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SCHOOL SAFETY GUIDE FOR NATURAL HAZARDS

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Abstract

Globally, many school buildings are highly vulnerable to significant damage or collapse in earthquakes or other natural disasters. Past events have clearly demonstrated the devastating effects of school damage and destruction. Even the students who survive a school building collapse can suffer long-term negative effects from school closure and other secondary stressors associated with a disaster; their education might be delayed causing their future to be completely derailed.

School buildings serve other critical functions within communities and the loss of a school building can disrupt family life and the broader community. Schools often serve as centers for communal activity, and as a focal point for social and cultural life. Schools are also often designated as shelters for displaced families after a severe earthquake or other disaster.

Despite the critical role that schools play in people's lives, many obstacles exist in attempting to improve school safety from natural hazards. These include competing public needs and demands, scarce resources in an increasingly difficult economic and political environment, and lack of understanding of hazards risks, among others. Yet, there is hope. Many successful school safety efforts have been initiated by informed and dedicated advocates. In recognition of this need for action, the U.S. Federal Emergency Management Agency (FEMA) funded an effort led by the Applied Technology Council (ATC) in 2015 to develop a guide to serve as a tool for school safety advocates throughout the United States and potentially even abroad.

This guide, which will be completed by the end of 2016, offers actionable advice on how to improve the safety of schools in the United States from various natural hazards, including earthquake, tsunami, flood, hurricane, and tornado, and focuses on both operational guidance (i.e., what to do before, during and after an event) and on the physical protection of school facilities (i.e., what can be done to the structure and facility to improve safety). The guide aims to equip school safety advocates and stakeholders, including school administrators, teachers, staff, school emergency managers, and concerned parents, with information and resources to help improve the safety of their schools. It also is designed to provide tools for school safety advocates to communicate clearly with decision makers to ultimately spark action. The guide is being developed by engineers, an architect, social scientists, and risk communication experts with the review and input from representatives of the intended audience. It includes several primary chapters covering general natural hazard safety information, supplements that are hazard-specific, lessons learned from past failures, and case examples of successful mitigation efforts.

Keywords: Schools; School seismic safety; Advocacy; Mitigation

1. Background

Elementary and secondary school buildings across the United States and globally are the places where future leaders are educated. In the U.S., most parents send their children off to school with the belief and expectation that their children will be safe from natural disasters. These children not only have the right to an education, but also have the right to an education in a safe environment. However, in many portions of the U.S., which is home to over 310 million people and roughly 55 million school-age children, many children attend classes in buildings that are highly vulnerable to collapse in a natural hazard. These school buildings tend to be older and of poorer construction than other types of buildings making them particularly vulnerable [1]. In particular, many of the school buildings in the U.S. are older unreinforced masonry (URM) structures that are vulnerable to severe damage and collapse in an earthquake, or are vulnerable to some other type of natural hazard, such as a tornado or flash flooding.

Beyond educating children, school buildings also serve other critical functions within the communities where they are located. For example, they often are the sites for aid distribution and shelters for displaced families after a disaster. Even when they may not be a designated shelter, school policy across the country is that if children cannot return home safely, they are sheltered in place in the school until parents can pick them up. Schools are also hubs of community life during non-disaster times. They are the places where many members of the American public vote for their future leaders and they often serve as a focal point for a community's social and cultural life, be it a community meeting or an evening sporting event. The loss of a school building can disrupt family life and the entire social fabric of a given community.

The United States has had many "near miss" events that could have resulted in much greater loss of life among school children. For instance, the 1933 Long Beach California M6.4 earthquake is best known for collapsing or severely damaging thousands of URM buildings, including close to 200 school buildings [2]. Fortunately, school had ended for the day and classes were not in session at the time of the earthquake. Had that not been the case, thousands of children would have been seriously injured or killed. The public outcry from this poor performance of school buildings led to the State of California passing the Field Act, which mandated earthquake resistant construction requirements and inspection for all future public school buildings [3].

