the two earthquakes are striking, thus enabling the S-cubed approach. For example, the Bhuj event had a fault length of only ~50 km as determined by aftershocks recorded by the MAE Center [14]. The 7 Feb. 1812 largest New Madrid main shock fault length of ~75 km yields a CUS $\mathbf{M}_{max}$ of 7.78 using S-cubed anchored by the Bhuj event. Johnston concludes this quantitatively supports the USGS CUS $\mathbf{M}_{max}$ of 7.7 and hopefully will lead to a less contentious acceptance of the IBC in the CUS.

### 4.2.3. Paper No. 3 by E.C. Wolf and Y. Wang

Wolf and Wang (9) begin by stating: "Schoolchildren have the right to learn in buildings that are safe from earthquakes". These words from a recommendation in a NEHRP report [38] would strike most parents as common sense. To date the US has no national policy that affirms this right. The purpose of this paper was to present what the State of Oregon has been doing to reduce future losses to its children from earthquakes and hopefully Tennessee and other states in the CUS would become a supporter of such earthquake risk reduction measures to protect their school children from earthquake occurrences. Wolf and Wang concluded with a national agenda goal for safe schools which they titled: "URM Free by ' 33" with the following additional goals: 1) as stated in Reference 37 and in the introduction of the author's paper (9) and noted above ; "School children have the right to learn in buildings that are safe from earthquakes;" 2) a shared goal to unite the efforts underway so that "assess, rank, and mitigate can be seen to serve a larger-than – local purpose; 3) make public school districts in the country's high-seismic hazard zones URM- free by 2033; 4) set an aggressive aspirational goal for statewide legislation to require earthquake resistant design and construction of all public school facilities; 5) no URM hazard to school children should be left unaddressed; 6) establish a national message that can begin to unite fledgling efforts that need to grow, and 7) a national agenda built on these goals/priorities would affirm the right of schoolchildren to learn in buildings that are safe from earthquakes.

### 4.2.4. Paper No 4 by C. Taylor, N. Uddin; J. Lee; K. Yu; C. Poland; and W. Graf;

Taylor, et al.(9) discuss the result of the 2008 Sichuan, China earthquake and state that intraplate earthquakes such as this one (and such events in the CUS) are less common and hence less anticipated than earthquakes in interpolate regions. Taylor, et al. state that these events fit the definition of a "Black Swan" occurrence: nearly unpredictable, having a massive impact, and followed by numerous post-disaster explanations. Taylor, et al. concluded: 1) that before the clock stopped, China had engaged in multi-generational efforts to improve seismic construction and planning processes; 2) since the 1976 Great Tangshan earthquake [39], China has engaged in significant efforts to improve seismic protection and response and the supporting expertise and instrumentation; 3) many national laws, codes, standards, and regulations had been established before the 2008 earthquake; and 4) as a result, many structures fared much better in the 2008 earthquake, but only some portion of the older building stock had been replaced and some buildings lacked quality assurance during a period of rapid expansion.

### 4.2.5 Paper No. 5 by P. Schneider

Schneider's presentation/paper (9) was about multi-hazard issues and focused on earthquakes, floods and tornadoes in the region of the NMSZ including the cities of St. Louis, Missouri and Memphis, Tennessee. In addition to the NMSZ being the source of a future large earthquake the Mississippi River (Fig. 1), the largest river in the contiguous US on its way to the Gulf of Mexico, runs right through the NMSZ. In fact during the 1811 and 1812 New Madrid earthquakes there is documented evidence of the Mississippi river running backwards. As noted by Schneider the CUS experienced major flooding from the Mississippi River in 1993 and 2011. In addition, Schneider also points out that frequent devastating tornadoes have also occurred in the CUS, i.e., the Joplin, Missouri and Tuscaloosa, Alabama events of 2011. In Schneider's conclusions he asked some good questions when trying to reduce losses from multi-hazard events. Schneider also uses the case of the "Black Swan" event to get across his point of lower probabilities associated with multi-hazard events occurring and he states: "…with higher potential losses and consequences with greater complexity than for a single hazard event". More analysis is required to determine combined loss estimates and eliminate double counting, but it is certain that in each case the combined losses will exceed those for a single event. The CUS faces similar issues before the "clocked stopped" in China, and China had over thirty years to prepare since the 1976 Tangshan earthquake [39], but it was not enough. In his conclusions, Schneider talks about the 'Black Swan" events having very important implications for emergency management if they were to happen by stating: 1) First in each of the events, the disaster victims will be relying on their own resources and each other for a period of time, since there will be a loss of facilities and infrastructure that support emergency response. 2) If the Mississippi levees are breached in Shelby County, people will find themselves cut off as were the victims of Hurricane Katrina in 2005. The good news is that Schneider concludes by saying: ". . . that despite expected higher levels of damage, preparing for and responding to multiple hazards fortunately is not necessarily beyond the resources of the emergency management and response community."

