Building and Infrastructure Resilience: Strategies for Disaster Reduction in Emergency Response, Recovery, and Rebuilding

Joint US-Taiwan Workshop

SUMMARY

Typhoon Morakot hit Taiwan on August 7 and 8 (Friday and Saturday) of 2009 bringing torrential rains that caused serious flooding in the south of Taiwan; over 2000 mm of rain fell. A typhoon-spawned mudslide engulfed a mountain village in southern Taiwan, burying up to 600 people. Besides, other damage caused by flooding from Typhoon Morakot includes collapse of bridges due to severe scouring and severe landslides. Changing rainfall patterns, the over-developed land use and dense population distributions characteristic of both Taiwan and parts of the US, create serious problems for forecasting potential hazard areas using traditional natural hazard mitigation strategies. Catalyzed by the tremendous human and economic costs of recent disasters, this proposal seeks funding from the US National Science Foundation (NSF) and the National Science Council (NSC) of Taiwan to hold a workshop that crosses traditional disciplinary boundaries to develop the new knowledge needed to mitigate the impact of such disasters. Because of their potential impact on today's urban agglomerations we term them Mega-City Mega-Disasters (MCMD). The workshop will explore specific strategic measures for Emergency Response/Recovery/Rebuild against MCMD and examine the broader questions that surround these issues, including factors that may cause long-term changes in the risk of disaster and factors that may affect and impede response by governments, agencies, and populations. The workshop is to be held in Taipei on May 6-7, 2010. This proposal seeks funding to allow a delegation of 10 researchers from the United States of America to participate in this important joint workshop.

Intellectual Merit: Topics to be discussed at the workshop include: (i) methods to predict natural hazard occurrence, (ii) technology to increase societal and infrastructure resiliency, (iii) assessment techniques to quantify the risk posed to individual infrastructure and systems of infrastructure systems, and (iv) post-event management plans that minimize the social-economic impact of natural hazards. The conference participants will discuss many of the unique challenges presented by MCMD, advances in mitigation strategies, multihazard solutions, real-world challenges, and educational initiatives on interdisciplinary and cross-cultural MCMD curricula. The location of the conference will take advantage of the unique opportunity to interact with researchers from an urban society that is historically susceptible to a significant MCMD. During the conference, the delegation will participate in interdisciplinary dialogue that promotes extensive information dissemination and transfer of ideas and technology.

Broader Impact: Based on the principle of mutual support and benefit in order to achieve cost effective and practical applications of MCMD mitigation, response, and recovery planning, the proposed activity will advance the concept of international cooperation and collaboration. In addition to fostering new collaborations between US and Taiwan researchers, participation of the US delegation attending the conference will expose the participants, including members of underrepresented groups, to the international research and engineering community. The connections and networking opportunities presented by this experience will equip the US participants for new collaborations and enable them to embark on new multidisciplinary avenues of research while simultaneously assisting them in their development as international leaders and role models in earthquake engineering research, education, and practice. Thus, the support of the U.S. delegation has great potential to yield wide-reaching effects through the future influence of the participating young researchers.

1. Introduction

The economic prosperity of developed nations like the United States and Taiwan relies upon national networks of infrastructure systems. These include both physical infrastructure (roadways, bridges, pipelines, utilities) and the infrastructure of information and communications technologies (ICT) that are increasingly essential both to the functioning of modern societies and to effective emergency response. Indeed, physical infrastructure alone, in both its construction and maintenance, represents the largest societal investment in the US, outside of the health care industry. Yet, infrastructure systems have performed so well that they are often "taken for granted" until a catastrophic failure occurs, as witnessed by the collapse of New Orleans levees in 2005 or the I-35W Bridge in Minnesota in 2007. The economic impact of this specific bridge failure was staggering; it is estimated that the loss of this major transportation artery resulted in over $200M worth of business losses to commercial supply-chains. The failure of bridges in the U.S. is not as uncommon as the public may think. Even though bridges are inspected to ensure they meet minimal safety standards, collapses still occur. From 1989-2000, 134 bridges in the U. S partially or totally collapsed In addition, 13% of the national inventory is classified by the Federal Highway Administration as "deficient"; the same classification given to the I-35W Bridge prior to collapse. To compound the problem, the economic resources available to maintain our infrastructure are shrinking at an alarming rate; the Highway Trust Fund will be several billion dollars in deficit by year's end.