Although the 1994 M6.7 Northridge earthquake did not collapse any school buildings, the amount of damage from heavy nonstructural components, including the collapse of suspended ceilings and light fixtures, would have injured many children had the earthquake occurred during school hours instead of early in the morning on a Monday holiday [4]. The damage and the potential consequences were so severe that the U.S. Federal Emergency Management Agency (FEMA) funded a major seismic retrofitting program to seismically brace all of the suspended ceilings and light fixtures in every Los Angeles County school building.

In the May 2008 M7.9 Sichuan China earthquake, many of the over 69,000 fatalities were the children attending school in the thousands of vulnerable school buildings that collapsed [5]. In a nation that has long observed a "one-child" policy for population control, some of the most heart-breaking images to come out of the earthquake were the reactions of parents losing their only child. Following the earthquake, parents and many others joined to protest against the government for allowing such poor school construction.

There have been some successful efforts to address natural hazard safety in schools. As an example, the Canadian government funded an extensive national program to identify seismically vulnerable school buildings and to require their seismic retrofitting. In the U.S., however, federal agencies have not been as proactive at the national level. This inaction may be due, in part, to the fact that in the U.S., schools and their construction are controlled at the state level. Although there have been recent notable efforts by some states, particularly in Oregon and Utah, to identify at-risk school buildings and begin the process of addressing the seismic risk they present, these activities have been severely limited by budget issues and the day-to-day problems that local and state governments face to keep their schools operating.

Although much attention has been paid to the risks that schools in seismic areas face, it is important to note that school safety from natural hazards is not just an "earthquake issue." The U.S. has had recent sharp reminders of this fact. For example, on March 1, 2007, an EF4 tornado struck the town of Enterprise, Alabama.

Among the buildings destroyed was the local high school, where a collapsing unreinforced concrete masonry wall killed eight students and injured over 50 people [6]. On May 20, 2013, the EF5 tornado that struck Moore, Oklahoma resulted in 24 fatalities, including seven children at Plaza Towers Elementary School [7]. More recently, on April 27, 2014, an EF3 tornado leveled a brand new school still under construction in the Little Rock, Arkansas, suburb of Vilonia. Schools generally have some short-term notification of a tornado warning; however, many times this short warning does not provide enough time for students to get to a safe place that is not in the immediate vicinity. Tornado safe rooms in schools are becoming an accepted standard of care and are now a requirement for new schools in the highest tornado risk areas under the 2015 International Building Code; however, most existing schools with a high tornado hazard do not have a safe haven for students and staff.

The risk from flooding is generally well-known and mapped in the U.S., and warning time is usually sufficient that the risk from this hazard is well-controlled. However, the risk from flash flooding in mountainous terrain or from storm surge flooding in coastal areas can still be significant for schools located in harm's way. On September 21, 1989, Hurricane Hugo, by then a Category 4 storm, made landfall on the coast of South Carolina above Charleston. The Town of McClellanville had a single approved shelter for its residents—the local high school. However, the floor elevation of the building had been erroneously recorded as being many feet higher than it actually was. When the storm reached its peak, the storm surge entered the school building and the shelter's occupants were forced to stand on desks and place their children into the suspended ceiling above to avoid drowning. On August 29, 2005, Hurricane Katrina led to the damage or destruction of hundreds of school buildings; over 100,000 school children missed some or all of the 2005-2006 academic year as a consequence [8].

A significant number of schools located along U.S. coast lines are also exposed to tsunami inundation. Although many have evacuation plans to get students to high ground, some schools (especially those along the coasts of the Pacific Northwest, Hawaii and Alaska) are exposed to near-source tsunamis where tsunami waves can reach the coast within 15 to 30 minutes, making it basically impossible to reach high ground before the tsunami waves arrive. For these cases, FEMA and the U.S. National Oceanic and Atmospheric Agency (NOAA) teamed up to develop design guidance for vertical evacuation refuges [9]. These types of vertical evacuation structures have been common in Japan for some time, but the first U.S. vertical evacuation refuge was only recently completed. This tsunami refuge is on the roof of the gymnasium of the newly rebuilt school, Ocosta Elementary School, in the City of Westport, Washington. This effort was led by the State of Washington under Project Safe Haven. Although this is a great start, there is still a great need for more of these tsunami vertical evacuation refuges along the coast where students will be unable to reach safe ground before a tsunami strikes.