### 4.2.6 Paper No. 6 by Y. Hashash; B. Kim; S. Olson; and S. Moon

Hashash, et al. [9] focused on a key component of earthquake engineering, the geotechnical aspects of understanding earthquake losses to the building infrastructure. The Mississippi Embayment is the result of reshaping the region's tectonic province of the contiguous US. As engineers have learned, geotechnical response from earthquakes in the CEUS can be significantly different from those on the West Coast and the State of California. Hashish's, et al., key conclusions of geotechnical issues in the CUS are: 1) Significance of using the Conditional Mean spectrum for seismic design at the periphery of the NMSZ: The commonly used Uniform Hazard Response Spectrum does not represent any specific earthquake event in the NMSZ whereby the seismic hazard is a composite of two or more distinct sources of significantly different characteristics. Treatment of these sources results in a more realistic assessment of the seismic hazard. 2) Site response at deep soil deposits in the Mississippi Embayment: There is a need to use depth-dependent site amplification factors instead of commonly used depth-independent NEHRP site coefficients and 3) Unique aspects of liquefaction in the CUS, particularly in the NMSZ: Currently used liquefaction triggering analysis has been developed for plate margin settings which differ from the tectonic setting in the CUS.

### 4.2.7 Paper No. 7 by R. Hunt

Hunt [9] discusses the state-of-the-art history and development of earthquake response spectra and highlights ground motion attenuation in the eastern US. Hunt also gives a brief history of response spectrum development in the US and defines it into five periods: 1) 1960-1970, 2) 1970-1980, 3) 1980-1990, 4) 1990-2010 and 5) 21010 to Present. During the fourth period he points out comparisons between the well-known Newmark and Hall [40] and the Nuclear Regulatory Guide (R.G.) 1.60 spectrum shapes [41] used in the design of US nuclear power plants and a site-specific spectrum for "hard" rock sites in the eastern US. Hunt shows that these "hard" rock sites have response spectrum acceleration, velocities, and displacements for frequencies greater than 15 Hz that are higher than the R.G. 1.60 spectrum by as much as a factor of 2.0 and concludes that re-evaluation of existing critical facilities will be required to address these increases in ground motion. In the fifth period, Hunt discusses the development of new attenuation curves for the eastern US being developed by a joint venture of EPRI, DOE, and the NRC. Hunt's conclusions are: 1) the next generation of CEUS ground motion attenuation relationships need updating (now is scheduled to be complete in 2016); 2) the August 23, 2011 Mineral Virginia earthquake ground motion data needs to be considered in the ground motion studies; 3) existing critical nuclear facilities need updating considering NUREG-2115 [42]and performing seismic re-evaluations of all eastern nuclear power sites considering the high frequency ground motions; and 4) significant changes in seismic design criteria for critical facilities have occurred in the last 50 years and these changes have increased the ground motions, especially the high frequency for hard rock and shallow soil sites in the CEUS.

### 4.2.8 Paper No. 8 by R. Mauer and J. Beavers

Mauer and Beavers paper [9] discuss the building code adoption process in Tennessee in the eastern part of the state, an area known as the East Tennessee Seismic Zone (ETSZ). Mauer and Beavers talk about participation in the building code process being one of the most important aspects of getting seismic design included into local building codes. They also point out that political infighting and the “blame game” accomplishes nothing and the code process must be progressive. Their conclusions are: 1) participation is the most important part of the code process; 2) regrettably, local governments typically do not have funds to support training and attendance to annual code hearings; 3) all parties within industry need to cooperate for the betterment of all; 4) government agencies, architects, engineers, and construction material suppliers must recognize the code provides better building quality; 5) political infighting and the “blame game” accomplishes nothing; and 6) the future of the code world must be progressive.

### 4.2.9 Paper No. 9 by Z. Wang

Wang (9) starts out by discussing adoption and implementation of new seismic safety regulations and design standards have caused serious problems in many communities in the New Madrid region, including western Kentucky (Fig. 1). Wang goes on to state the main reason for these problems are: 1) misunderstanding of the national seismic hazard maps and 2) confusion between seismic hazard and seismic risk. Both are caused by probabilistic seismic hazard analysis (PSHA). Wang conclusions are: 1) although seismic hazard and seismic risk have often been used interchangeably, they are two fundamentally different concepts. Seismic hazard describes the natural phenomena . . . seismic risk describes the probability of loss or damage . . . 2) The difficulties in the development of design ground motion for the NEHRP provisions are caused by the use of the national seismic hazard maps which are neither seismic risk nor seismic hazard. 3) The resulting ground motions for building codes and other policy considerations are therefore problematic”.