Each year the United States and Taiwan sustain natural and manmade disasters that cost hundreds of lives and average billions of dollars in losses. These disasters are caused by floods, wildfires, winter storms, tornadoes, landslides, earthquakes, hurricanes, and other natural events, as well as intentional and unintentional manmade hazard events. These circumstances demand the attention of government at all levels, the private sector, and individuals, to take steps to decrease hazard risks. According to the World Commission on Environment and Development, sustainable development must meet the needs of the present without compromising the ability of future generations to meet their own needs. In sustainable communities, decisions made by the present generation will not reduce the options of future generations. The present generation should seek to pass on a natural, economic, and social environment that will provide a high quality of life. Some U.S. communities, devastated by hurricanes and other hazard events in the first 5 years of the millennium, have demonstrated that developed, populated hazard areas may not be sustainable.

Taiwan is situated in a highly seismically active region of the world with devastating earthquakes occurring almost every decade. The most recent serious earthquake to strike Taiwan was the Chi Chi Earthquake (1999) which resulted in 2,416 dead and over NT$300 billion in structural damage. In addition to seismic hazards, Taiwan is situated along the primary path of Northwestern Pacific tropical cyclones. For example, Typhoon Morakot (2009) wrought catastrophic damage in Taiwan, leaving 461 people dead and 192 others missing, most of whom are feared dead and roughly NT$110 billion in damages. As a result, civil, mechanical, and ICT infrastructure systems in Taiwan must be designed to be resilient in the face of multiple categories of natural hazards including earthquakes, floods and extreme winds. A direct result of the extensive investment by the NSC is that Taiwan is a recognized leader in the hazard mitigation field, along with the U.S.

A framework for an integrated research frontier is envisioned to revitalize US-Taiwan collaboration on emerging areas serving pressing societal needs. The proposed program is focused on two fronts: (1) a global interest in the broad impact potential of multidisciplinary research in building and infrastructure resilience, and (2) reinforcement of bilateral interest as explicitly shown at the recent NSF-NSC annual meeting at the NSF in seeking new mitigation solutions for mega disasters such as catastrophic mega-earthquakes, hurricanes/typhoons, floods, and massive rock/mud/land slides.

1.1. Hazard Reduction

Strategies for reducing disaster damage and destruction are commonly referred to by the term “hazard reduction”. Hazard reduction is defined as sustained actions taken to reduce or eliminate long-term risk to people and property from hazards and their effects. The purpose of hazard reduction is twofold: (1) to protect people and structures and (2) to minimize the costs of disaster response and recovery. Designing to resist any hazard should always begin with a comprehensive risk assessment. This process includes identification of the hazards present in the location and an assessment of their potential impacts and effects on the built environment based on existing or anticipated vulnerabilities and potential losses. When hazard mitigation is implemented in a risk-informed manner, every dollar spent on mitigation actions results in an average of four dollars' worth of disaster losses being avoided (WBDG Secure/Safe Committee, 2009).

Tasks and functions of emergency management may be summarized into a cycle through which communities prepare for emergencies and disasters, respond to them when they occur, help people and institutions recover from them, mitigate their potential effects to reduce the risk of future loss, and rebuild the associate structure for living as soon as possible. Response needs to begin as soon as a disaster is detected or threatens. It involves search and rescue mass care, medical services, access control, the acquisition and sharing of vital information, including geospatial data (NRC, 2007a,b), and bringing damaged services and systems back on line. Recovery and rebuilding after a disaster takes years. Services, infrastructure (*e.g.,* utilities, communication, and transportation systems), facilities, operations, and the lives and livelihoods of many thousands of people may be affected by a disaster. The impacts of natural hazards and the costs of the disasters they cause will be reduced whether mitigation measures are implemented during new construction (preventively) or as retrofits (correctively). Proactively integrating mitigation measures into new construction is typically more economically feasible than retrofitting existing structures. Risk reduction techniques must address as many applicable hazards as possible. This approach, known as multi-hazard mitigation, is the most cost-effective approach, maximizes the protective effect of complementary mitigation measures and optimizes multi-hazard design techniques with other building technologies.