Given the long-standing and recognized risks that schools face, FEMA's Earthquake Program addressed the issue of seismic protection of schools, as well as child care facilities with several publications in the late 1980's and early 1990's. These documents include the following:

- FEMA 88, *Guidebook for Developing a School Earthquake Safety Program* [10], provides guidance for the school community, including principals, teachers, staff, parents and students, on how to develop an earthquake safety program for their school.
- FEMA 240, *Earthquake Preparedness: What Every Child Care Provider Needs to Know* [11], targets child care providers and features practical and low-cost techniques to make child care facilities safer in the event of an earthquake, whether they are based in a home or a larger facility. It offers tips for conducting earthquake drills and includes a checklist of supplies to keep in an emergency kit.
- FEMA 241, *Identification and Reduction of Nonstructural Earthquake Hazards in Schools* [12], provides simple guidance on how to identify and mitigate the risk from nonstructural items found in most classrooms.

These publications, however, are now out of date and need to be updated. In response to this, FEMA initiated and funded the Applied Technology Council (ATC) to conduct the ATC-122 Project, *Reducing the Risk to our Schools from Natural Hazards and Improving the Safety of our Children*. This Project is intended to replace the out-of-date publications listed above, but also to address all natural hazards in a single publication. The Project is in the process of developing a School Natural Hazard Safety Guide that focuses on operational

guidance (i.e., what to do before, during, and after an event), as well as physical protection (i.e., what can be done to the structure and facility to improve safety). The development and review process for the Guide includes design professionals, emergency managers, school administrators, teachers, representatives of concerned parent groups, and other representatives of relevant entities.

Early in this Project, the project team identified a planning document that was recently developed by several U.S. agencies, including FEMA and the U.S. Department of Education [13]. This document, *Guide for Developing High-Quality School Emergency Operations Plans*, is the primary resource for developing school emergency operations plans, which is required as a prerequisite for funding from both agencies, and represents the latest information to be developed by the U.S. government. While that document provides some general information on natural hazards, it refers the reader to other sources for more detailed information. The School Natural Hazard Safety Guide that is being developed under this Project and summarized in this paper is intended to provide more detailed guidance specific to natural hazards, all in one document. In an effort to make the School Natural Hazard Safety Guide compatible with the guidance provided in the *Guide for Developing High-Quality School Emergency Operations Plans*, the Project team is coordinating with the U.S. Department of Education.

2. Overview of School Natural Hazard Safety Guide

2.1 Intended Audience

The School Natural Hazard Safety Guide is designed to address the needs of a wide variety of individuals and entities associated with schools. The intended primary audience includes school administrators, school facilities managers, school emergency managers, teachers, and school staff. However, the information in the Guide can also be valuable for district administrators, school boards, and legislative bodies to gain knowledge about their roles in providing safe schools from natural hazards. Parents, caregivers, students, community planners, and local and state emergency managers may also find this information valuable.

2.2 Overview of Content and Structure of School Natural Hazard Safety Guide

The School Natural Hazard Safety Guide provides both general guidance that is applicable to multiple natural hazards, as well as guidance that is specific to earthquakes, floods, tornadoes, hurricanes, tsunamis, and other natural hazards. The front material of the Guide is general and not specific to any particular hazard. The opening chapters are intended to speak to “decision-makers” and those in administrative positions who might not have the time to read through a detailed document. The hazard-specific information is provided within a series of Supplements to the Guide. The Supplements within the Guide are intended to be used by “implementers,” who will likely need more detailed information. The supplements include: Earthquake, Flood, Tsunami, High Winds, and Other Hazards. The Other Hazards Supplement provides brief information and a list of resources for hazards that are not covered in detail. These hazards include snow and wildfire, both which were identified as high priority hazards during focus group sessions with representatives of the intended audience (see Section 4).