The authors must disagree with Wang’s conclusions 2 and 3 in that as stated by Beavers and Hunt (34): “The primary goals of . . . Project '97 were as follows: 1) to develop national seismic hazard maps that represent a consensus baseline for seismic hazard definition throughout the US) and 2) to develop national seismic risk design values for use as consensus input for the 1997 update . . . using the seismic hazard maps as the baseline.” To develop the Phase 2 goal portion of Project 97 a 15 member Seismic Design Procedures Group was established to make sure the design values were as realistic as possible and to assure the design values were not overly conservative.

### 4.2.10 Paper No. 10 by J. Harris

This was the second paper in Table 2 that was identified as not being published in the workshop proceedings. In conclusion, since the subject matter had been previously published basically in the form of ASCE 7-10 standard [32], the workshop organizers used Paper No. 10 as filler for the workshop presentations to allow for last minute flexibility in the workshop agenda.

### 4.2.11 Paper No. 11 by N. Luco

Paper No. 11 was the third paper in Table 2 that was identified as not being published in the workshop proceedings. This was because the paper had previously been published [36]. The organizers of the workshop felt the subject matter was critical to the workshop agenda and message to the workshop attendees.

### 4.2.12 Paper No. 12 by J. R. Harris

Paper No. 12 was the final (fourth) paper in Table 2 that was identified as not being published in the workshop proceedings. The reason for the omission was the subject matter involved an age old problem of defining the cost for seismic design, a controversial issue in the CUS for the last forty years. However, in conclusion, the results of this study showed that the added cost for seismic design following the IBC [17, 31] and ASCE 7-10 [32] varied from 0.5% to 2.8% as a function of six building types. The average value of the seismic costs increase was 1.63% and the medium value was 1.4%. The results of the study verified what many seismic design engineers have been saying for over 40 years and supported the earlier cost studies conducted 30 years ago [36]. In comparison, these costs are far different by almost an order of magnitude than those cost increase values presented at the ACEHR meeting held in November of 2010 and shown in Table 2.

### 4.2.13 Paper No. 13 V. Mujumdur

Mujumder [9] presents a holistic approach to reducing the seismic hazard impact in the CUS. To reduce the seismic hazard impact there is a need for a community system-lead approach that necessarily includes interaction of technical systems, economic systems, and societal systems within the constraints of existing organizational systems. To minimize the impact of a damaging earthquake, community resiliency must be developed. While some measures of resiliency in physical systems can be quantified, resiliency measures for socio-economic systems are difficult to quantify. Qualitative measures for socio-economic systems are difficult to quantify. Qualitative measures are most appropriate to describe the overall community resiliency. Mujumder's conclusions are as follows: 1) The impact of an earthquake event depends not only on its intensity and duration but also on the pre-existing conditions in a community; 2) pre-existing conditions can be assessed in three broad areas: built environment, economic structure, and social institutions…..; 3) Functionality/operations of various systems play a critical role in determining resiliency of each component; 4) Overall resiliency of a community comprises of resiliency of social institutions; 5) A well-defined organizational structure and clarity in hierarchical responsibilities and clear lines of communications are necessary; 6) It is almost impossible to assign numerical score …… can best be described on a five measure qualitative scale varying from very high to very low: 7) By comparing various communities, impacts can be compared and priorities for deploying resources can be generated for enhancing resiliency and 8) Enhancing community resilience results in minimizing the impact of an earthquake hazard.

## 5. Conclusions

In conclusion, the workshop subject matter authors and speakers did an outstanding job of addressing many of the issues facing the adoption of a seismic building code for MST as they tried to shed some light on the uncertainty on the issues that seemed to continue to delay the code adoption process in this HCLP region. In addition, light was placed on multi-hazard issues that the CUS must deal with. This paper and the workshop authors have addressed some major issues of adopting a seismic code in a HCLP region.  It may take many years to get a building code adopted in other HCLP regions because of the many issues demonstrated above for the CUS.  The authors' of this paper hope what has happened in this HCLP region of MST will provide information and ideas to others around the world to get proper seismic codes adopted for their respective HCLP regions.  Also, as briefly noted in the earlier part of this paper the MST adopted a slightly modified version of the 2012 Edition of the IBC that became effective December 31, 2013.  And as stated by Ms. Julie Furr (43) few local and regional engineers now oppose the new seismic provisions and the NIBS cost study was a key factor in MST's recent adoption of the IBC.

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