Viewed broadly, the goal of all hazard reduction efforts is risk reduction. The emphasis on sustained actions to reduce long-term risk differentiates mitigation from preparedness and response tasks, which are required to survive a disaster safely. Mitigation is an essential component of emergency management. Effective mitigation actions can decrease the impact, the requirements, and the expense of a natural hazard event.

1.2. Opportunities and Challenges for Earthquakes

Structural design will be influenced by the level of seismic resistance desired. This can range from prevention of nonstructural damage in frequent minor ground shaking to prevention of structural damage and minimization of nonstructural damage in occasional moderate ground shaking, and even avoidance of collapse or serious damage in rare major ground shaking. These performance objectives can be accomplished through a variety of measures such as structural components like shear walls, braced frames, moment resisting frames, and diaphragms, base isolation, energy dissipating devices such as visco-elastic dampers, elastomeric dampers, and hysteretic-loop dampers, and bracing of nonstructural components.

Earthquakes cannot be prevented, but their impacts can be managed to a large degree so that loss of life and property can be reduced. To this end, the National Earthquake Hazards Reduction Program (NEHRP) seeks to mitigate earthquake losses in the United States through both basic and directed research and implementation activities in the fields of earthquake science and engineering. The NEHRP is the Federal Government's coordinated approach to addressing earthquake risks. Congress established the program in 1977 (Public Law 95-124) as a long-term, nationwide program to reduce the risks to life and property in the United States resulting from earthquakes. The NEHRP is managed as a collaborative effort among the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), and the United States Geological Survey (USGS).

1.3. Opportunities and Challenges for Hurricanes/Typhoons

The key strategy to protecting a building from high winds caused by hurricanes, typhoons and gust fronts is to maintain the integrity of the building envelope, including roofs and windows, and to design the structure to withstand the expected lateral and uplift forces. For example, roof trusses and gables must be braced; hurricane straps must be used to strengthen the connection between the roof and walls; and doors and windows must be protected by covering and/or bracing. When planning renovation projects, designers should consider opportunities to upgrade the roof structure and covering and enhance the protection of fenestration.

In the United States, the National Hurricane Program conducts and supports many projects and activities that help protect communities and their residents from hurricane hazards. Three key components of the Program are Response and Recovery; Planning, Training, and Preparedness; and Mitigation. (1) Helping communities and individuals repair damage, rebuild, and recover after hurricanes and coastal storms. Activities include: providing liaison teams to assist in the coordination of National Hurricane Center advisories and emergency evacuation activities with Federal, state, and local governments, and conducting post-flood evacuation studies. (2) Taking action to lessen the impact of hurricanes and coastal storms on communities and their residents. Activities include: evaluating and recommending improvements for emergency evacuation shelters, evaluating and developing emergency evacuation plans, and increasing public awareness of hurricane hazards through training and outreach programs. (3) Reducing the damage caused by hurricane winds and flooding through improvements in the built environment, including residential and non-residential buildings and their utility systems. Activities include: assessing building performance after significant hurricanes and coastal storms, developing designs for hazard resistant construction in new buildings and retrofitting techniques for existing buildings, and recommending improvements in state and local regulatory programs.

1.3. Opportunities and Challenges for Floods

Flood mitigation is best achieved by hazard avoidance—that is, risk-informed site selection away from coastal, estuarine, and riverine floodplains. Should buildings be sited in flood-prone locations, they should be elevated above expected flood levels to reduce the chances of flooding and to limit the potential damage to the building and its contents when it is flooded. Flood mitigation techniques include elevating the building so that the lowest floor is above the flood level; dry floodproofing, or making the building watertight to prevent water entry; wet floodproofing, or making uninhabited or non-critical parts of the building resistant to water damage; relocation of the building; and the incorporation of levees and floodwalls into site design to keep water away from the building.