2.3 Project Team

The School Natural Hazard Safety Guide Project team consisted of a Project Management Committee (PMC), which led the development of the material, as well as a Project Review Panel (PRP), which provided feedback at key development stages of the Guide. Project Working Groups (PWG) conducted work around the literature review (see Section 3.1) and the Focus Group sessions (see Section 4). For a list of people involved in each one of these groups, see the acknowledgements in Section 7.

3. Literature Review and State-of-the-Art Report

3.1 Literature Review

During the first year of the Project, the PWG conducted a literature review of relevant documents. The primary objective of the literature review was to identify existing relevant resources, as well as gaps in current resources.

Dr. Lori Peek, PMC member, led a team of graduate students at Colorado State University to conduct this literature review. The review consisted of a total of 255 documents and was organized around the internationally-adopted Comprehensive School Safety Framework (Fig. 1). This framework consists of the following three pillars: (1) Safe Learning Facilities, which mostly entails the design and construction of safe school facilities; (2) School Disaster Management, which encompasses emergency planning and emergency management operations; and (3) Risk Reduction and Resilience Education, which focuses on awareness-raising, outreach, and education.

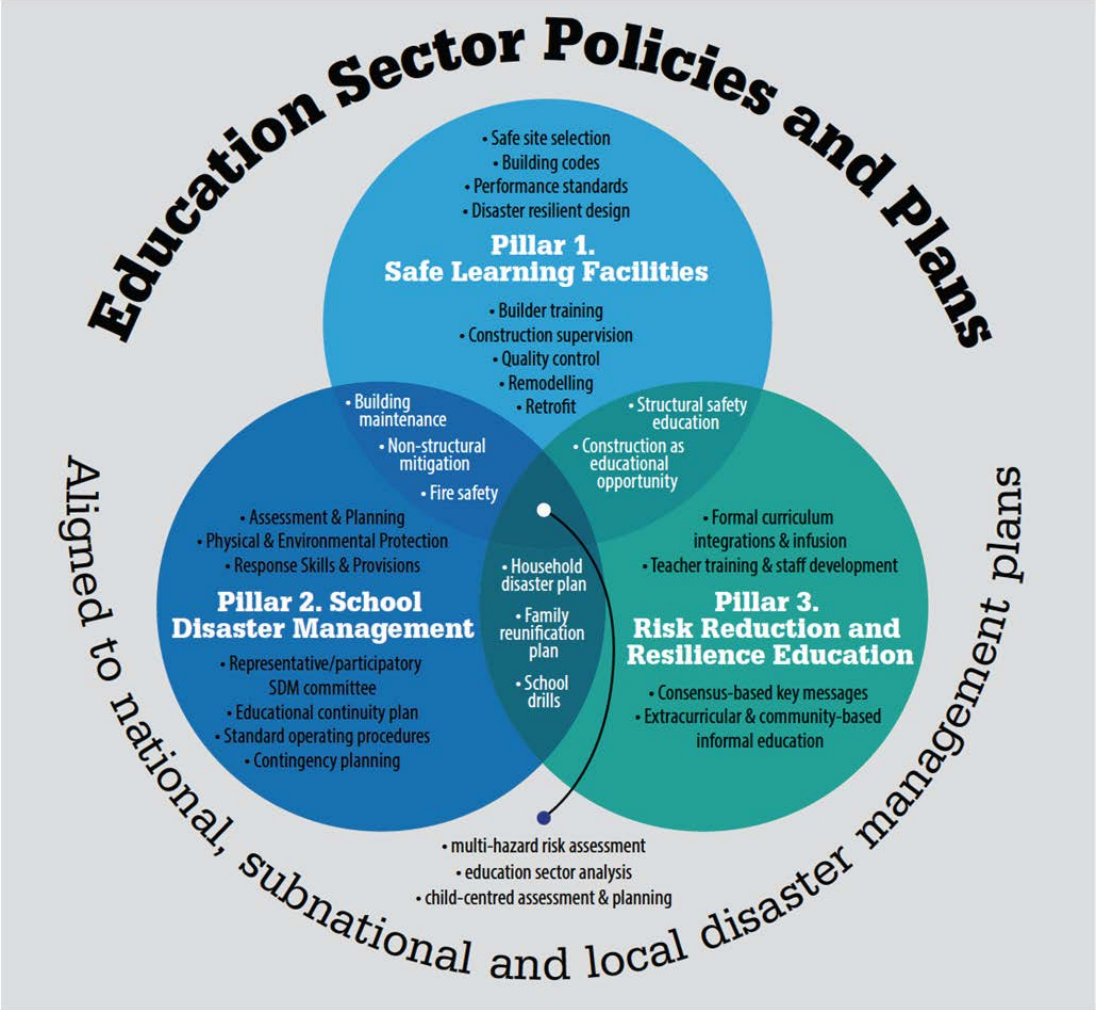