For decades, the national response to flood disasters was simply to provide disaster relief to flood victims. Efforts also were made to install flood-control constructions such as dams, levees, and seawalls. Funded by tax dollars, this approach failed to reduce the losses. It also did not provide a way to cover the damage costs of all flood victims. To compound the problem, the public generally could not buy flood coverage from insurance companies, because private insurance companies see floods as too costly to insure. In the face of mounting flood losses and escalating costs of disaster relief to U.S. taxpayers, Congress established the National Flood Insurance Program (NFIP) in 1968. The goals of the program are to reduce future flood damage through floodplain management, and to provide people with flood insurance. More than 35 years later, the NFIP continues to offer flood insurance to homeowners, renters and business owners, provided their communities use the NFIP's strategies for reducing flood risk. Community participation in the NFIP is voluntary, although some states require NFIP partnership as part of their floodplain management programs. NFIP flood insurance is the best protection against the devastating financial losses that floods cause.

Floodplain management refers to an overall community program of corrective and preventive measures for reducing future flood damage. These measures generally include zoning, subdivision, or building requirements, and special-purpose floodplain ordinances. When a community chooses to join the NFIP, it must adopt and enforce minimum floodplain management standards for participation. FEMA works closely with state and local officials to identify flood hazard areas and flood risks. Floodplain management requirements within Special Flood Hazard Areas (SFHAs) are designed to prevent new development from increasing the flood threat and to protect new and existing buildings from anticipated flood events. Communities participating in the NFIP must require permits for all development in the SFHA. Permit files must contain documentation to substantiate how buildings were actually constructed. The community also must ensure that construction materials and methods used will minimize future flood damage. In return, the Federal government makes flood insurance available for almost every building and its contents within the community.

Flood maps are used to locate a property within a particular flood zone. When considering purchasing or renewing a flood insurance policy, a property owner needs to know whether the property is in a low- to moderate or high-risk area to determine which policy is right for them. Over the years, many of the U.S. government's flood insurance maps have become obsolete due to urban growth, changes to river flows and coastlines, and even flood mitigation efforts like drainage systems and levees. Accurate information is essential to inform property owners of emerging flood risks and to determine appropriate rates for flood insurance coverage.

1.4. Opportunities and Challenges for Rock/Mud/Land Slides

Gravity-driven movement of earth material can result from water saturation, slope modifications, and earthquakes. Techniques for reducing landslide and mudslide risks to structures include selecting non-hillside or stable slope sites; constructing channels, drainage systems, retention structures, and deflection walls; planting groundcover; and soil reinforcement using geo-synthetic materials, and avoiding cut and fill structural sites.

Landslides constitute a major geologic hazard because they are widespread, occur in all 50 states and U.S. territories, and cause $1-2 billion in damages and more than 25 fatalities on average each year. Expansion of urban and recreational developments into hillside areas leads to more people that are threatened by landslides each year. Landslides commonly occur in connection with other major natural disasters such as earthquakes, volcanoes, wildfires, and floods. The primary objective of the National Landslide Hazards Program (LHP) is to reduce long-term losses from landslide hazards by improving our understanding of the causes of ground failure and suggesting mitigation strategies. The LHP has operated since the mid-1970's in gathering information, conducting research, responding to emergencies and disasters, and producing scientific reports and other products for a broadly based user community including geologists and engineers in government, academia and private practice, planners and decision makers from governmental entities at all levels, and the general public. The results of these efforts have led to significant improvements in understanding the nature and scope of ground-failure problems nationally and worldwide. Such improvements are central to the role of the program, because opportunities remain for fundamental advances in understanding that promise to save lives and dollars.

2. Proposed Research Topics for US-Taiwan Collaboration

Future research collaboration between the NSC and NSF needs to be strengthened to accelerate the advancement of building and infrastructure resilience for hazard reduction of disasters in both Taiwan and the U.S. Possible future collaborations are proposed to include, but not limited to, the following 5 multidisciplinary team-oriented topic areas.