Fig. 1 – Three pillars of comprehensive school safety. Source: *Comprehensive School Safety* [14].

Each of the 255 documents in the literature review was categorized by pillar and the following information was captured for each: purpose, disaster stage(s), disaster impacts, methods, target audience, study location, school type/characteristics, building information, hazard type, disaster risk reduction activity, communication information, challenges, negative/positive case examples, figure(s)/image(s), and relevance to the School Natural Hazard Safety Guide being developed under the ATC-122 Project. Fig. 2 illustrates the distribution of documents by resource type (academic resources include: journal articles, conference papers, proceedings, book chapters, and dissertations; institutional/organizational resources include: operational guidance, school disaster plans, design guides, reports, informational overviews, and resource guides; and media or public relations resources include: news articles, posters, first person accounts, podcasts, websites, and videos). Fig. 3 illustrates the distribution of documents in the literature review by hazard type. About half of the 255 documents that were reviewed fell under Pillar 2, while the other half were about evenly distributed between Pillars 1 and 3.

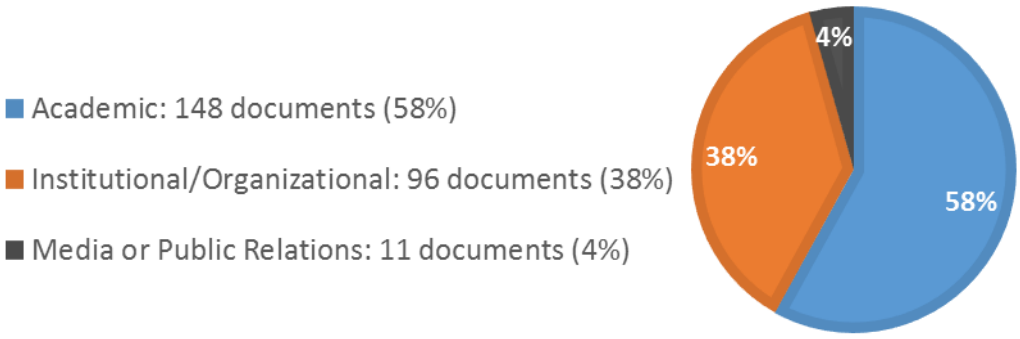

Fig. 2 – Types of resources considered in the literature review.

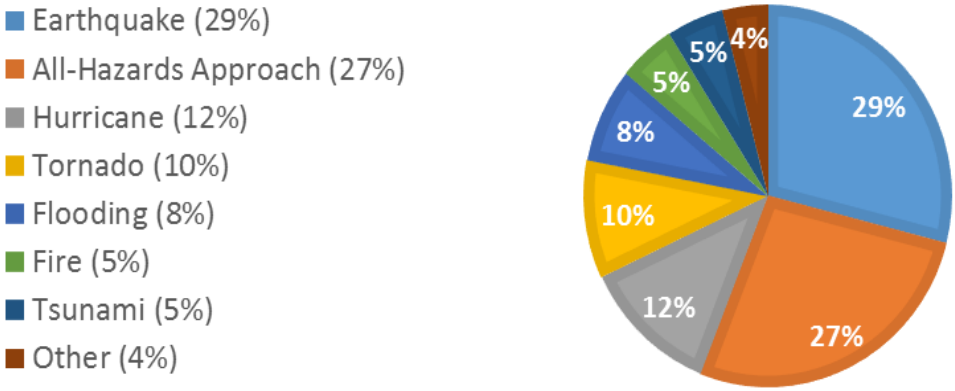

Fig. 3 – Resources by hazard type in the literature review.