2.1. General Knowledge for Mega-City Mega-Disasters

Relevant hazards (*e.g.,* earthquakes, typhoons/hurricanes, floods) are recognized and understood. Government officials, the private sector, and individuals will have access to increasingly accurate assessments of disaster risk that incorporate the vulnerability of homes, transportation systems, lifelines, emergency and health care facilities, communications systems, business activity, and the general functions of society. These assessments and lessons learned from past disasters will be used to develop improved structural construction codes and practices, plan for future development, and prepare for disaster response. Specific topics of collaborative interest include:

(a) Methods to predict natural hazard occurrence.
(b) Technology to increase societal infrastructure resiliency.
(c) Assessment techniques to quantify the risk posed to individual and critical infrastructure and systems of infrastructure systems.
(d) Post-event management plans that minimize the social-economic impact of natural hazards.
(e) Methods to mitigate compound disasters in urban areas.
(f) Urban planning for sustainability to accommodate expanding populations and aged or aging lifeline systems.

(g) Techniques to identify, simulate, and demonstrate natural hazards to provide scenario-based plans for mitigation.
(h) Methods to assess social vulnerability and to assist pre-disaster mitigation and post-disaster recovery.
(i) Strategies for emergency response to MCMD
(j) Strategies for coordinating the acquisition, sharing, and use of disaster-related data among multiple agencies.

2.2. Emergency Response/Recovery/Rebuilding against Seismic Hazards

Techniques for constructing new infrastructure and retrofitting existing infrastructure will be based on best practices. Buildings will be structurally sound after an earthquake, and critical facilities can be reoccupied without delay. Transportation systems are easily repaired and open for service with minimal interruption to support response and recovery efforts. Recovery will be more effective as communities are able to make informed decisions based on an improved understanding of the true costs. Specific topics of collaborative interest include:

(a) Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society-at-large.
(b) Assess earthquake hazards for research and practical application.
(c) Develop advanced loss estimation and risk assessment tools.
(d) Develop comprehensive earthquake risk scenarios and risk assessments.
(e) Develop remote sensing techniques for monitoring geological change.
(f) Explore emerging opportunities for the use of cyberinfrastructure to couple sensor data and models with the decision making process of first-responders.
(g) Develop reliable early-warning detection systems to protect the public ahead of earthquakes.
(h) Promote the implementation of earthquake-resilient measures in professional practice and in private and public policies.

2.3. Emergency Response/Recovery/Rebuilding against Hurricanes/Typhoons

The risk posed by hurricanes to a particular country is a function of the likelihood that a hurricane of certain intensity will strike it and of the vulnerability of the country to the impact of such a hurricane. Vulnerability is a complex concept, which has physical, social, economic and political dimensions. It includes such things as the ability of structures to withstand the forces of a hazardous event, the extent to which a community possesses the means to organize itself to prepare for and deal with emergencies, the extent to which a country's economy depends on a single product or service that is easily affected by the disaster, and the degree of centralization of public decision-making. Specific topics of collaborative interest include:

(a) Monitor hurricanes/typhoons and develop effective warning mechanism.
(b) Develop models that estimate tracking, landfall, and potential damage
(c) Define mitigation measures that follow the statistical analysis and consider long-term effects, including structural and nonstructural mitigation measures.

2.4. Emergency Response/Recovery/Rebuilding against Floods

Flood damages are most commonly caused by excessively heavy rains, successive rainstorm events, or rapid melting of heavy snow accumulations. With these events, peak flood levels are reached and recede relatively rapidly. Mitigation measures are designed to reduce or eliminate future damage to facilities. Determination of the appropriate mitigation measure depends, in part, on an assessment of the cause of damage. A proper assessment is critical, as mitigation applied inappropriately could actually increase risk to the facility or other structures in the floodplain. Specific topics of collaborative interest include:

(a) Develop methods to identify damages to bridges, such as inadequate hydraulic capacity of the bridge, misaligned piers and/or abutments, or accumulation of debris.
(b) Enhance flood hazard mapping techniques and apply satellite data to improve the accuracy of floodplain mapping (NRC, 2009).
(c) Apply remote sensing data to flood-prone areas, *e.g.,* photo-optical technique employed for spectral analysis, analysis of land surface changes, and etc.