3.2 State of the Art Report

The PMC developed a State of the Art report to summarize the findings from the literature review. The purpose of the State of the Art report was to inform the development of the School Natural Hazard Safety Guide during the second year of the Project. The literature review yielded an extensive number of relevant publications that are summarized in the State of the Art Report, and it in turn served as a valuable resource for the Project.

The State of the Art report covers both national and international resources and provides information on school safety from different aspects and points of view. The Report not only covers specific examples of how school safety against natural hazards has advanced, but also what challenges the schools faced and how they were overcome. Fig. 4 illustrates an example of some of the results that were gathered around types of challenges mentioned in the documents.

The State of the Art Report served as an excellent literature resource for the project, and is intended to also serve as a source for future school safety projects and efforts related to natural hazards. For this reason, the team plans to publish this Report and reference it in the School Natural Hazard Safety Guide.

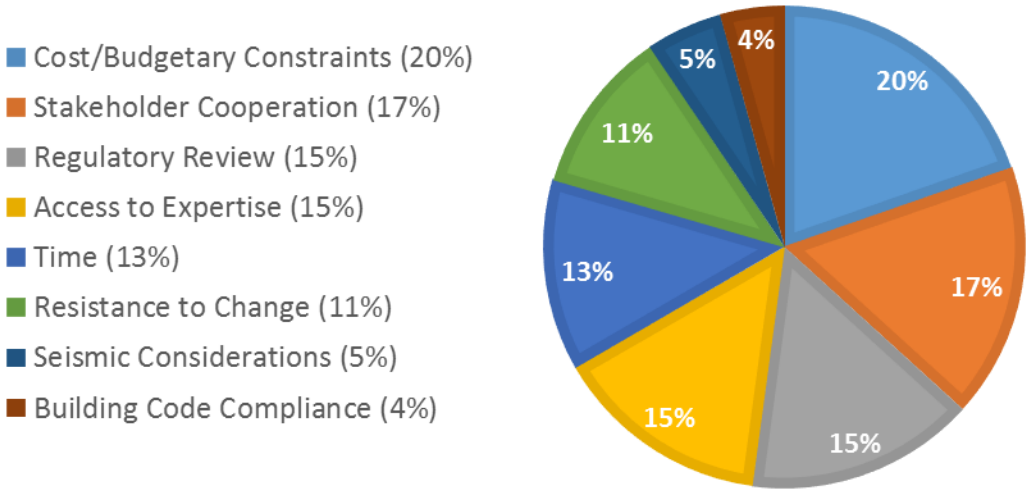

Fig. 4 – Types of challenges mentioned in the literature review for documents categorized as Pillar 1.

4. Focus Group Sessions

During the second year of the Project, focus group sessions were held to review the development of the draft School Natural Hazard Safety Guide. The main purpose of the focus group sessions were to "field test" the draft guidebook and receive feedback from key stakeholders and representatives of the intended audience. The focus group sessions were conducted via videoconference calls of three to four people, all led by PMC member, Dr. Lori Peek. In selecting the focus group participants, the team aimed for diversity on several levels, including level of experience with school safety planning, geographical area, hazard exposure and hazard experience, and size of school/district. As of May 2016, the focus group sessions included school facilities managers, school emergency managers, school superintendents, school board representatives, and principals. The team plans to conduct three to five more focus group sessions before the end of the Project, which is scheduled for September 2016, in order to continue to receive feedback on the guide. These future focus groups will include other representatives of school facilities managers, school emergency managers, teachers, parents, superintendents, and principals.