2.5 Emergency Response/Recovery/Rebuilding against Massive Rock/Mud/Land Slides

Landslide losses are increasing in the United States and worldwide as development expands under pressures of increasing populations. This trend will continue due to development in hazardous areas, expansion of transportation infrastructure, deforestation of landslide-prone areas, and changing climate patterns. Landslides have a large adverse effect on infrastructure and threaten lifelines, including transportation corridors, fuel and energy conduits, and communications linkages. Roads, bridges, and tunnels suffer economically devastating effects from landsliding every year. Railroads, pipelines, electric and telecommunication lines, dams, offshore oil and gas production facilities, port facilities, and waste repositories continually experience the consequences of land movement. Road building and construction often exacerbate the landslide problem in hilly areas by altering the landscape, slopes and drainages, and changing and channeling runoff, thereby increasing the potential for landslides. Specific topics of collaborative interest include:

(a) Develop a national research agenda and a multi-year implementation plan based on the current state of scientific knowledge concerning landslide hazard processes, thresholds, and triggers, and the ability to predict landslide hazard behavior.
(b) Develop improved, more realistic scientific models of ground deformation and slope failure processes, and implement their use in predicting landslide hazards nationwide.
(c) Develop dynamic landslide prediction systems capable of interactively displaying changing landslide hazards in both space and time in areas prone to different types of landslide hazards (e.g., shallow debris flows during intense rain, deep-seated slides during months of wet weather, and rock avalanches during an earthquake).
(d) Develop and implement a plan for mapping and assessing landslide and other ground-failure hazards.
(e) Develop and implement a national landslide hazard monitoring and prediction capability (e.g., Synthetic Aperture radar and laser altimetry).
(f) Incorporate state-of-the-art techniques such as microseismicity, rainfall and pore-pressure monitoring integrated with hydrologically based models of slope stability and Global Positioning Systems (GPS).

3. Workshop Organization

Our primary purpose is to develop a program that will foster the collaboration between US and Taiwan joint research effort in MCMD mitigation. We propose to have a two day workshop. The third day will be optional and allocated for site and laboratory visits. The language of the workshop will be English.

We will stress small group discussions in lieu ofof presentations. Only 2 to 4 keynotes in the morning of the first day are proposed. Each invited participant will submit a one page short description of their research interests and accomplishments. Each participant will also be asked to answer two to three questions related to our workshop agenda in advance. Each participant will have 5 minutes to talk about their vision, grand challenges, and opportunities for MCMD mitigation..

3.1. Workshop Format

***First Day**:* May 6, 2010 (Thursday)

- Morning: Keynote lectures from both sides

- Afternooon: Group Discussion – based on the three identified session topics

***Second Day**:* May 7, 2010 (Friday)

- Morning: Group discussion – draw resolution from each group
- Afternoon: Presentation from each group, and draw recommendation

***Third Day**:* May 8, 2010 (Saturday)

- Optional site visits

The ultimate objective is to develop a road map for planning a comprehensive bilateral US-Taiwan team- and center-based research and implementation plan for realizing significant advances in building and infrastructure resilience: strategies for disaster reduction in emergency response, recovery, and rebuilding.

3.2. Workshop Organizers

For the U.S. Side:

Chair: *Billie F. Spencer, Jr.*, Nathan M. and Anne M. Newmark Endowed Chair in Civil Engineering, University of Illinois at Urbana-Champaign. Dr. Spencer's research and teaching focuses on engineering application of information technology, smart sensing technology, and structural health monitoring. He led the deployment of the world's largest wireless smart sensor network to monitor civil infrastructure on the Jindo Bridge in South Korea. He also leads the Mid-America Earthquake (MAE) Center's efforts to develop MAEviz, the open-source cyberenvironment for seismic risk assessment.

Co-chair: *Michael F. Goodchild*, Director Center for Spatial Studies, University of California Santa Barbara. Dr. Goodchild's research and teaching focus on geospatial data and technologies. In 2005-7 he chaired a National Research Council study committee that addressed failings in the use of geospatial data and tools in emergency response, in the aftermath of Hurricane Katrina. His recent research has focused in part on the role of citizens and Web 2.0 technologies in providing accurate and timely information during disasters, using California wildfires as a case study.

Co-chair: *Jerome P. Lynch*, Associate Professor of Civil and Environmental Engineering and Electrical Engineering and Computer Science, University of Michigan. Dr. Lynch's research is focused on the development of low-cost sensor technologies aimed to monitor and control large-scale infrastructure systems before, during and after natural hazards. His research has explored the adoption of wireless sensors, “smart” sensors that process their own measurements and decentralized control algorithms in the domain of smart civil structures.

For the Taiwan Side:

Chair: *Chin-Hsiung Loh*, Professor, Department of Civil Engineering, National Taiwan University. Dr. Loh’s research and teaching focuses on structural control, earthquake engineering, and structural health monitoring. As a Director of National Center for Research in Earthquake Engineering (NCREE) from late 1997 to 2003, he led NCREE research team to conduct reconnaissance and the follow up research on seismic hazard mitigation after the Chi-Chi earthquake (Sept. 21, 1999). From 2001 to 2004 he served as the program director at the office of the National Science and Technology Program for Hazards Mitigation. He received his honorable award on 2006 from National Taiwan University as a distinguished professor in the university

Co-chair: *Chang-Yu Ou*, Professor and Dean of the College of Engineering, National Taiwan University of Science and Technology. His research and teaching focuses on deep excavation, soil-structure interaction, and electro-osmotic chemical ground improvement.

3.3. Selection of Participants

Participants will be selected by the workshop organizers. Determining factors in the selection of participants will be unique expertise and demonstrated capability for innovation as well as international experience in and knowledge of cooperative research in the Asia-Pacific region. A balance between junior and senior researchers will be sought, with particular attention paid to selecting participants from underrepresented groups.

4. Anticipated Impacts

In addition to fostering new collaborations between US and Taiwan researchers, the US delegation (many of whom will be young researchers, including members of underrepresented groups) will receive an exceptional amount of exposure to the international MCMD community. Through technical presentations, social activities, sharing of common research experiences, and site visits, the participants will develop professional relationships that will serve as the basis for future US-Taiwan collaboration. US and Taiwan researchers that present their work will open up new avenues for discussion that will lead to synergistic generation of future ideas and developments. The connections and networking opportunities made possible by this experience will equip the US participants for new collaborations or enable them to embark on new multidisciplinary avenues of research while simultaneously assisting them in their development as international leaders and role models in this growing and expanding area of research, education, and practice.

The U.S. delegation to the conference will participate in an extra day of activities following the conference, which will include organized site visits. This day will serve to reinforce technical material presented at the conference by examining real-world applications of concepts. The location of the conference in Taiwan will take advantage of the unique opportunity to observe and interact with practitioners from an urban society that is historically susceptible to significant MCMD threat. The day will continue to provide opportunities for further studies in MCMD mitigation, along with continuing to foster connections and networking between the young U.S. researchers in the delegation.

A workshop website will be established, with details of participants, their expertise, the workshop presentations, and its discussions and conclusions. Conclusions will be summarized in a report which will be widely disseminated through the website.

4. Joint OISE/CMMI Funding

In view of the fact that the technical thrusts of the proposed workshop is of the current interest of the Sensors and Sensing Systems Program (PD: Dr. S.C. Liu) and the Hazard Mitigation and Structural Engineering Program (PD: Dr. M.P. Singh) of the Civil, Mechanical and Manufacturing Innovations (CMMI) Division, it is requested that possible co-funding of the proposal by OISE and CMMI be considered.

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