The feedback from the focus group sessions conducted so far has been instrumental in helping to drive the development of the Guide. In particular, feedback has included advice on appropriate language and length for the Guide, as well as level of detail and structure of material within the Guide. Focus group participants also shared several experiences that are currently planned to be highlighted as vignettes to stress certain topics in the Guide. These experiences included stories of how certain schools have been able to gain support of their community by involving their students in school safety efforts.

5. Next Steps

The School Natural Hazard Safety Guide is still under development and will undergo several review cycles before being finalized. These reviews will include focus group sessions as described in Section 4, as well as a thorough review by the Project Review Panel. The Guide will be completed by the end of 2016. Once the Guide is published, FEMA will promote the use of the School Natural Hazard Safety Guide through direct reference in materials directed to local community school boards and state education departments. FEMA and ATC will also work to disseminate the Guide through training programs and outreach materials.

6. Conclusions

The threat from natural hazards to our schools and to our children that occupy them every day is significant. Any action to address this risk should include educating, empowering, and supporting decision-makers, such as the

school and district administrators and school boards, as well as partners and advocates such as concerned parents, parent teacher associations/organizations, teachers unions, local/regional seismic safety advocates, the local building code department, and local elected officials.

Many advocates for improving school safety have struggled to succeed because they must fight for limited public attention and resources in an ever increasingly difficult economic and political environment. The comprehensive School Natural Hazard Safety Guide that is being developed under this Project aims to equip school safety advocates and stakeholders with the information, tools, and resources they need to help strengthen their efforts in improving school natural hazard safety.

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8. References

[1] U.S. Department of Education, National Center for Education Statistics (2013): *Public-Use Data Files and Documentation (FRSS 105): Condition of Public Schools Facilities: 2012-13*, Fast Response Survey System.

[2] Meehan JF (1982): Public schools and hospital building geological hazards considerations. *Proceedings of the Conference on Earthquake Hazards in the Eastern San Francisco Bay Area*, California Division of Mines and Geology, Sacramento, California, Special Publication No. 62, 387-391.

[3] California Seismic Safety Commission (2009): *The Field Act and its Relative Effectiveness in Reducing Earthquake Damage in California Schools*, CSSC 09-02, Sacramento, California.

[4] Federal Emergency Management Agency (1994): *Reducing the Risks of Nonstructural Earthquake Damage*, FEMA 74, Washington, D.C.

[5] Peek L (2008): Children and Disasters: Understanding Vulnerability, Developing Capacities, and Promoting Resilience. *Children, Youth and Environments*, **18** (1), 1-29.

[6] U.S. Department of Commerce, National Oceanic and Atmospheric Administration (2007): *Tornadoes in Southern Alabama and Georgia on March 1, 2007*. Service Assessment, Silver Spring, Maryland.

[7] Federal Emergency Management Agency (2014): *Tornado: Moore, Oklahoma, May 20, 2013: Safe Room Performance, Observations, and Conclusions*, Formal Observation Report, FEMA P-1020, Washington, D.C.

[8] Fothergill A, Peek L (2015): *Children of Katrina*, University of Texas Press, Austin, Texas.

[9] Federal Emergency Management Agency (2012): *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis*, FEMA P-646, Washington, D.C.

[10] Federal Emergency Management Agency (1990): *Guidebook for Developing a School Earthquake Safety Program*, FEMA 88, Washington, D.C.

[11] Federal Emergency Management Agency (2006): *Earthquake Preparedness: What Every Child Care Provider Needs to Know*, FEMA 240, Washington, D.C.

[12] Federal Emergency Management Agency (1993): *Identification and Reduction of Nonstructural Earthquake Hazards in Schools*, FEMA 241, Washington, D.C.

[13] U.S. Department of Education, U.S. Department of Health and Human Services, U.S. Department of Homeland Security, U.S. Department of Justice, Federal Bureau of Investigation, and Federal Emergency Management Agency (2013): *Guide for Developing High-Quality School Operations Plans.*

[14] Global Alliance for Disaster Risk Reduction and Resilience in the Education Sector, United Nations International Strategy for Disaster Reduction (2014): *Comprehensive School Safety*.